ART IN TRANSIT

Handbook for

Packing and Transporting Paintings
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— Editors —

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National Gallery of Art

Washington
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Cover: Detail, Taking in the Pictures at the Royal Academy, wood engraving by M. Jackson, printed in the Illustrated London News, 21 April 1866, page 381 (Collection of Ross M. Merrill). (Note: The legend below the illustration incorrectly identifies the institution as the Royal Academy; it is actually The National Gallery, London.)
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INTRODUCTION

This handbook serves as a companion to the National Gallery of Art publication *Art in Transit: Studies in the Transport of Paintings* prepared for the International Conference on the Packing and Transportation of Paintings held in London, 9-13 September 1991. The purposes for preparing these two books were very different. Theoretical studies containing scientific and analytical information, describing sophisticated methodology and analytical equipment needed to be translated into practical, "how to" language for using the available information. This handbook fills that need as it describes procedures that will enable packers, registrars, curators, and conservators to effectively use the results of the research of specialists in the field.

Information contained in these pages has been drawn from numerous sources and publications, and much has been extracted from the information contained in *Art in Transit: Studies in the Transport of Paintings*. The reader, therefore, does not find authors' names with the various sections as Mervin Richard and Marion Mecklenburg have extracted and assembled information relevant to each topic, rewording it in lay terms, writing original material when necessary. Without their efforts, this handbook would not have been possible.

This publication could not have been realized without the support of our colleagues. In particular, I wish to thank National Gallery of Art director emeritus, J. Carter Brown and Roger Mandle, then deputy director, for their commitment to this project, enabling us to give it our attention when many other pressing Gallery projects made that time a very precious commodity.

The Gallery's conservation division has been fortunate to have Janice Gruver, an editor who has approached both publications with diligence, patience, and aplomb. Michael Skalka labored long hours handling the complexities and many details required to bring this handbook to completion. Numerous others made significant contributions by reading manuscripts, producing drawings and illustrations, and taking care of endless details to ensure that the publication was completed on schedule.

Although other books have offered tips and instructions on proper packing, this modest handbook, revised in a second edition, has become a major reference resource for those concerned with the safe transit of paintings.

R.M.M.
HOW TO USE THIS HANDBOOK

This handbook is intended to be a reference for anyone involved in the packing and shipping of paintings. It represents a practical summary of theoretical research conducted on the subject to date as well as the collective experience of conservators, packers, and shippers of paintings. It also brings together in one volume most of the factors important in determining whether it is safe or desirable to lend or borrow a painting. Once that determination has been made, the sections that follow provide important information to ensure that the best methods are used to transport the painting with the least amount of risk.

This handbook is divided into sections that cover topics that may be new to the user. Once the user is familiar with the handbook, some of the sections will be more frequently used than others and a tab system has been provided to assist in locating pertinent information. This handbook has been designed so that updates and revisions might be made to sections as research provides new information. A glossary is included to familiarize the reader with new or special terms.

In many circumstances, the rationale is not included along with the recommendations. Much of this information is found in the companion book, Art in Transit: Studies in the Transportation of Paintings. The user is advised to consult this publication for further details as well as the information listed at the end of each topic under the heading, "For Further Information, See."

M.F.M.
Handbook Use Questionnaire

To make the handbook more useful for practical solutions, it is important to have users indicate if the handbook met their needs. Periodic updates are planned based on these needs. Please take time to complete the questionnaire and return it to us. Your name and organization will be kept confidential.

Does the handbook adequately address situations and problems that you usually encounter? If no, please list topics you would like to see included.

Does the handbook adequately explain procedures and hands-on applications? If no, please list any suggestions for improvement.

Are the text and explanations readily understandable for packers? If no, please list desired changes.

General impression of handbook format.

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Section 1

ASSESSING RISKS

Topics

- Criteria for the Selection of Paintings for Loan
- Selection Criteria for Frames
- Selection Criteria for Paintings on Canvas or Paper Mounted on Canvas
- Additional Issues for Large Paintings on Canvas
- Selection Criteria for Contemporary Paintings on Canvas
- Selection Criteria for Paintings on Rigid Supports
- Paintings on Wood, Ivory, or Bone
- Paintings on Metal and Other Nonporous Rigid Supports
CRITERIA FOR THE SELECTION OF PAINTINGS FOR LOAN

No high-tech packing method will guarantee the absence of damage... Damage occurs when paintings that are too fragile for loan are included in traveling exhibitions.


Figure 1 - Typical Painting/Frame Structure.

- Glazing (Optional)
- "False Rabbet" - Glazing Retainer
- Padding
- Painting
- Frame
- Backing Board
- Stretcher

LOAN EVALUATION

Generally, paintings are remarkably resilient constructions and are surprisingly able to tolerate stress. However, each paint-
ing has a tolerance threshold that is determined by the materials the artist used and how the painting is constructed; this threshold also includes the artist's painting technique.

If a painting is stressed beyond its limits, its structure will fail. A responsible selection procedure should identify the weaknesses in the painting and assess the risks posed by a loan. If the painting has a narrow range of tolerance or the expected conditions during the loan will produce stresses beyond its limits, then the risk of damage increases. If an unstable painting is loaned to an institution with a poorly controlled environment, is subjected to indifferent handling, or is improperly packed, the risk of damage will increase dramatically. Additional risks from extended venues on the loan circuit also occur because of the increased risk exposure each time it is handled for packing and unpacking.

Political issues can also find their way into the loan decision-making process. The curator and conservator may have the ultimate decision in allowing the painting to travel although, unfortunately, in some museums the condition of the painting is not a key factor in the decision to lend a work of art. Political issues and internal policies are not part of the guidelines given in this handbook. Guidelines are given in the assumption that the protection of the painting during its loan is the foremost issue for the reader. The following considerations are intended for assessing a painting's tolerance under the anticipated conditions.

Rarely does a painting suffer catastrophic failure without first exhibiting indications that its stress limits have been approached or exceeded. These limits may be indicated by changes in the painting's structure such as checks or cracks in a panel or delaminations in the paint film resulting in flaking paint. The conservation history and the condition of the painting will indicate its stability and durability and will add insight about its ability to tolerate the anticipated risks of a given loan. An unstable structure with a history of condition problems and conservation treatment will readily indicate a painting unfit for loan, especially when compared to the anticipated conditions of the loan. Even if a painting is considered fit to travel for one type of loan, it should not be assumed that the same painting can safely survive the conditions of another type of loan.

Catastrophic failures in a painting rarely occur from natural causes, rather, they are commonly caused by damage incurred due to improper handling, insecure installation, or accidents resulting in major damages to the painting such as punctures, tears, or dents. Most damage to paintings occurs in handling during deinstallation, packing, or unpacking. Once the painting is properly packed in a well-constructed shipping case, the risk of
damage is greatly reduced.

Each institution responsible for the care of works of art must develop their own loan policies and procedures for selecting loans from their collection. Lending a painting may subject the work to stress not normally encountered in the home institution although lending a painting does not necessarily imply unacceptable stress. Careful evaluation of the painting considered for travel must include a critical review of the borrowing institution, a discriminating survey of the transit route and its anticipated conditions, and the proper construction and packing of the traveling case.

**SELECTION ISSUES**

In selecting a painting for loan, the following issues must be evaluated in relationship to the painting and frame during transport:

- **Fitness for travel of the painting and frame.**
- **Evaluating the borrowing institution.**
- **Environmental conditions expected during transit and exhibition.**
- **Aspects of the transit phase.**

**EVALUATING THE BORROWING INSTITUTIONS**

The lending institution should consider the following in evaluating conditions relating to the proposed loan:

- Does the borrowing institution have adequate staff and equipment to handle the loan, especially if the painting/case is oversized.
- Are the staff members involved at the borrowing institution well trained in packing, handling, and installation.
- Does the borrowing institution have a full-time professional packer. If the handling and packing is to be contracted to an outside firm, are they well qualified and is their staff adequately trained.
- Is a courier required to oversee the unpacking and installation of your painting.
Section 1 - Assessing Risks

- Does the institution have a secure storage space.
- Will the crate be stored in an environmentally controlled space during the exhibition.
- Are adequate fire protection and suppression equipment provided? Does the institution's fire suppression system pose an additional risk.

**TO DETERMINE WHAT ENVIRONMENTAL CONDITIONS WILL OCCUR DURING TRANSIT AND EXHIBITION, ASK THE FOLLOWING QUESTIONS:**

- What conditions are the case expected to encounter during the transit phase of the loan.
- Can the painting be packed in such a way to protect it from the anticipated external environment.
- What are the normal environment conditions at the borrowing institution. Can they be adjusted to meet your requirements.
- Are the institution's environmental monitoring equipment and heating, air conditioning, and ventilation equipment in good working order and reliable.
- If necessary, can the institution provide documentation of the environmental conditions during the exhibition.
- Will the local weather be extreme during the period of the exhibition and can the borrowing institution maintain a stable environment during the period.

**ASPECTS OF THE TRANSIT PHASE TO CONSIDER**

- Will the route encounter extreme environmental conditions?
- Can the route be modified to reduce handling of the case?
- Will there be an overnight layover during the transit?
- Where will the customs inspection occur?
- Is security adequate?
**PREPARATION FOR LOAN**

The following should be part of the preparation of the loan:

- The rabbet of the frame should be padded to prevent abrasion of the painting's edge.
- The painting should be properly mounted in the frame with mending plates rather than nailed into the frame.
- Panel paintings should be mounted with plates at the end grain so they can move with changes in relative humidity.
- Establish if it is necessary to remove glass from the painting.
- Determine if the painting will need a backing board.
- Determine whether the frame is too fragile to lend. If so, what are replacement provisions?
- Determine if the frame will need repair before lending.
- Ascertained whether the painting/frame is to have a traveling "collar" for the loan.
SELECTION CRITERIA FOR FRAMES

The frame must be regarded as an integral part of the painting since its primary role is to protect the painting. Since antique frames are themselves works of art, their condition must also be considered.

- In addition to enhancing the painting, the primary goal of the frame is to protect the painting it surrounds. If the frame cannot perform this function and safely travel, a "traveling frame" should be considered. Allow adequate time to design and construct the frame for the loan.

- The frame must be free of active wood worms, mold, and fungus. The presence of wood dust from the interior of the frame may not always be an indication of active wood worms. If wood dust is present, ask a conservator to check for active wood worms.

- The frame must not have any loose parts such as corner moldings. Should a piece become detached during transit, it would be free to move about inside the case and damage the painting.

- The frame should not have any loose corner joints. As a wooden frame dries out, the corners shrink, opening the joints. In many frames, the corner structure remains sound but fragile. Often the weakened joint becomes loose, allowing the corner to move, therefore providing insufficient protection for the painting.

- The frame must have no flaking or looseness in the surface decoration. Most frames are gilded or painted although some may be verneered with exotic wood or shell. Some have raised designs of "compo" or other material glued to the surface.

- The frame members should have no splits, warps, or delaminations that result in an unstable structure. Often splits occur along the rabbet of the frame due to pressure from the reverse. Ideally, the back of the frame should be built up to the level of the painting.

- Remove any glass from the frame before packing unless it is a laminated safety glass or a clear plastic sheet such as Plexiglas®.
• The frame rabbet should be padded to prevent abrasion along the painting's edge. The padding may be cork or felt glued into the rabbet or a protective molding may be attached to the edge of the painting.
SELECTION CRITERIA FOR PAINTINGS ON CANVAS OR PAPER MOUNTED ON CANVAS

Figure 1 — Cross-section diagram of painting on canvas.

Aside from proper packing, the easiest way to protect the painting is to have a sturdy backing board applied. The majority of paintings have no backing board, making them highly vulnerable. The most common condition problem with canvas paintings are loose keys that fall between the canvas and stretcher creating stress on the canvas and disfiguring bulges. The usual condition problem that puts the painting at greatest risk is loose or flaking paint. Fabric tears are also common in canvas paintings,
especially along the edges of the stretcher.

**BACKING BOARD**

The painting should have a rigid backing board attached to the reverse of the frame or stretcher. The rigid backing board helps to reduce the effects of vibration, prevents dirt accumulation, and moderates changes of relative humidity. In some museums, they are attached to the stretcher if it is heavy enough to receive the screws. The edges may be taped if there is no risk of humidity buildup. Thin, pressed wood, foam core paper sheets, or heavy laminated paperboard are used for backing boards. The hardware should be corrosion resistant material such as brass or chromed steel. Do not use nails or staples as they are likely to loosen and fall out.

**STRETCHER**

- The painting should not be nailed into the frame but properly mounted with mending plates. Brass or corrosion resistant chrome-plated steel plates should span between the stretcher and frame with firm attachment to the frame. In some museums the system is to attach the other end to the stretcher.

- There must be no active wood worms in the stretcher.

- There should be no loose keys; they can become dislodged and stuck between the stretcher and canvas.

- There should be no splits or breaks in the stretcher bars. An overexpanded stretcher often splits at the ends where the keys are wedged.

**CANVAS**

"Canvas" is defined as a fabric that may be of cotton, linen, or other fiber used as a support for the ground and paint layers.

- The canvas should not be weak, dry, or brittle. As canvas ages, it oxidizes and dries out, becoming weak and easily damaged. A weak canvas may have tears or severe distortions.

- The canvas should not have large bulges in the corners. These cause uneven tension on the fabric.

- There must be no unrepaired tears in the canvas.
• The canvas **should show no evidence of tearing** along the edge where it turns over the stretcher. This is often caused by the abrasion of an unprotected frame rabbet. If the tacking edges are unsound, changes in relative humidity (either high or low) can initiate tearing of the canvas along the stretcher bar.

• The canvas support **should not be slack**. The tension of the canvas varies with relative humidity. A slack canvas can contact the stretcher and cross braces causing damage to the paint.

• The canvas support **should not be overtensioned**. This is usually caused by the overexpansion of the stretcher. Under the dry conditions of low relative humidity, a highly tensioned painting's limited ability to shrink can cause new corner cracks.

**LINING CANVAS**

All of the above considerations also apply to the lining canvas in addition to the following:

• Since **glue and paste lining adhesives are very susceptible to dimensional changes** with relative humidity variations, use caution when considering for loan paintings that have been lined. The packing case should be buffered to reduce humidity variations.

• The lining **adhesive should not be dry and powdery** which indicates a loss of holding power.

• If the painting has a traditional adhesive lining, **the original canvas should be firmly attached to the lining fabric**.

**PAINT/GROUND**

• The painting **should not have loose or tented paint/ground** or be delaminating within the paint/ground layers. Often the detached paint is hidden as a "blister" (blind cleavage) and is not readily apparent. If delamination within the paint/ground structure is suspected, have the painting examined by a conservator. A cracked paint/ground layer is susceptible to severe stress and flaking if the relative humidity drops 15% below the relative humidity to which it has become accustomed.
- The painting _should not have a history of chronic instability in the support or paint layer_ such as recurring paint flaking. Such chronic problems indicate an unstable structure that is more responsive to environmental changes making the painting more vulnerable and increases the loan risks.

**VARNISH**

Although the varnish may be discolored or is flaking from the paint layer, rarely does this cause losses in the paint. Although this condition may not put the paint layer at risk, _paintings should not be lent if they have flaking varnish._

**SENSITIVITIES**

- **Sensitivity to Relative Humidity**—Moderate range of tolerance, usually 50% or 55% ±5%
  
  Canvas paintings are sensitive to relative humidity extremes. It is especially important that a painting that has become accustomed to a high relative humidity not be suddenly subjected to low relative humidity. Examples of this are paintings from European collections accustomed to a high relative humidity being moved to American museums that are centrally heated without controlled relative humidity.

- **Sensitivity to Temperature**—Low response to temperature changes except for extremes
  
  Paint films become more brittle at low temperatures while wax lining adhesives soften at high temperatures. The relationship of temperature and its effect on relative humidity must be considered when selecting the packing materials. Generally, if the moisture content in the air is held constant, lowering the temperature raises the _relative_ humidity and raising the temperature reduces the _relative_ humidity.

- **Sensitivity to Vibration**—Low response to usual transit vibrations
  
  Recent research has shown that the vibrations normally encountered in various transit modes do not reach the same natural harmonic as canvas or panel paintings and do not pose a threat to the paintings. Note: fragile paintings with loose paint are extremely vulnerable to any vibrations.

- **Sensitivity to Shock**—High sensitivity to shock and impact
  
  All paintings are extremely vulnerable to the shock gener-
ated by high impacts such as dropping a painting or case on its corner, especially if the temperature and humidity are low. As the condition of the painting becomes more fragile, its vulnerability become greater. Cracked paintings are at greater risk than paintings with uncracked paint layers.
ADDITIONAL ISSUES FOR LARGE PAINTINGS ON CANVAS

TYPICAL DEFECTS

In addition to the comments and criteria found under the topic, Paintings on Canvas, overly large canvas paintings may have unique problems because of their size. The painting's dimensions determine the dimensions and weight of the packing case. With large cases, the height of cargo containers, trucks, etc. become major issues that must be considered for the loan. Usually these very large paintings have no backing boards, making them highly vulnerable. They may be on strainers, rather than stretchers, that cannot be expanded with the canvas having become slack on the stretcher allowing the canvas to come into contact with the strainer or cross bars. Like smaller paintings, these large works are susceptible to the dangers of loose or flaking paint. Fabric tears may be more common because of their greater weight and larger size, especially along the edges of the stretcher. Often oversize paintings may be inadequately framed causing poor protection.

A serious problem with extremely large paintings is fitting them into the cargo hold of an aircraft. Frequently the oversized painting must be removed from the stretcher and rolled for shipment. Other paintings may be folded on specially designed stretchers. If necessary to fold or roll the painting, the paint layer must be thin and should be rolled (or folded) facing outside. The larger the roller or radius of the fold, the less stress on the paint film, reducing the potential damage. Large paintings that require folding or rolling for loan are at a higher risk of damage due to the additional handling required and the inherent potential for damage of an embrittled paint layer. Rolled paintings must carry their weight on a central axle rather than on the painted surface.

BACKING BOARD

Like smaller paintings, very large paintings need the protection of a rigid backing board, see Paintings on Canvas. Unfortunately, large paintings often do not have a backing board because of their size. Attaching a backing board can make the painting/frame construction more rigid in addition to helping reduce the effects of vibration, preventing dirt accumulation, and moderating changes of relative humidity. The backing board may require two or more sheets; if so, it may be necessary to screw
them into the cross bars if the cross bars have adequate thickness. Use hardware of corrosion resistant material such as brass or chromed steel. Do not use nails or staples as they are likely to loosen and fall out.

**STRETCHER**

The painting may be larger than the usual easel painting and often the width and thickness of the stretcher members are inadequate to support the weight of the canvas. These undersized *stretcher members should not be warped, split, or twisted* and there should be adequate center braces.

- The stretcher should not be contacting the canvas. The bevel on the inside of the stretcher should be deep enough to prevent the canvas and stretcher from coming in contact.

**CANVAS**

In addition to the comments that apply to normal easel paintings, the canvas of a very large painting should not be slack enough to allow the canvas to slap against the stretcher or center braces in case of vibration during transit. A slack canvas can incur severe damage.

- There must be *no unrepaired tears in the canvas, especially along the edges of the stretcher*. Tears in the canvas are particularly common in large paintings, usually due to mishandling.

For comments on the Lining Canvas, Paint/Ground, and Varnish, see the topic, *Selection Criteria for Paintings on Canvas or Paper Mounted on Canvas*.

**SENSITIVITIES**

The sensitivities to relative humidity, temperature, vibration, and shock are much the same as canvas easel paintings although the dimensions and weight of very large paintings make it more difficult to properly protect the painting in a packing case that can be safely handled. Due to the greater weight of the painting, thicker *shock cushioning is necessary to provide the same static load on the foam*. 

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*Topic: Add'l. Large Paintings on Canvas (9/91)-2*
SELECTION CRITERIA FOR CONTEMPORARY PAINTINGS ON CANVAS

Figure 1 — Construction diagram showing cross-section diagram of painting on canvas.

In addition to the comments and criteria found under the Topic, *Paintings on Canvas*, contemporary paintings often have nontraditional constructions that increase the potential for problems. There may be mixed materials that are often incompatible (collage) and may include paints of various types, found objects, unbound chalks, paper, or corroded objects in the process of their own deterioration. In addition to being large, these paintings often incorporate materials not customarily associated with paintings which may be attached to the canvas. The
supports may be of mixed construction and unsound, taxing the skills of even the best packer. Like other large paintings, these works often lack backing boards. Often the stretcher or nonexpanding strainer may be "home-made" of low-grade materials.

These nontraditional paintings may have a mixture of supports where part is on stretched canvas and part on hardboard. Inevitably, the frame does not provide sufficient protection.

Contemporary paintings, particularly color field paintings, often wrap around the side of the stretcher, preventing the painting from having a frame. The lack of a frame leaves the stretcher edges vulnerable to soiling and abrasion from mishandling. When lending these paintings, a temporary traveling frame should be constructed to protect the edge and allow safe handling.

For comments on the Backing Board, Lining Canvas, and Varnish, see the topics, Selection Criteria for Paintings on Canvas or Paper Mounted on Canvas and Additional Issues for Large Paintings on Canvas.

The sensitivities to relative humidity, temperature, vibration, and shock are similar to canvas easel painting although they may be complicated by the variety of materials and dissimilar constructions found within a single painting. As with other large paintings, the dimensions and weight of very large contemporary paintings make it more difficult to properly protect the painting in a packing case that can be safely handled. A combination of packing methods, incorporating techniques for packing three-dimensional objects may be necessary to adequately secure some unusual constructions.

**BACKING BOARD**

As with other paintings, backing boards can make the painting's structure more rigid as well as deterring damage. Adding a backing board may be difficult due to unusual constructions. Adequate hand holds should be provided.

**STRETCHER**

As mentioned, the stretcher or strainer should be sturdy without splits, warps, or insecure construction. With contemporary paintings, a variety and mixture of supports will be found, even within a single painting.

The stretcher of some large contemporary paintings is constructed so they separate in the center and allow the painting to
be folded. The repeated flexing of the paint/ground layer can cause paint loss.

**CANVAS**

These paintings may be on unprepared canvas, making the support very vulnerable to ingrained dirt and grime. These raw canvas supports are susceptible to water staining, shrinkage, and other moisture damage.

- The canvas should not be so slack as to contact the stretcher bars.
- Use special care when the painting has extreme impasto that increases the weight or loose attachments on the surface. These constructions can concentrate the weighted mass on the canvas, dramatically changing the vibration dynamics of the canvas resulting in damage to the surrounding paint.

**PAINT/GROUND**

Contemporary paintings present serious problems for the packer. Their unusual combination of materials, inclusion of non-paint components, and unorthodox aging deterioration make them unpredictable.

- The painting should be completely dried without tacky or sticky parts. This may indicate that parts of the painting are actively drying, producing “drying crackle” which is very vulnerable to high temperatures.
- If possible, delicate surfaces such as chalk, matte areas, etc. should be glazed; use either safety glass or plastic sheeting.

**VARNISH**

Rarely do contemporary paintings have a traditional varnish coating of natural or synthetic resin. Often they do not have a protective varnish coating, making the paint surface vulnerable to scratches, abrasions, and rubbing that will polish the surface, changing the sheen of the paint.

**SENSITIVITIES**

For comments on the Sensitivities to Relative Humidity, Temperature, Vibration, and Shock, see Selection Criteria for
Paintings on Canvas or Paper Mounted on Canvas and Additional Issues for Large Paintings on Canvas. The sensitivities to relative humidity, temperature, vibration, and shock are usually the same as canvas easel painting. The unusual construction and dimensions of contemporary paintings can make packing more difficult since some parts may be three-dimensional objects that require special packing. It is important to immobilize objects attached to the canvas so their concentrated weight does not damage the surrounding paint and canvas. Often the greater weight of the painting and construction require additional shock cushioning.
SELECTION CRITERIA FOR PAINTINGS ON RIGID SUPPORTS

Hardboard, Paperboard, or Academy Board

Figure 1 — Construction diagram showing cross section of a painting on paperboard.

**TYPICAL DEFECTS**

Rigid supports other than wood panels (discussed under the topic, Paintings on Wood, Ivory, or Bone) have unique problems. Usually they are constructed of low-grade, acidic material and become dry and brittle. Their layered construction makes them prone to delamination, especially along the edges. Because of their sensitivity to moisture, they may warp and distort. Their paint and ground layers are prone to the usual problems of paintings on canvas, see Selection Criteria for Paintings on Canvas or Paper Mounted on Canvas.

**BACKING BOARD**

Like paintings on canvas, paintings on rigid supports should have a rigid backing board attached to the reverse of the frame. Although the rigid support of the painting helps to guard against impact, as it becomes embrittled and dries out, the added protec-
Section 1 - Assessing Risks

tion of a backing board can offer inexpensive protection. The rigid backing board prevents dirt accumulation and moderates changes of relative humidity. Thin, pressed wood, foam core paper sheets, or heavy laminated paperboard are used for backing boards. Hardware should be corrosion resistant materials such as brass or chromed steel. Do not use nails or staples as they are likely to loosen and fall out.

Ascertain that there is no history of an unstable support or paint layer, such as:

- Detachment of paint layer (tenting paint, flaking, cupping, or losses of the paint layer)
- Recent treatment for cleavage or flaking paint

**RIGID SUPPORT**

There is a variety of rigid supports used for paintings. They may be reinforced fiber glass used for contemporary paintings, academy boards constructed of a layer of paper or canvas glued to an acidic wood pulp board, inexpensive plywood with water soluble glue between its laminates, pressed woodboard, or common cardboard. Each of these has individual problems although many of their faults are common.

- The rigid support should not be delaminating and separating between layers. With all of these materials, the edges are most vulnerable to damage from impact, abrasion, and aging. Layered structures such as these are sensitive to relative humidity changes that can cause the layers to move.

- There should be no unrepaired checks or splits in the support. Plywood panels will check with age showing small cracks with raised edges which may be over the entire surface. Water soluble glues in the plywood may deteriorate with age.

- There must be no insecure repairs of the support. Often broken corners may be poorly reglued without reinforcement and are easily rebroken.

- Canvas or paper attached to a rigid support assumes the character of the rigid support and may become damaged as the rigid support deteriorates. Paper glued to plywood or a wooden panel will often tear as the wood below moves in response to relative humidity changes. However, an alu-
minimum honeycomb cored support is not susceptible to dimensional changes from temperature or relative humidity.

- The support should be of sound construction without signs of insects (such as silverfish, wood worms, termites), fungus activity, or dry rot.

- There should be no signs of internal stress within the support such as pronounced warpage, severe checks, or splits. Care should be taken when cross-grain additions are found since they may be incompatible with the original support. Pressed wood panels are prone to warping unless both sides of the support are coated with the ground layer.

**PAINT/GROUND**

- The painting should not have loose or tented paint/ground or be delaminating within the paint/ground layers. Often the detached paint is hidden as a “blister” (blind cleavage) and is not readily apparent. If delamination within the paint/ground structure is suspected, have the painting examined by a conservator.

- The painting should not have a history of chronic instability in the support or paint layer such as recurring paint flaking. Such chronic problems indicate an unstable structure which is more responsive to environmental changes making the painting more vulnerable and raising loan risks.

**VARNISH**

Although the varnish may be discolored or flaking from the paint layer, rarely does this cause losses in the paint. Although this condition may not put the paint layer at risk, the painting should not be lent if it has flaking varnish.

**SENSITIVITIES**

- Sensitivity to Relative Humidity—Moderate range of tolerance, usually 50% or 55% ±5%
  Rigid supports are sensitive to relative humidity extremes which cause dimensional movement of the materials leading to warping and delamination.

- Sensitivity to Temperature—Low response to tempera-
ture changes except for extremes

Paint films become more brittle at low temperatures. The relationship of temperature and its effect on relative humidity must be considered when selecting the packing materials. Generally, if the moisture content in the air is held constant, lowering the temperature raises the relative humidity and raising the temperature reduces the relative humidity.

- **Sensitivity to Vibration**—Very low response to usual transit vibrations
  
  Recent research has shown that the vibrations normally encountered in various transit modes does not reach the same natural harmonic as paintings on rigid supports and does not pose a threat to the paintings. Note: fragile paintings with loose paint are extremely vulnerable to any vibrations.

- **Sensitivity to Shock**—High sensitivity to shock and impact
  
  All paintings are extremely vulnerable to the shock generated by high impacts such as dropping a painting or case on its corner, especially if the temperature and humidity are low. As the condition of the painting becomes more fragile, its vulnerability becomes greater. Cracked paintings are at greater risk than uncracked paint layers and paintings with separating support layers are especially vulnerable to high shock loads.
PAINTINGS ON WOOD, IVORY, OR BONE

Figure 1 — Construction diagram showing cross section of a painting on wood.

* TYPICAL DEFECTS

Sound, undamaged wood panels were thought to be more vulnerable to the transit environment than canvas paintings but recent scientific research is proving this to be incorrect in most instances. **Sound, undamaged panel paintings are less responsive to relative humidity changes than traditional canvas paintings, especially glue lined paintings.** Panel paintings (especially large ones) with separated joints, splits, and major checks in the support are, however, more sensitive than aged canvas paintings in good condition. Panel paintings are prone to **internal stress and damage from wild grain, wood worms, dry rot, and inappropriate repairs** and care must be taken to identify all potential problems so that appropriate packing materials are used. The most common problem is **inappropriate mounting in the frame** where the frame rabbet is not padded and the panel is nailed into the frame on all sides, restricting the natural movement of the panel caused by changing relative humidity.

Aside from proper mounting, safe packing materials and methods, **the simplest protection for a panel painting is to apply a sturdy backing board** attached to the frame. The majority of panel paintings have no backing board.

Like canvas paintings, the condition **problem that puts the painting at greatest risk is loose or flaking paint.**
Section 1 - Assessing Risks

**BACKING BOARD**

- The painting **should have a rigid backing board** attached to the reverse of the frame. Under no circumstances should the backing board be attached to the panel. The rigid backing board prevents dirt accumulation and moderates changes of relative humidity. Thin, pressed wood, foam core paper sheets, or heavy laminated paperboard are used for backing boards. The hardware should be of corrosion resistant materials such as brass or chromed steel. **Do not use nails or staples** as they are likely to loosen and fall out.

**PANEL**

- The panel must be sound and **not have extensive worm tunneling or dry rot**. The wood panel must be free of active wood worms, mold, and fungus. The presence of wood dust from the interior of the panel may not always be an indication of active wood worms but if wood dust is present, ask a conservator to check for wood worms.

- Since panel paintings change dimension with variations in relative humidity, **use caution when considering paintings of unusual construction for loan**. Multimember panel paintings or paintings with cross grain members (the grain of one panel board is perpendicular to the other boards in the panel) are more vulnerable to damage and require tighter relative humidity limits. Any dimensional change across the grain may result in paint loss along the joint.

- There must be **no unrepaired splits, large checks, or open joints** in the panel support. Debris or filling material can act as wedges in open cracks, prohibiting the cracks from reclosing. Partially repaired splits and open joints permit the concentration of stress at the end of the opening, encouraging enlargement of the opening with slight movement.

- There should be **no signs of** internal stress within the wood panel; these may be **locked cross braces** (movable members) in the cradle, **detached or loose battens** (normally glued fast to the reverse of the panel), **checks along fixed members of the cradle**, or a **warped panel** restrained in the frame by the mounting attachments.
• If the panel has taken a permanent warp, **the rabbet should be rebuilt so its shape matches the warped panel.** Make certain that the panel is not temporarily warped with the potential for it returning to a flat plane.

• There should be **no history of treatment for an unstable support.** Wild grain, compression, or expansion wood can cause flaking, blisters, and tenting paint. Persistent regular treatment for these conditions may be evidence of stress within the panel.

• There should be **no insecure panel repairs. Battens glued across joints or bridging repairs** across the grain can cause internal stress as the panel attempts to accommodate changing relative humidity.

• The panel **should not be improperly mounted in the frame** since this is often a major source of stress in the panel. With a drop in relative humidity, restraint of the panel can cause checks and splits in the wood as the panel relieves its internal stresses. Often the panel may be held in the frame with improper mounts on all four sides of unyielding nails, stout plates, or wood strips. The panel should be held near the center at the ends of the grain with two brass mending plates rather than mounting along the sides parallel to the grain.

**CRADLE**

Like the wooden panel, the cradle must be of sound construction and in good condition. Although it is rare, the **cradle must not be detaching from the panel.**

• The **cross grain members of the cradle must be free to move.** If they are binding, this indicates that the panel is under stress as it attempts to warp.

• There **should not be any splits or checks in the panel along the fixed members of the cradle.** Other than old joints, this is the most likely area for the panel to split and check.

• There **should not be any warping of the panel between the fixed members of the cradle.** This may indicate stress in the panel as it attempts to adjust to its environment.
**PAINT/GROUND**

- The painting **should not have loose or tented paint/ground or be delaminating within the paint/ground layers.** Often the detached paint is hidden as a "blister" (blind cleavage) and is not readily apparent. If delamination within the paint/ground structure is suspected, have the painting examined by a conservator. A cracked paint/ground layer is susceptible to severe stress and flaking if the relative humidity drops 15% below the relative humidity to which it has become accustomed.

- The painting **should not have a history of chronic instability** in the support or paint layer such as recurring paint flaking. Such chronic problems indicate an unstable structure, which is more responsive to environmental changes, making the painting more vulnerable and raising the risk of the loan.

**VARNISH**

Although the varnish may be discolored or flaking from the paint layer, this rarely causes losses in the paint. Although this may not put the paint layer at risk, **paintings should not be lent if they have flaking varnish.**

**SENSITIVITIES**

- **Sensitivity to Relative Humidity**—Moderate but within a narrow range. Normally 50% or 55% ±5%
  
  Like paintings on canvas, wooden panels are sensitive to extremes of relative humidity. When the relative humidity varies substantially beyond the described limits, the panel can dramatically shrink, resulting in extensive loss of the paint. This becomes especially important if the painting has become accustomed to a high relative humidity and is suddenly subjected to low relative humidity. An example of this is a painting moving from a collection in Europe with a high relative humidity environment to an American museum that has central heating but no humidity control system.

- **Sensitivity to Temperature**—Low response to temperature changes except for extremes
  
  All paint films become more brittle at low temperatures and care must be taken to control the temperature by selecting the appropriate packing materials. Also, the relationship of temperature and its effect on relative humidity must be considered when
selecting the packing materials. If the moisture content in the air is held constant, lowering the temperature raises the relative humidity and raising the temperature reduces the relative humidity.

- **Sensitivity to Vibration**—Low response to usual transit vibrations
  Recent research has shown that the vibrations normally encountered in various transit modes does not reach the same natural harmonic as panel paintings and does not pose a threat to the paintings. Note: fragile paintings with loose paint or insecure panel structures are extremely vulnerable to any vibrations.

- **Sensitivity to Shock**—Extremely high sensitivity to shock and impact
  All paintings are extremely vulnerable to the shock generated by high impacts such as dropping a painting or case on its corner, especially if the temperature and humidity are low. In the case of panel paintings, they are even more vulnerable to impact shock than canvas paintings since they are a rigid structure. As the condition of the painting becomes more fragile, its vulnerability becomes greater. Cracked paintings are at greater risk than uncracked paint layers.
PAINTINGS ON METAL AND OTHER NONPOROUS RIGID SUPPORTS

Metals, Stone, Polymers, Ceramics, Glass, Etc.

Figure 1 — Construction diagram showing metal support, ground, paint, and varnish.

RIGID SUPPORT

Although water can penetrate some of these supports, they are not hygroscopic (moisture-absorbing) and will be considered as nonporous supports. These supports are responsive to temperature changes. The most common nonporous support is metal, although paintings have been executed on plastic laminates, fiber glass, ceramics, glass, and stone. The comments will be directed toward paintings on metal although they often apply to the other supports. The most common difficulty encountered with paintings on this support is a broken support or, in the case of metal supports, a bent metal support. The usual cause is physical impact, breaking, or bending the support. Often there is flaking of the paint along the bend of a metal support or the break line. Flaking paint and ground is common to these paintings since the ground is not always firmly attached to the nonporous support. A simple backing board can dramatically reduce the risk of damage from impact. One of the major risks to metal supports is their sensitivity to temperature fluctuations. They dimensionally change, expanding or shrinking with changes in temperature.

In addition to their problems of flaking paint, paintings on glass are extremely fragile and susceptible to breakage. When broken, they are virtually impossible to repair. Glass becomes more brittle with age, increasing its risk of damage.
Section 1 - Assessing Risks

**BACKING BOARD**

- The painting **should have a rigid backing board attached to the reverse of the frame**. The rigid backing board helps reduce the effects of vibration, prevents dirt accumulation, and the risk of impact. Thin, pressed wood, foam core paper sheets, or heavy laminated paperboard are used for backing boards. The hardware should be corrosion resistant material such as brass or chromed steel. **Do not use nails or staples** as they are likely to loosen and fall out.

**PAINT/GROUND**

- Like all paintings, the painting on a nonporous support **should not have loose or tented paint/ground or be delaminating within the paint/ground layers**. Often the detached paint is hidden as a "blister" (blind cleavage) and is not readily apparent. If delamination within the paint/ground structure is suspected, have the painting examined by a conservator. A cracked paint/ground layer is susceptible to severe stress and flaking if the support dimension changes.

- The painting **should not have a history of chronic instability** in the support or paint layer such as recurring paint flaking. Such chronic problems indicate an unstable structure, which is more responsive to environmental changes, making the painting more vulnerable and raising the loan risks.

**VARNISH**

- Although the varnish may be discolored or flaking from the paint layer, rarely does this cause losses in the paint. Although this may not put the paint layer at risk, **paintings should not be lent if they have flaking varnish**.

**SENSITIVITIES**

- **Sensitivity to Relative Humidity**—Very slight except for embrittlement of paint layer

  Unlike paintings on canvas or wooden panel which are hygroscopic and absorb/desorb moisture, these nonporous paintings are sensitive to extremes of temperature rather than relative humidity.

Topic: Paintings on Metal/Other (9/91) - 2
- **Sensitivity to Temperature**—Very high response to temperature changes especially extremes
  In addition to the paint layer becoming embrittled at low temperatures, paintings on metal shrink, often resulting in severe flaking paint and losses. This becomes even more dramatic if the drop in temperature is sudden. Extra care must be taken in properly insulating the shipping case when shipping paintings on metal supports.

- **Sensitivity to Vibration**—Low response to usual transit vibrations
  Recent research has shown that the vibrations normally encountered in various transit modes do not reach the same natural harmonic as paintings on rigid supports and do not pose a threat to the paintings. Note: fragile painting with loose paint or insecure panel structures are extremely vulnerable to any vibrations.

- **Sensitivity to Shock**—Extremely high sensitivity to shock and impact
  All paintings are extremely vulnerable to the shock generated by high impacts such as dropping a painting or case on its corner, especially if the temperature and humidity are low. In the case of paintings on rigid supports such as metal, ceramic, or stone, they are even more vulnerable to the shock of impact than many panel and canvas paintings. Many of these supports such as stone, ceramic, or glass may have fine hairline cracks and flaws that make them especially vulnerable to impacts. As the condition of the painting becomes more fragile, its vulnerability become greater. Cracked paintings are at greater risk than uncracked paint layers.
Section 2

TRANSIT CLIMATE CONDITIONS

Topics

- Expected Transit Environments in Summer and Winter
EXPECTED TRANSIT ENVIRONMENTS IN SUMMER AND WINTER

EXPECTED TEMPERATURE AND RELATIVE HUMIDITY VARIATIONS

Research has shown that damage to paintings can be a result of moisture loss in drying (drops in relative humidity) and cold temperature. Considering this, it is worth commenting on the outdoor environment that can be anticipated while paintings are in transit. In his article, David Saunders states, "The majority of the world's museums and galleries are to be found in the four temperate climactic bands." Saunders describes these four bands as: the cool, temperate oceanic having few extremes in temperature; the continental, cold temperate having extremes of hot and cold temperatures; the wet, warm temperate band having hot wet summers and mild winters; and the dry, temperate zone having warm dry summers and mild wet winters. The United States and its possessions, Puerto Rico, Guam, and the Virgin Islands have all four of these climactic regions and they can exhibit temperature extremes and some deviation in relative humidity. More importantly, these climactic variations deviate severely from the benign environment of the climate-controlled museum, which is usually maintained at about 23°C (73°F) and 50%-60% relative humidity. Transporting a work of art requires that the transport system affords protection against severe deviations from the museum environment.

Most meteorological information is usually given in monthly or seasonal averages whereas extremes in temperature can be dramatic. In the central United States for example, winter temperatures can easily reach as low as -30°C (-22°F) while in the same area the summer temperatures can reach 38°C (100°F). It is necessary to keep in mind that the extremes in temperature can differ widely from the average recorded values.

With few exceptions, outdoor relative humidity does not exhibit the same extremes as temperature. In the United States, the mean relative humidity is around 70% ranging from average lows of 30% to average highs of 85%. This does not reflect however, the summer peaks of 90% or above occurring during rainy periods. Figure 1 shows the highest/lowest temperature record versus average relative humidity for weather stations in all of the fifty states, Puerto Rico, and the Pacific Islands. This chart illustrates the average range of relative humidity as well as the expected temperature extremes in the United States. Saunders gives average weather data for different cities of the world show-
ing only Khartoum and Las Vegas having relative humidity levels below 30% and all of the rest of the cities higher than 45% at any time of the year. This data indicates that throughout the world, temperature differences can vary widely, but with the exception of dry desert areas, the relative humidity will vary from low averages of 45% to high averages of 85%. These worst-case possibilities should be incorporated when planning the transportation of works of art.

- The important point is that the packing case plays a major role in the control of relative humidity even with major temperature variations; internal temperature variations of the case are only slowed by the use of insulation. The primary control of temperature will fall on the transportation system, therefore special attention should be given to the temperatures expected in transit and the transportation equipment used.
TEMPERATURE AND RELATIVE HUMIDITY CONTROL
WITHIN TRANSPORTATION VEHICLES

For the most part, environmental control in transportation vehicles is limited to temperature control such as cooling in the summer and heating in the winter. This means that relative humidity is uncontrolled and can vary even more dramatically than as described for the outdoor environment. For example, heating the inside of a truck to 20°C (68°F) in the winter when the outdoor temperature and relative humidity are 0°C (32°F) and 60% relative humidity will lower the relative humidity in the truck interior to about 16% relative humidity which can be potentially damaging to works of art. Designing the packing case to provide relative humidity control is almost always necessary for wintertime travel.

- **Aircraft**
  
  Aircraft flying at high altitudes are exposed to very cold temperatures. The median outside air temperature at 10,000 meters (27,500 ft.) is approximately -40°C (-40°F).\(^4\) The temperature inside the aircraft, including the cargo hold, is heated and will usually be maintained at reasonable levels. While it is unlikely that the temperature will fall below 5°C (41°F), temperatures above 10°C (50°F) are typical. It is impossible to accurately predict the temperature range in the cargo holds, however, since it depends on the thermostat settings chosen by the flight engineer and the mechanical condition of the aircraft.

- **Trucks**
  
  In general, the greatest temperature extremes occur in trucks when they are stationary in the hot sun. Solar radiation can substantially increase the heat in noncooled trucks. Parked trucks can become very hot inside, therefore avoid having paintings left in them for long periods of time. Convection cooling of the air passing over a moving truck can reduce the internal temperature by 6°-8°C (11°-15°F) so in moderate temperatures, for short periods such as local delivery, it might be possible to use unheated trucks.\(^5\) If trucks are to be used for transportation for long periods of time and in adverse weather, use temperature-controlled trucks and relative humidity-controlled cases.

- **Rail Transport**
  
  The environmental control for cargo railcars can be very similar to trucks. The interior spaces of the passenger cars are controlled to maintain human comfort.
• **Ship Transport**

  Paintings are rarely transported by ship due to their slow speed. Usually this mode of transport is used for extremely large and heavy objects such as sculpture. Very large contemporary paintings are often removed from their stretchers and rolled or the stretchers are designed for folding. If this method is used, make sure the sea container is kept in the cargo hold, not on the deck.

• **Warehouses**

  Warehouses where objects are often stored for a short period of time at transfer points may only be heated but not cooled. Due to the heavy traffic of loading equipment into and out of the warehouse, large bay doors are often left open causing variations in temperature. If transporting during extremely hot or cold periods is expected, case insulation is recommended.

**NOTES**


Section 3

TEMPERATURE PROTECTION

Topics

- Insulating Materials
- Temperature Half-Time
- Temperature Half-Times of Packing Cases
INSULATING MATERIALS

Temperature changes can cause damage to works of art, particularly if they occur very rapidly. No amount of insulation will eliminate temperature variations though temperature changes can be slowed by adding insulation to the packing case. The temperature half-time is frequently used to describe rate of temperature change inside a packing case. (Refer to Temperature Half-Time for more information.)

There can be substantial variation in the thermal conductivity of the materials used in packing cases. Materials having a low thermal conductivity are better insulators than those having higher conductivity values. For example, some polyethylene foams have a thermal conductivity as high as 0.055 W/(m °C), (0.38 BTUin./h ft.°F), and they will conduct heat one and one-half times faster than a polyester urethane foam that has a thermal conductivity of 0.036 W/(m °C), (0.25 BTUin./h ft.°F).

Increasing the thickness of the insulating materials will reduce the heat flow rate in direct proportion to the thickness increase. Therefore, if the insulation thickness is doubled, the rate of heat loss or gain through the material will be reduced by one-half. This does not imply, however, that doubling the thickness of the insulation will necessarily halve the thermal half-time of a packing case because insulation thickness is only one variable affecting the temperature half-time.

Figure 1 — A comparison of the insulating properties of several materials used in the construction of packing cases.
A few comments about Figure 1 are useful to ensure that the graph is properly understood.

- In general, polyethylene foams are a better insulator than wood but are less effective than polystyrene foam.

- Contrary to the belief of many packers, flexible polyurethane foams are as good an insulator as polystyrene foams.

- Most rigid polyurethane foams are better insulators than polystyrene.

## R-VALUES

R-values, also called R-factors, are used to compare the insulating properties of materials. The R-value is a measure of a material's ability to resist the flow of heat with higher R-values having better insulating power. (See Table 1.) When comparing the properties of various materials, the R-value is provided for a specified material thickness. When an R-value is given for a wall in a house, it refers to the insulating properties of the total thickness of all the materials in the wall.

Table 1 — R-values for several construction and insulating materials. The values are based on the average thermal conductivity of the materials in BTU/ft.²/hr./°F/in. and W/m/°C.

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value (per inch)</th>
<th>R-value (per meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>English Units</td>
<td>Metric Units</td>
</tr>
<tr>
<td></td>
<td>h·ft.²·F/ BTU-in.</td>
<td>m·°C/W</td>
</tr>
<tr>
<td>White Pine</td>
<td>1.2</td>
<td>8.2</td>
</tr>
<tr>
<td>Plywood</td>
<td>1.3</td>
<td>9.0</td>
</tr>
<tr>
<td>Polyethylene foam</td>
<td>2.7</td>
<td>18.6</td>
</tr>
<tr>
<td>Fiber glass blanket</td>
<td>3.1</td>
<td>21.4</td>
</tr>
<tr>
<td>Rigid polystyrene planks</td>
<td>4.1</td>
<td>28.3</td>
</tr>
<tr>
<td>Flexible polyurethane foam</td>
<td>4.4</td>
<td>30.4</td>
</tr>
<tr>
<td>Rigid polyurethane planks</td>
<td>7.1</td>
<td>49.0</td>
</tr>
</tbody>
</table>
FOR FURTHER INFORMATION, SEE:


TEMPERATURE HALF-TIME

Packing cases containing works of art are frequently exposed to temperature variations during transit and this affects the case's interior temperature. If a well-sealed packing case is moved from the warmth of the museum into a cold airport warehouse, its interior temperature will fall. The temperature difference between the museum and the warehouse, the case's size, shape, air leakage rate, thickness of the case walls, the heat capacity of the contents, and the thermal conductivity of the case materials determines the rate of change. If the packing case sits outdoors, it is also affected by sunlight and wind. There are various ways to minimize temperature fluctuations in packing cases. Couriers can strive to keep packing cases away from harsh environments that are unusually hot, cold, in direct sunlight, or exposed to wind. Quality case construction minimizes air leakage. Cube-shaped cases are affected less than large, slender cases. Finally, thick layers of insulating materials will slow the heat loss or gain of the interior.

Figure 1 is a graph of the interior temperature of a packing case that is initially equilibrated to 20°C (68°F) and then moved to an environment at 0°C (32°F). The midpoint between these two temperatures is 10°C (50°F) and it takes five hours for the interior case temperature to drop to 10°C (50°F). Five hours is the Temperature Half-Time for the case in this example. Additionally, it takes five more hours for the temperature to drop to 5°C (41°F), the midpoint between 10°C (50°F) and 0°C (32°F).

Figure 1 — The rate of temperature change in a packing case having a temperature half-time of five hours.
Measuring thermal half-time for a packing case is not difficult. The simplest approach is to place a recording device inside the case that monitors the interior temperature and then move the case from a room at one temperature to a room at a very different temperature. The recorded temperature history will reveal the time it took for the case to reach the midpoint between the initial and final temperatures.

FOR FURTHER INFORMATION, SEE:


TEMPERATURE HALF-TIMES OF PACKING CASES

Temperature half-time is a very convenient way to compare the insulating performance of packing cases. It can be easily determined by monitoring the temperature inside a packing case that is moved from a room at one temperature to a room at a very different temperature (see Topic, Temperature Half-Times). Temperature half-times can also be estimated mathematically based on the insulating properties of the painting and the materials used in the case's construction.

Table 1 on the following page provides the mathematically estimated temperature half-time for various packing cases and compares them with the experimentally determined temperature half-times for several packing cases.
Table 1 — Theoretical and experimentally determined temperature half-times for several packing cases (made of 3/4 in. [1.9 cm] plywood reinforced with 3/4 in. [1.9 cm] pine battens) containing various quantities of thermal insulation. The packing cases contained a framed painting on canvas measuring 60 x 60 x 5 cm (23.62 x 23.62 x 2 in.) and having a heat capacity of 0.069 J/°C (5.5 BTU/°F).

<table>
<thead>
<tr>
<th>Insulation Materials</th>
<th>Insulation Thickness</th>
<th>Temperature Half-Time</th>
<th>Theory</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plywood Case Only</td>
<td>—</td>
<td>.4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>*Polyester Urethane Foam-Flexible</td>
<td>2.5</td>
<td>1.6</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Polyester Urethane Foam-Flexible</td>
<td>5.0</td>
<td>2.6</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>Polyester Urethane Foam-Flexible</td>
<td>10.0</td>
<td>4.6</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Polyether Urethane Foam-Flexible</td>
<td>15.0</td>
<td>6.6</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>+Polyether Urethane Foam-Rigid</td>
<td>10.0</td>
<td>7.8</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>++Polyethylene Foam</td>
<td>10.0</td>
<td>3.0</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>†Polystyrene Foam-Rigid</td>
<td>5.0</td>
<td>2.6</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

* The foam density is 33 kg/m³ (2 lb./ft.³) and a thermal conductivity of 0.036 W/(m·°C) or (0.25 BTU·in.)/(h·ft²·°F) was used in the calculations.

+ The foam density is 33 kg/m³ (2 lb./ft.³) and a thermal conductivity of 0.02 W/(m·°C) or (0.14 BTU·in.)/(h·ft²·°F) was used in the calculations.

++ The foam density is 36 kg/m³ (2.2 lb./ft.³) and a thermal conductivity of 0.055 W/(m·°C) or (0.38 BTU·in.)/(h·ft²·°F) was used in the calculations.

† The foam density is 33 kg/m³ (2 lb./ft.³) and a thermal conductivity of 0.036 W/(m·°C) or (0.25 BTU·in.)/(h·ft²·°F) was used in the calculations.

** FROM TABLE 1 IT CAN BE DETERMINED:**

- A plywood case without insulation material provides minimum insulation, e.g. a low temperature half-time.
• Insulation material increases the temperature half-time significantly.

• Different types of insulation material provide varying degrees of insulation.

• Doubling the thickness of insulating material does not double the temperature half-time.

NOTES

1. The theoretical values are based on the formula provided by: Peter Wilson, "Temperature and Relative Humidity Control in Packing Cases," UKIC Meeting on Packing Cases—Safer Transport for Museum Objects Preprints, S. Staniforth, ed. (London, 1985), 1-3. The experimentally determined half-times were measured at the National Gallery of Art, Washington.

FOR FURTHER INFORMATION, SEE:


N. Stolow, Controlled Environment for Works of Art in Transit (1966).


Section 4

RELATIVE HUMIDITY PROTECTION

Topics

- Wrapping Materials for Paintings: Polyethylene
- Wrapping Materials for Paintings: Glassine
- Wrapping Materials for Paintings: Kraft Paper
- Wrapping Materials for Paintings: Kraft Paper or Glassine Covered with Polyethylene
- Wrapping Materials for Paintings: Inner Packing Case
- General Properties of Silica Gel
- Use of Silica Gel in Packing Cases for Paintings
WRAPPING MATERIALS FOR PAINTINGS:
POLYETHYLENE

**ADVANTAGES OF WRAPPING PAINTINGS IN POLYETHYLENE**

- Polyethylene wrapped around a painting encloses a very small volume of air. The moisture-absorbing materials of the painting will establish a relative humidity in the enclosed air that is at the same level the painting has been exhibited or stored. The quantity of moisture contained in a typical painting, particularly one that is in a wooden frame, can easily be a thousand times greater than the water in the surrounding air. Therefore, a change in temperature causes very small fluctuations in the moisture content of the painting.

- Since packing cases are too frequently stored in areas that have unsuitable environments, polyethylene wrapping materials can help protect the painting. If a painting is placed in a wooden packing case that has been stored for several months at 30% relative humidity, the relative humidity in the packing case will be 30%. However, if the painting comes from a 50% relative humidity environment, wrapping it in polyethylene will create a 50% relative humidity environment inside the plastic wrapping.

- Polyethylene is waterproof. If water leaks into a packing case, a painting wrapped in polyethylene that has been sealed with waterproof tape will not get wet.

- The painting is visible through polyethylene.

- Polyethylene has a very smooth surface, reducing the possibility of abrasion.

**DISADVANTAGES OF WRAPPING PAINTINGS IN POLYETHYLENE**

- Polyethylene increases the risk of condensation when paintings are packed in uninsulated cases. However, experiments have indicated that the risk is small when the packing case contains a minimum of 5 cm (2 in.) of thermal insulation and the painting is maintained at a level of relative humidity below 70%.
• Some polyethylene has an oil residue on the surface that could soil a painting.

FOR FURTHER INFORMATION, SEE:


N. Stolow, Controlled Environment for Works of Art in Transit (1966).


WRAPPING MATERIALS FOR PAINTINGS: GLASSINE

- **ADVANTAGES OF WRAPPING PAINTINGS IN GLASSINE**
  - There is small risk of condensation because glassine is slightly absorbent.
  - The painting is slightly visible through glassine.
  - Glassine has a smooth surface, reducing the possibility of abrasion.

- **DISADVANTAGES OF WRAPPING PAINTINGS IN GLASSINE**
  - Glassine is permeable to water vapor. A painting wrapped in glassine will be exposed to the relative humidity created by the packing case. If a wooden packing case has been inappropriately stored at 30% relative humidity, a painting wrapped in glassine will be exposed to 30% relative humidity when it is packed.
  - Glassine is not waterproof, therefore, if water leaks into the case, the painting may get wet.
  - Glassine is easily torn.
  - It is difficult to see the painting through glassine.
  - Glassine can develop creases that are hard enough to scratch a delicate varnish.

**FOR FURTHER INFORMATION, SEE:**


WRAPPING MATERIALS FOR PAINTINGS:
KRAFT PAPER

- ADVANTAGES OF WRAPPING PAINTINGS IN KRAFT PAPER
  - There is a very small risk of condensation because kraft paper is absorbent.
  - Kraft paper is inexpensive.
  - Kraft paper is readily available.

- DISADVANTAGES OF WRAPPING PAINTINGS IN KRAFT PAPER
  - Kraft paper is permeable to water vapor. A painting wrapped in kraft paper will be affected by the relative humidity in the packing case. If a wooden packing case has been inappropriately stored at 30% relative humidity, a painting wrapped in kraft paper will be exposed to the 30% relative humidity in the case.
  - Kraft paper is not waterproof, therefore, if water leaks into the case, the painting may get wet.
  - Kraft paper is easily torn.
  - The painting is not visible through kraft paper.
  - Kraft paper can develop creases that are hard enough to scratch a delicate varnish.

FOR FURTHER INFORMATION, SEE:


WRAPPING MATERIALS FOR PAINTINGS: KRAFT PAPER OR GLASSINE COVERED WITH POLYETHYLENE

ADVANTAGES OF WRAPPING PAINTINGS WITH KRAFT PAPER OR GLASSINE COVERED BY POLYETHYLENE

- The polyethylene encloses a very small quantity air around the painting. The moisture-absorbing materials in the painting will establish a relative humidity in the enclosed air that is appropriate for the painting. The quantity of moisture contained in a typical painting, particularly one that is in a wooden frame, can easily be a thousand times greater than the water in the surrounding air. Therefore, a change in temperature causes very small fluctuations in the moisture content of the painting.

- The polyethylene protects the painting from the inappropriate environment that may be created by the packing case. Unfortunately, packing cases are too frequently stored in areas that lack the proper environments. If a painting is placed in a wooden packing case that has been stored for several months at 30% relative humidity, the relative humidity in the packing case will be 30%.

- Polyethylene is waterproof. If water leaks into a packing case, a painting wrapped in polyethylene that has been sealed with waterproof tape will not get wet.

- There is small risk of condensation because kraft paper and glassine are absorbent.

- These materials are inexpensive and readily available.

DISADVANTAGES OF WRAPPING PAINTINGS WITH KRAFT PAPER OR GLASSINE COVERED BY POLYETHYLENE

- More handling of the painting is required to wrap it in several layers of different material.

- The painting is not visible through kraft paper and is minimally visible through glassine.

- Kraft paper and glassine can develop creases that are hard enough to scratch a delicate varnish.
FOR FURTHER INFORMATION, SEE:


WRAPPING MATERIALS FOR PAINTINGS: INNER PACKING CASE

Wrapping the inner packing case with polyethylene is recommended before placing the inner packing case in the outer case.

**ADVANTAGES OF PLACING PAINTINGS IN AN INNER PACKING CASE**

- If the inner packing case is made of wood or paper, there is a small risk of condensation in uninsulated packing cases and virtually no risk of condensation in packing cases containing at least 5 cm (2 in.) of thermal insulation.

- The inner packing case encloses a very small quantity of air around the painting. The moisture-absorbing materials of the inner packing case and the painting will establish a relative humidity in the enclosed air that is appropriate for the painting. It is important, however, that the inner packing case be conditioned to the proper relative humidity before the painting is packed.

- If the inner packing case is wrapped in polyethylene, it will protect the painting from the inappropriate environment that may be created by the outer packing case. This assumes that the inner packing case has been conditioned to the proper relative humidity. Unfortunately, packing cases are too frequently stored in areas that lack proper environments. If a painting is placed in a wooden packing case that has been stored for several months at 30% relative humidity, the relative humidity in the packing case will be 30%.

- If the inner packing case is wrapped in polyethylene, the package will be waterproof.

- An inner packing case reduces the possibility of abrasion on the frame.

**DISADVANTAGES OF PLACING PAINTINGS IN AN INNER PACKING CASE**

- If the inner packing case and outer packing case are stored in an inappropriate environment, the painting will
be exposed to an undesirable relative humidity when it is packed in the inner packing case.

- Additional work is required to construct the inner packing case.

- An inner packing case increases the size and weight of the outside packing case.

FOR FURTHER INFORMATION, SEE:


N. Stolow, Controlled Environment for Works of Art in Transit (1966).


GENERAL PROPERTIES OF SILICA GEL

Works of art made of moisture-absorbent materials, e.g. wood, fabric, paper, parchment, or ivory, are sensitive to changes in relative humidity. When the relative humidity increases, these materials adsorb water from the air, causing them to swell. When the relative humidity goes down, moisture-absorbent materials lose moisture, causing them to shrink. The repeated expansion and contraction of the materials can cause damage.

Ideally, the relative humidity for art objects should be controlled within a few percent. The relative humidity range recommended for objects depends on the materials of construction and the environmental conditions to which the objects have become accustomed. An object acclimated in the tropics might be damaged if it is moved to the desert. In fact, such an object might also be damaged if it were moved into a typical museum in the United States because the conditions in the museum would probably be much drier than found in the tropics.

It is not always possible to control the relative humidity in an exhibition gallery to match the exact needs of every object. To overcome this problem, objects are frequently exhibited in display cases. Humidity buffers, for example silica gel, are often added to the cases to help control the relative humidity. Other moisture-absorbent materials, e.g. wood and paper, also work as humidity buffers but they do not work as well. Silica gel is more efficient because for its weight, it contains a much larger quantity of water than other materials of the same weight. Therefore, when the relative humidity of the surrounding air changes, for example as a result of a temperarture fluctuation, it can readily adsorb or desorb large quantities of moisture. This stabilizes the relative humidity and reduces the moisture content fluctuations of the objects in the case.

The quantity of water in a moisture-absorbent material at a given temperature and relative humidity is called its equilibrium moisture content (EMC). The equilibrium moisture content is usually expressed as a percentage of the oven dry weight of the material. The equilibrium moisture content of three types of silica gel and wood are graphed as a function of relative humidity in Figure 1. Art-Sorb® and Arten Gel®, are good humidity buffers because they can absorb a high amount of moisture and are more efficient at a higher relative humidity.
Figure 1 — Relationship between relative humidity and the equilibrium moisture content for three types of silica gel and wood.

NOTES

1. Art-Sorb is a product of Fuji-Davison Chemical, Ltd., Nagoya-shi, Japan. Arten Gel is a product sold by Art Preservation Services, New York, NY.

FOR FURTHER INFORMATION, SEE:


USE OF SILICA GEL IN PACKING CASES FOR PAINTINGS

INTRODUCTION

Ideally, the relative humidity in a packing case should be constant and equal to the relative humidity in the place where the packed painting is exhibited or stored. In a well-sealed packing case containing moisture-absorbing materials, the relative humidity will remain constant if the temperature remains constant. If the temperature does change, the relative humidity will be affected. The control of relative humidity with changes in temperature can be accomplished with moisture-absorbing (hygroscopic) materials or "buffers." The fabric, paper, or wood used in the construction of paintings and packing cases are all moisture-absorbent and can be considered buffers. Even some foams used in packing cases function as humidity buffers.

Under most circumstances, the volume of enclosed air in a packing case is small and the materials in the painting are more than adequate buffers. There are circumstances where the addition of silica gel as a buffer is useful. Packing cases constructed using metal or fiber glass will not act as buffers. Paintings on metal need additional buffering material when in transit, though paper, wood, or other moisture-absorbing materials will suffice in place of silica gel.

ADVANTAGES OF ADDING SILICA GEL TO PACKING CASES

- Silica gel is a very efficient buffer for controlling relative humidity in exhibition display cases and packing cases.

- If a painting is stored in a packing case for a long time—\textit{which is not advisable}—several weeks or months, silica gel will slow the rate of the relative humidity change in the packing case.

- When used in very large exposed surface areas within the case, silica gel can lessen the rapid relative humidity changes in uninsulated packing cases caused by a rapid temperature change. Silica gel can stabilize the environment for works of art made from materials that are not moisture absorbent, e.g. metals.
DISADVANTAGES OF ADDING SILICA GEL TO PACKING CASES

- Given the small volume of air in packing cases and that most paintings are made from moisture-absorbent materials, silica gel is usually an unnecessary addition to the packing case.

- Silica gel that has been conditioned to the wrong relative humidity could be accidentally added to the packing case. This means that the relative humidity in the packing case would be inappropriate for the painting.

- If the silica gel is left in the packing case and the case is stored in an environment having the wrong relative humidity for the painting, the silica gel will maintain the wrong relative humidity in the case when the painting is re-packed.

- It usually increases the construction time for the packing case.

- It increases the cost of packing cases.

FOR FURTHER INFORMATION, SEE:


Section 5

SHOCK AND VIBRATION HAZARDS

Topics

- Shock and Vibration Hazards
- Vibration Fragility of Paintings
SHOCK AND VIBRATION HAZARDS

The transportation of a painting can be divided into five segments.

- Handling in the museum or gallery before the painting is packed.
- Transfer from the museum or gallery in a truck to the terminal of the long-distance carrier such as an airport. Long-distance transportation in an aircraft, truck, train, or even ship.
- Transfer from the long-distance terminal to the museum or gallery.
- Unpacking and handling the painting at the destination museum or gallery.

These five events can happen twice, once each way, every time the painting is lent.

**HANDLING WITHIN THE MUSEUM**

Handling a painting within the museum presents the greatest hazard to the object. The painting is unpacked and there is no protection to either the painting or frame from impact. **This is a time when caution is recommended.** Large paintings are especially vulnerable because they require several people to move them and there are usually no special grips for holding. Large, modern paintings often approach or exceed the dimensions of doors and elevators and sometimes need to be removed from their stretchers. In the museum, the greatest hazards are impact from dropping and puncture caused by collisions or bumping against other objects.

**LOCAL TRANSIT, TRUCKS, AND DEPOTS**

Properly packed paintings are normally protected from accidental shocks and drops while loading them onto and off the trucks used as transport to airports and terminals. Vibration due to trucks not equipped with air-ride suspension is the most severe of any of the transport systems, in the 1-200 Hertz (cycles per second) range. The vibration levels are, however, relatively low in magnitude and random in nature. Unless resonant conditions develop, the truck vibration levels are low compared to
critical levels that may cause direct damage to paintings. A properly stretched and packaged canvas or a panel painting should suffer no ill effects due to vibration if the painting case is secured to the side or bottom of the vehicle and not permitted to bounce freely on the truck bed. On the other hand, vibration can damage paintings that are slack on the stretcher and able to slap against the stretcher bars. Modern paintings having objects and artifacts glued or otherwise attached to the canvas represent a potential problem due to vibration if the objects are not secured from movement. Vibration can also cause abrasion of the frame and painting edges if improperly packed. Painting cases should ride on edge whenever possible.

Depots and terminals use mechanical equipment to move cargo and working conditions can be crowded. The greatest hazards are case puncture from forklifts and topple from accidental collisions.

**LONG-DISTANCE TRAVEL**

- **Trucks**
  In the United States, the general cargo long-distance trucking industry can be roughly broken into two categories. One, the overland motor freight companies used to haul heavy cargos; they tend to use equipment without air-ride suspension. The other are moving companies that haul high-volume, light cargos, such as household goods, which tend to use air-ride suspension. This suspension has clearly demonstrated a reduction in vibration and shock and, interestingly, is employed primarily to extend the service life of the trailers.

  Because of this, the trucking industry is installing this type of suspension on an ever-increasing number of trucks. The use of air-ride suspension-equipped trucks is recommended whenever possible.

- **Rail Transport**
  Vibration levels in railcars can be summarized as frequencies between 1-500 Hertz at a maximum of 0.2 G, which is considerably lower than trucks. The most severe shocks result from coupling cars and can reach 43 G's. Although coupling shocks may not affect the contents of a properly designed package, the shocks are long in duration and may result in high compressive forces on shipping cases that are surrounded by inadequately braced cargo.

- **Aircraft**
  Vibration levels from aircraft have higher frequencies than trucks and railcars, between 100-1,000 Hertz, and magnitudes
up to 1 G. Since high-frequency vibrations are easily reduced by common case cushioning materials, there is little problem to works of art. The maximum shock an aircraft experiences at landing is around 1.1 G, well below the damage potential to all sound paintings. 4

- **Ships**
  Ship vibration while it is under operation is mainly low-frequency, 1-100 Hertz and less than 0.2 G. The maximum shock is typically 1.5 G due to slamming of the bow after rising into large waves. 5

This type of shock can have a multiplying effect on the weight of a stack of shipping containers resulting in high compressive loads on the lower containers in the stack. Ship transport may also involve the use of cranes and the possibility of drops from heights as high as 40 feet. For these reasons, ship transport requires highly durable containers.

## SHOCK AND VIBRATION HAZARDS DURING SHIPMENT

- The levels of shock and vibration encountered in the transport system are generally low with the most severe vibration resulting from trucks. Air-ride suspension offers a considerable improvement over standard spring suspension. In general, however, it is incumbent on the shipper to provide the necessary levels of protection for the objects shipped. The most severe shock results from handling during loading and unloading operations and accidents occurring in the depots and terminals.

### NOTES

VIBRATION FRAGILITY OF PAINTINGS

**VIBRATION FRAGILITY**

In order for there to be a serious possibility of damage due to vibration, three factors must exist.

- The painting has a natural frequency in the range of the frequencies produced by the transport vehicle.
- The vibration of the transportation vehicle must contain frequencies that may cause the painting to resonate.
- The magnitude of the resulting vibration must be high enough to cause damage.

The vibration produced by trucks, trains, planes, and ships consists largely of random low-level vibrations whose magnitudes are too low to cause direct damage to sound paintings.

**Also of interest during transport are such secondary effects as abrasion of frame and painting surfaces** due to vibration induced by rubbing and having loose paintings slapping the stretcher bars.

**CANVAS PAINTINGS**

For canvas paintings under normal tension, their lowest natural frequency will be in the range of 1-50 Hertz (cycles per second) depending on their size. This falls in the range of the frequencies developed in trucks and trains. However, research has shown that neither trains or trucks develop vibration in those frequencies at sufficiently high magnitudes to cause cracking or flaking of well-treated paintings. **It is important that the painting be firmly secured to the side or the bottom of the truck to prevent the packing case from bouncing within the truck.**

**PANEL PAINTINGS**

Panel paintings are sensitive to much higher frequencies than canvas paintings. These frequencies will be attenuated by the cushioning systems used in the protective packaging for transport.
FOR FURTHER INFORMATION, SEE:


Section 6

SHOCK PROTECTION

Topics

- Fragility Factors
- Probable Drop Heights
- How to Use a Dynamic Cushioning Curve: Procedure A
- How to Use a Dynamic Cushioning Curve: Procedure B
- Optimum Static Loads — Quick Reference Table
- Load-Bearing Areas
FRAGILITY FACTORS

All art objects are vulnerable to damage if they are subjected to sufficient force. The degree of vulnerability is called a fragility factor. The magnitude of the fragility factor is normally expressed in G's, which are multiples of the force due to gravity that the object will experience on impact. The lower the fragility factor, the more delicate the object.

Table 1 gives fragility factors for other well-known objects.

Table 1 — Approximate fragility of typical packaged articles.

<table>
<thead>
<tr>
<th>Extremely Fragile</th>
<th>18 – 25 G’s</th>
<th>Precision electronic test equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Delicate</td>
<td>25 – 40 G's</td>
<td>Scientific instruments, x-ray equipment</td>
</tr>
<tr>
<td>Delicate</td>
<td>40 – 60 G’s</td>
<td>Computer display terminals, electric typewriters, most solid state electronic equipment</td>
</tr>
<tr>
<td>Moderately Delicate</td>
<td>60 – 85 G’s</td>
<td>Stereo equipment, televisions, computer floppy disk drives</td>
</tr>
<tr>
<td>Moderately Rugged</td>
<td>85 – 110 G’s</td>
<td>Major appliances, furniture</td>
</tr>
<tr>
<td>Rugged</td>
<td>Over 110 G’s</td>
<td>Table saws, sewing machines, machinery</td>
</tr>
</tbody>
</table>

PAINTING FRAGILITY

The exact fragility factors for paintings are not known although research has provided some estimates and practical information.

CANVAS PAINTINGS

- Tests at the Canadian Conservation Institute using 25 in. x 30 in. test canvas paintings prepared with 5 to 6 brush-coated layers of brittle gesso (93% PVC) without frames, that were dropped onto moderately hard surfaces such as
a floor with a thin layer of carpet, were visibly cracked at shock levels in the range of 80 to 100 G's. Computer modeling of similar paintings and materials by the Smithsonian Institution's Conservation Analytical Laboratory predicted similar damage at shock levels in the range of 90 G's.

- Canvas paintings without frames were most sensitive to impacts on their corners, impacts to the stretchers perpendicular to the canvas, and impacts resulting from end-over or topple hazards.

- Measures that can decrease the shock sensitivity of a painting include backing boards and wrapping (which reduces canvas displacement for impact in the plane of the canvas and end-over hazards) strong frames and back boards (which reduces stretcher distortion in the event of corner impact).

- Although this section discusses painting fragility, it should be noted that elaborate frames may be far more susceptible to damage from impacts on their surface than the fabric supported paintings they contain.

Typically, museum packing cases are designed to provide impact protection between 40-60 G's. Even lower G levels, however, can be attained if the packing case is carefully designed.

**FOR FURTHER INFORMATION, SEE:**


PROBABLE DROP HEIGHTS

The environmental factors that result in shocks to packaged items are common to all modes of shipment. For package design purposes, shock hazard severity is normally expressed in terms of a probable drop height. Package designers frequently use package weight to estimate drop heights because weight tends to determine the manner in which packages are handled. Typical handling methods and probable drop heights for a range of package weights are provided in Table 1. This can be used when specific information on the handling operation that will be encountered is unavailable. For packing extremely valuable or fragile objects, it is best to choose higher than anticipated drop heights to ensure maximum protection.

A typical small painting in a hand-carried case might weigh up to 9 kg (20 lb.). A small painting case for cargo shipment might weigh up to 22 kg (50 lb.). Typically, larger easel paintings, packed one to a case might weigh from 22-136 kg (50-300 lb.). Large paintings with frames and shipping case might weigh up to 363-408 kg (800-900 lb.), rarely more. Works over 450 kg (1,000 lb.) are usually sculpture.

Table 1 — Probable drop heights based on package weight and handling methods.

<table>
<thead>
<tr>
<th>Package Weight kg (lb.)</th>
<th>Type of Handling</th>
<th>Drop Height cm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9 (0-20)</td>
<td>1 Person Throwing</td>
<td>105 (42)</td>
</tr>
<tr>
<td>10-22 (21-50)</td>
<td>1 Person Carrying</td>
<td>90 (36)</td>
</tr>
<tr>
<td>23-110 (51-250)</td>
<td>2 Persons Carrying</td>
<td>75 (30)</td>
</tr>
<tr>
<td>111-225 (251-500)</td>
<td>Light Equipment</td>
<td>60 (24)</td>
</tr>
<tr>
<td>226-450 (501-1,000)</td>
<td>Medium Equipment</td>
<td>45 (18)</td>
</tr>
<tr>
<td>Over 450 (1,000)</td>
<td>Heavy Equipment</td>
<td>30 (12)</td>
</tr>
</tbody>
</table>

Although Table 1 does not predict hazard occurrence, it does anticipate the probable drop height if a hazard does occur. The validity of these hazards has been confirmed by comprehensive
studies. These studies indicate that the values in Table 1 provide a reasonable worst-case scenario. Packages designed using these values may therefore include a certain degree of over-design. Following are generalizations collected by Ostrem and Godshall that support the drop height information listed in Table 1.

- 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.
- Consolidated loads are subjected to fewer and lower drops than are individual packages.
- Most packages are dropped on their bases. Over 50% of the total are base drops.
- The heavier the package, the lower the drop height.
- The larger the package, the lower the drop height.
- Handholds reduce the drop height by lowering the container height relative to the floor during handling.
- Labels such as *fragile* and *handle with care* have only minor effectiveness.

**EXTREME HAZARDS**

There is always a possibility that the drop heights in Table 1 could be exceeded during the course of a shipment. Lifting devices can, on occasion, be released too quickly, resulting in severe corner or edge drops. End impacts can occur when a swinging crate is lowered using slings. Containers can be dropped from heights as high as 12 m (40 ft.) during the loading or unloading of ships. For other modes of travel, the extreme hazards would be much less. For example, the maximum hazard that could be expected for truck shipments corresponds to a package being pushed or skidding off the tailgate, in which case the drop height would be approximately 75 cm (30 in.). In conditions such as postal sorting and distribution networks, light packages up to 10 kg (22 lb.) may experience impact velocities of up to 8 m per second (26 ft. per second) or the equivalent of a 3 m (9.8 ft.) drop. This information enables conclusions to be
Designing packages that are capable of withstanding potential hazards during a shipment would normally result in costly overdesign. For valuable or rare items such as museum artifacts, a reasonable degree of overdesign is considered an asset and the additional packaging costs are justifiable. At present, many museums use a high overdesign policy with good results.

NOTES


2. Ostrem and Godshall 1979, 9.


FOR FURTHER INFORMATION, SEE:


HOW TO USE A DYNAMIC CUSHIONING CURVE:
PROCEDURE A

Calculating the Shock Protection Provided by a Packing Case

Foam products are frequently used to cushion paintings inside packing cases. If used correctly, these materials can be effective for protecting paintings from shock and vibration during transit. When a painting is dropped on a hard surface without a cushioning material, the motion of the painting is abruptly halted on impact and a relatively large force (measured in G's) is transmitted to the painting, possibly causing damage. Foam cushioning materials reduce the force of impact by slowly bringing the painting's motion to rest.

How foam cushioning materials will perform at a specified thickness and drop height is graphically shown in Dynamic Cushioning Curves. These curves can be used to predict the shock levels that will be transmitted to the painting inside the packing case. Two procedures using the dynamic cushioning curves are outlined in this handbook. In procedure A, the objective is to design foam cushions for shock isolation that give the best protection for a painting should the packing case be dropped from a specific height. In procedure B, the method for evaluating an existing packing case is shown.

PROCEDURE A:

- **Step 1**
  Estimate the level of protection required by the packing case. Packing cases can be designed that subject paintings to less than 20 G's in a 75 cm (30 in.) drop. However, typical packing cases used by museums and commercial firms provide a level of shock protection between 40-60 G's. This level of protection is adequate for most paintings. When a painting is very fragile, however, packers should strive to build a case that provides 20 G protection.

- **Step 2**
  Select the cushioning material to be used for the packing case. Our example uses 10 cm (4 in.) thick polyester urethane foam.
**Step 3**
To establish an estimate of the most probable drop height that might occur in transit, the total weight of the painting and the packing case is needed. The painting can be easily weighed. It is not always possible to weigh the actual packing case because it has not yet been constructed. An estimate can be obtained by weighing another case of similar size. In the example, the painting weighs 15 kg (33 lb.) and the packing case (with the painting inside) weighs 70 kg (154 lb.).

**Step 4**
Determine the probable drop height using Table 1. The probable drop height for a packing case weighing 70 kg is 75 cm (30 in.). Refer to *Probable Drop Heights* for more information.

<table>
<thead>
<tr>
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<td>Heavy Equipment</td>
<td>30 (12)</td>
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</tbody>
</table>

**Step 5**
Refer to the dynamic cushioning curve for the selected cushioning material and drop height. In our example (Figure 1), the foam is 10 cm (4 in.) thick polyester urethane foam and the drop height is 75 cm (30 in.).

**Step 6**
Determine the optimum static load for the cushioning material. This will be the bottom-most point on a *dynamic cushioning*
curve. In this example, point A. (These values are summarized in the Chart provided in Topic, Optimum Static Loads—Quick Reference Table.)

Note that the bottom-most point on the curve is approximately 22 G peak acceleration (point B). This is the maximum G the painting will experience in a 75 cm (30 in.) drop.

**Figure 1 — Dynamic cushioning curve for polyester urethane foam when dropped from a height of 75 cm (30 in.). The foam thickness is 10 cm (4 in.) and the density is 33 kg per m$^2$ (2 lb. per ft.).**

- **Step 7**

Now it is necessary to determine how much foam is needed to support our 15 kg (33 lb.) painting. It is necessary to determine the surface area of foam that will be in contact with the painting. This is our load-bearing area. We divide the weight of the painting by the optimum static load, 0.025 kg/cm$^2$ (.35 lb./in.$^2$), which is obtained from Figure 1 and labeled point C.
This is:

\[
LBA = \frac{15 \text{ kg}}{0.0025 \text{ kg per cm}^2} = 600 \text{ cm}^2
\]

or

\[
LBA = \frac{33 \text{ lb}}{0.35 \text{ lb per in.}^2} = 93 \text{ in.}^2
\]

- **Step 8**
  Design cushions that provide a load-bearing area of 600 cm\(^2\) (93 in.\(^2\)) for each edge surface. If the depth of the painting frame is 5 cm (2 in.) and it is 120 cm (47 in.) long, a single cushion measuring 5 x 120 cm (2 x 47 in.) should be used (see Figure 2).

**Figure 2 — Cushion that provides a load-bearing area of 600 cm\(^2\) (93 in.\(^2\)).**

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**FOR FURTHER INFORMATION SEE:**


HOW TO USE A DYNAMIC CUSHIONING CURVE:
PROCEDURE B

Calculating the Shock Protection Provided by a Packing Case

Foam products are frequently used to cushion paintings inside packing cases. If used correctly, these materials can be effective for protecting paintings from shock and vibration during transit. When a painting is dropped on a hard surface without a cushioning material, the motion of the painting is abruptly halted on impact and a relatively large force (measured in G’s) is transmitted to the painting, possibly causing damage. Foam cushioning materials reduce the force of impact by slowly bringing the painting’s motion to rest.

How foam cushioning materials will perform at a specified thickness and drop height is graphically shown in Dynamic Cushioning Curves. These curves can be used to predict the shock levels that will be transmitted to the painting inside the packing case. In procedure A, the objective is to design foam cushions for shock isolation that give the best protection for a painting should the packing case be dropped from a specific height. The objective in procedure B is somewhat different. The packer is not concerned with getting the best performance from the foam cushions but wants to evaluate whether the packing case that has already been built will provide a level of shock protection that meets or exceeds what is required to protect the painting.

The problem can be described as follows:

PROCEDURE B:

Step 1
You are given an existing double packing case and you want to determine if it is suitable for transporting a painting that will fit into the inner case. (See Figure 1.) An inner case is being used since the painting has a very elaborate frame and the edges are too fragile to be placed directly against cushioning material.

The painting will be attached firmly to the inner case allowing no movement. This can be done either by placing heavy screws through the back of the inner case into the frame or with mending plates.

The outer case is completely lined with 10 cm (4 in.) polyester urethane foam. In other words, all internal surfaces are covered with foam. (See Figure 2.)
Figure 1 - Inner Case used in example.

![Inner Case Diagram]

- Long Narrow Side
- Short Narrow Side
- Height 80 cm (31.5 in.)
- Length 110 cm (43.3 in.)
- Depth 10 cm (4 in.)

Figure 2 - Double packing case used in example.

![Double Packing Case Diagram]

- Outer Case
- Inner Case
- 10 cm (4 in.) Polyester Urethane Foam
• **Step 2**
Measure and weigh the inner box, including the weight of the painting. In our example, the inner box measures 80 x 110 x 10 cm (31.5 x 43.3 x 4 in.) and weighs 20 kg (44 lb.) with the painting inside.

• **Step 3**
Calculate the static load on the foam on each of the narrow sides of the packing case. This is done by dividing the weight of the inner box (with the painting inside) by the load-bearing area (LBA) of the cushion (see topic, Load-Bearing Areas for further information). The load-bearing area of a cushion is the surface area of the cushioning material that actually supports the weight of the inner case containing the painting. (This method is particularly useful when designing a packing case for a painting that has an elaborate frame.)

**STATIC LOAD, LONG NARROW SIDE**

The two long narrow sides of the inner box are each 110 x 10 cm (43.3 x 4 in.), therefore the surface areas of these sides are each 1,100 cm² (170.5 in.²). As the total weight of the packed inner box is 20 kg (44 lb.), the static load on the foam is:

\[
\text{Static Load} = \frac{\text{Weight of Load-Bearing Area}}{\text{Load-Bearing Area}} = \frac{20 \text{ kg}}{1,100 \text{ cm}^2} \quad \text{or} \quad \frac{44 \text{ lb.}}{170.5 \text{ in.}^2}
\]

\[= 0.018 \text{ kg/cm}^2 \quad \text{or} \quad 0.258 \text{ lb./in.}^2\]

With the inner case resting on the foam in the bottom of the packing case, the static load on the foam is 0.018 kg/cm² or 0.258 lb./in.².

**STATIC LOAD, SHORT NARROW SIDE**

The two short narrow sides of the inner box are each 80 x 10 cm (31.5 x 4 in.), therefore, the surface areas of these two sides are each 800 cm² (124 in.²), this is the load-bearing area. As the total weight of the packed inner case is 20 kg (44 lb.), the static load on the foam is:

\[
\text{Static Load} = \frac{\text{Weight of Packed Inner Box}}{\text{Load-Bearing Area}} = \frac{20 \text{ kg}}{8,800 \text{ cm}^2} \quad \text{or} \quad \frac{44 \text{ lb.}}{1,364 \text{ in.}^2}
\]

\[= 0.025 \text{ kg/cm}^2 \quad \text{or} \quad 0.355 \text{ lb./in.}^2\]

Therefore, if the painting is shipped on its short narrow side, the static load of the foam would be 0.25 kg/cm (.35 lb./in.²).
Section 6 - Shock Protection

II  STATIC LOAD ON CASE FACE

The two large faces of the inner box are each 110 x 80 cm (43.3 x 31.5 in.), therefore, the surface areas of the two large faces of the inner box are each 8,800 cm$^2$ (1,364 in.$^2$). As the total weight of the packed inner case is 20 kg (44 lb.), the static load on the foam is:

$$\text{Static Load} = \frac{\text{Weight of Packed Inner Box}}{\text{Load-Bearing Area}} = \frac{20 \text{ kg}}{8,800 \text{ cm}^2} = \frac{44 \text{ lb.}}{124 \text{ in.}^2}$$

$$= 0.002 \text{ kg/cm}^2 \text{ or } 0.032 \text{ lb./in.}^2$$

If the inner case were shipped on the face of the case, that is, lying flat, the static load on the foam would be 0.002 kg/cm$^2$ (0.032 lb./in.$^2$).

After determining the static load for all sides and faces, it is necessary to determine the level of protection this case will provide in the event it is dropped on its side or is toppled over onto its face. **The recommended levels for protection are 40-60 G's for an average painting and 20-30 G's for a fragile painting.** The following steps calculate the level of protection provided by this case and we will compare the calculated values with the recommended values.

Table 1 — Probable drop heights based on package weight and handling methods. Gray area is the best solution.

<table>
<thead>
<tr>
<th>Package Weight kg (lb.)</th>
<th>Type of Handling</th>
<th>Drop Height cm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0- 9 (0-20)</td>
<td>1 Person Throwing</td>
<td>105 (42)</td>
</tr>
<tr>
<td>10-22 (21-50)</td>
<td>1 Person Carrying</td>
<td>90 (36)</td>
</tr>
<tr>
<td>23-110 (51-250)</td>
<td>2 Persons Carrying</td>
<td>75 (30)</td>
</tr>
<tr>
<td>111-225 (251-500)</td>
<td>Light Equipment</td>
<td>60 (24)</td>
</tr>
<tr>
<td>226-450 (501-1,000)</td>
<td>Medium Equipment</td>
<td>45 (18)</td>
</tr>
<tr>
<td>Over 450 (1,000)</td>
<td>Heavy Equipment</td>
<td>30 (12)</td>
</tr>
</tbody>
</table>
- **Step 4**
  Determine the most probable drop height that might occur in transit. The total weight of the painting, the inner packing case, and the outer packing case is needed. In the example problem, the packed inner case weighs 20 kg (44 lb.) and the outer packing case weighs 60 kg (132 lb.), so the total weight is 80 kg (176 lb.).

- **Step 5**
  Determine the probable drop height using Table 1. (See topic, *Probable Drop Heights* elsewhere in this section). The probable drop height for a packing case weighing 80 kg is 75 cm (30 in.).

- **Step 6**
  Refer to the dynamic cushioning curve (see Figure 3) for the cushioning material used in the packing case at the estimated drop height. In our example, the foam is 10 cm (4 in.) thick, polyester urethane foam and the drop height is 75 cm (30 in.).

*Figure 3 — Dynamic cushioning curve for polyester urethane foam when dropped from a height of 75 cm (30 in.). The foam thickness is 10 cm (4 in.)
• **Step 7**

To determine the protection provided by the packing case should it be dropped on one of its **long narrow sides**, we need to know the static load calculated in Step 3 and the dynamic cushioning curve shown in Figure 3. The static loading value for this side was 0.018 kg/cm$^2$ (.258 lbs./in.$^2$) and can be located on the horizontal axis labeled “static load” (point A) of Figure 3. A vertical line from this point intersects the dynamic cushioning curve at point B and going from point B horizontally to the left it will intersect the vertical axis labeled “peak acceleration” at point C. The value of 23 G's is read at point C and represents the level of protection provided by this case from a 75 cm (30 in.) drop on the long narrow side. This level of protection exceeds the 40-60 G protection desired for the average painting therefore the case is suitable in the event of this type of accident.

• **Step 8**

To determine the protection provided by the packing case should it be dropped on one of its **short narrow sides**, we need the static load calculated in Step 3 and the dynamic cushioning curve shown in Figure 3. The static load value for this edge was 0.025 kg/cm$^2$ (.355 lbs./in.$^2$) and can be located on the horizontal axis labeled “static load” (point D) of Figure 3. A vertical line from this point intersects the dynamic cushioning curve at point E and going from point E horizontally to the left it will intersect the vertical axis labeled “peak acceleration” at point F. The value of 22 G's is read at point F and represents the level of protection provided by this case from a 30 in. drop on the short narrow side. This level of protection exceeds the 40-60 G protection desired for the average painting therefore the case is suitable in the event of this type of accident.

• **Step 9**

To determine the protection provided by the packing case should it be dropped on one of its **faces** or if it topples over, we need to know the static load calculated in Step 3 and the dynamic cushioning curve shown in Figure 3. The static load value for the face is 0.002 kg/cm$^2$ (.032 lbs./in.$^2$) and can be located on the horizontal axis labeled “static load” (point G) of Figure 3. A vertical line from this point intersects the dynamic cushioning curve at point H and going from point H horizontally to the left it will intersect the vertical axis labeled “peak acceleration” at point I. The value of 82 G's is read at point I and represents the level of protection provided by this case from a 30 in. (75 cm) drop on the face. This level of protection is lower than the 40-60 G protection desired for the average painting therefore the case is suitable in the event of this type of accident.
will not give adequate protection in the event of this type of accident.

The faces have too much foam and it is necessary to remove some so that the case is effective against a topple or (face) drop.

The simplest approach for correcting the amount of foam used in our sample packing case is to remove the 10 cm (4 in.) thick piece of polyester urethane foam from the two large faces of the packing case and replace them with smaller pieces of foam. An easy way to do this is to make small foam triangular pads to position in each corner of the packing case. (See Figure 4.) This reduces the surface area of the foam supporting the two large faces of the inner case.

In Step 7 it was found that the static load on the long narrow sides, 0.018 kg/cm$^2$ (0.258 lbs./in.$^2$), provided an acceptable level of shock protection for a 75 cm (30 in.) drop. The surface area of foam cushions was 1,100 cm$^2$ (170.5 in.$^2$).

In Step 8, it was found that static load on the short narrow sides, 0.025 kg/cm$^2$ (0.355 lb./in.$^2$) also provided an acceptable level of shock protection for a 75 cm (30 in.) drop. The surface area of foam on the short narrow sides was 800 cm$^2$ (124 in.$^2$). It can be assumed that using a surface area of foam between 800 cm$^2$ (124 in.$^2$) and 1,100 cm$^2$ (170.5 in.$^2$) on each large face of the inner case will provide acceptable shock protection. Using a small triangular foam pad in each corner, each foam pad should have a surface area that is one-quarter of the total surface area required. Four foam pads, each having a surface area of 250 cm$^2$ (38.75 in.$^2$) would work well. The total surface area of the four pads is equal to 1,000 cm$^2$ (155 in.$^2$). See Figure 4.

Figure 4 — Double packing case modified using corner pads on the large faces of the outer case.
FOR FURTHER INFORMATION, SEE:


OPTIMUM STATIC LOADS — Quick Reference Table

The following table can be used as a quick guide and as an alternative to using cushioning curves. It is based on cushioning curve data for a 30 inch (75 cm) drop height. This drop height is a reasonable hazard assessment for typical shipments by truck for packages weighing 50 lbs. (20 kg) or more. Optimum load ranges are provided for seven different materials that will limit shock to less than 60 G's for packages containing paintings. For lighter packages, cushioning curve data for higher drop heights should be used.

<table>
<thead>
<tr>
<th>Material and Density</th>
<th>Thickness</th>
<th>Optimum Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-linked Polyethylene</td>
<td>50 mm</td>
<td>.028-.056</td>
</tr>
<tr>
<td>33 kg/m³ (2.0 lb./ft.³)</td>
<td>2 in.</td>
<td>.40 -.8</td>
</tr>
<tr>
<td></td>
<td>75 mm</td>
<td>.011-.140</td>
</tr>
<tr>
<td></td>
<td>3 in.</td>
<td>.15 - 2.0</td>
</tr>
<tr>
<td></td>
<td>100 mm</td>
<td>.011-.140</td>
</tr>
<tr>
<td></td>
<td>4 in.</td>
<td>.15 - 2.0</td>
</tr>
<tr>
<td>Cross-linked Polyethylene</td>
<td>75 mm</td>
<td>.014-.140</td>
</tr>
<tr>
<td>24 kg/m³ (1.5 lb./ft.³)</td>
<td>3 in.</td>
<td>.20 - 2.0</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>50 mm</td>
<td>.021-.070</td>
</tr>
<tr>
<td>33 kg/m³ (2.0 lb./ft.³)</td>
<td>2 in.</td>
<td>.31 - 1.0</td>
</tr>
<tr>
<td></td>
<td>75 mm</td>
<td>.014-.140</td>
</tr>
<tr>
<td></td>
<td>3 in.</td>
<td>.20 - 2.0</td>
</tr>
<tr>
<td></td>
<td>100 mm</td>
<td>.014-.140</td>
</tr>
<tr>
<td></td>
<td>4 in.</td>
<td>.20 - 2.0</td>
</tr>
<tr>
<td>Polyester Urethane</td>
<td>50 mm</td>
<td>.006-.035</td>
</tr>
<tr>
<td>33 kg/m³ (2.0 lb./ft.³)</td>
<td>2 in.</td>
<td>.08 - .5</td>
</tr>
<tr>
<td></td>
<td>75 mm</td>
<td>.004-.063</td>
</tr>
<tr>
<td></td>
<td>3 in.</td>
<td>.05 - .9</td>
</tr>
<tr>
<td></td>
<td>100 mm</td>
<td>.004-.098</td>
</tr>
<tr>
<td></td>
<td>4 in.</td>
<td>.05 - 1.4</td>
</tr>
<tr>
<td>Polyester Urethane</td>
<td>75 mm</td>
<td>.028-.049</td>
</tr>
<tr>
<td>24 kg/m³ (1.5 lb./ft.³)</td>
<td>3 in.</td>
<td>.40 - .7</td>
</tr>
<tr>
<td></td>
<td>100 mm</td>
<td>.002-.084</td>
</tr>
<tr>
<td></td>
<td>4 in.</td>
<td>.03 - 1.2</td>
</tr>
<tr>
<td>Polyether Urethane</td>
<td>50 mm</td>
<td>.002-.018</td>
</tr>
<tr>
<td>33 kg/m³ (2.0 lb./ft.³)</td>
<td>2 in.</td>
<td>.03 - .25</td>
</tr>
<tr>
<td></td>
<td>75 mm</td>
<td>.002-.021</td>
</tr>
<tr>
<td></td>
<td>3 in.</td>
<td>.03 - .30</td>
</tr>
<tr>
<td></td>
<td>100 mm</td>
<td>.002-.028</td>
</tr>
<tr>
<td></td>
<td>4 in.</td>
<td>.03 - .40</td>
</tr>
<tr>
<td>Polyether Urethane</td>
<td>25 mm</td>
<td>.002-.004</td>
</tr>
<tr>
<td>24 kg/m³ (1.5 lb./ft.³)</td>
<td>1 in.</td>
<td>.03 - .05</td>
</tr>
<tr>
<td></td>
<td>50 mm</td>
<td>.002-.011</td>
</tr>
<tr>
<td></td>
<td>2 in.</td>
<td>.03 - .15</td>
</tr>
<tr>
<td></td>
<td>75 mm</td>
<td>.002-.014</td>
</tr>
<tr>
<td></td>
<td>3 in.</td>
<td>.03 - .20</td>
</tr>
<tr>
<td></td>
<td>100 mm</td>
<td>.002-.021</td>
</tr>
<tr>
<td></td>
<td>4 in.</td>
<td>.03 - .30</td>
</tr>
</tbody>
</table>
LOAD-BEARING AREAS

Load-bearing area (LBA) is the surface area of a foam cushioning material that a packed item sits on in the packing case, usually expressed in square centimeters or square inches. It is used to calculate the static load on the foam, an important consideration when trying to get the best performance from foam. Figure 1 shows three identical cases sitting on three different foam cushion designs.

Figure 1 — The load-bearing areas for the three cases sitting on foam cushions is represented by the shaded areas in the drawings.

1. The load-bearing area is equal to 40 x 40 cm or 1,600 cm² (248 in²).
2. The load-bearing area of each cushion is equal to 40 x 10 cm, or 400 cm² (62 in²). Since there are two cushions, the total load-bearing area is 800 cm² (124 in²).
3. The load-bearing area of each cushion is equal to 10 x 10 cm, or 100 cm² (15.5 in²). Since there are four cushions, the total load-bearing area is 400 cm² (62 in²).
Load-bearing areas are easily calculated for the simple cases as shown in Figure 1.

**ELABORATELY CARVED PAINTING FRAMES**

It can be more difficult when dealing with elaborately carved painting frames. When sitting on its edge, a painting in an elaborate frame is supported by a small portion of the frame’s edge. The contour of four frames is shown in Figure 2. When calculating the load-bearing area for each frame, only the portion sitting on the foam should be considered. In other words, when determining the load-bearing area for elaborate frames, ignore all the framework above the outer “edge” (which can range from very narrow to very wide).

The load-bearing area (LBA) is:  
\[ \text{LBA} = \text{Length of frame edge} \times \text{Width of frame molding supporting the weight} \]

Figure 2 — The width of each frame profile that should be used in the calculations has been labeled with a “W.”
Sesction 6 - Shock Protection

Figure 2 — Continued

FOR FURTHER INFORMATION SEE:


Section 7

VIBRATION PROTECTION

Topics

- Vibration Control for Canvas Paintings—Backboards

- Vibration Control for Canvas Paintings—Foam Inserts behind the Painting

- Vibration Control for Canvas Paintings—Stretcher Lining
VIBRATION CONTROL FOR CANVAS PAINTINGS

Backboards

It is advisable to attach backboards to the reverse of all paintings because they can reduce the potential of damage caused by puncture, vibration, and shock.

- A stiff backing board will enclose an air cavity behind the painting. As a consequence, the painting’s tendency to vibrate is reduced due to the stiffening effect of air trapped between the backboard and the reverse of the painting canvas.

- A flexible backboard may have limited effectiveness. Relatively stiff materials are best for backboard or to secure the center of a flexible backboard to the cross braces on larger works.

- Large stretchers usually have crossbars. Cut several small pieces of the backboard material and attach them to each open rectangle bordered by crossbars and outer stretcher members if possible.

FOR FURTHER INFORMATION, SEE:


VIBRATION CONTROL FOR CANVAS PAINTINGS

Foam Inserts behind the Painting

During handling and transport, slack canvases on large paintings can strike the crossbars of the stretchers. This can be avoided by attaching pieces of foam to the backboard.

Figure 1 — Backboard (right) before it is attached to the stretcher (left).

- The foam should be very close to the back of the canvas without actually touching it.
- A low-density polyester urethane foam works well because it is soft and relatively lightweight. **Polyester urethane foams are not chemically stable and should not be left behind the painting for extended periods.** Many factors...
Section 7 - Vibration Protection

affect the rate of the foam's deterioration, making it impossible to estimate how long the foam can stay behind the painting.

- Most polyethylene foams are more stable chemically and could be left behind the painting for extended time periods. The surface of polyethylene foams are usually harder and they are heavier than the low-density polyester urethane foams. **Because of the increased weight, greater precautions must be taken to ensure that the foam is firmly attached to the backboard.**

- The foam can be attached to the backboard with double-stick tape or a hot-melt glue adhesive. **The foam must be securely attached to ensure that there is no risk of it pulling away from the backboard and coming in direct contact with the canvas.**

- The **backboard should be secured to the stretcher with screws.** Screws should be used around the perimeter of the stretcher and through the crossbars.

FOR FURTHER INFORMATION, SEE:


VIBRATION CONTROL FOR CANVAS PAINTINGS

Stretcher Lining

Stretcher lining is a procedure developed by Peter Booth at the Tate Gallery for reducing the vibration of a canvas painting. It involves attaching to the reverse of the original stretcher a new piece of fabric, preferably a thin but exceptionally stiff fabric such as polyester sailcloth. The painting is not in any way disturbed. The procedure should not be confused with the process conservators call “lining,” which is a procedure where the original canvas is adhered to a new fabric in order to strengthen it.

With the fabric in position, there is less risk of crossbar-related cracks developing through impact, as a continuous surface rather than the crossbar’s edges would be contacted. A further advantage has been demonstrated in vibration tests showing a marked reduction of canvas displacement in response to low-frequency vibration.

**METHOD OF ATTACHING THE STRETCHER LINING**

- Cut a piece of fabric approximately the same size as the painting.
- Temporarily attach it to the back of the stretcher with a few staples.
- Cut out curved segments of the fabric to allow space for the crossbar(s) and wedges (stretcher keys).
- Remove the staples to free the material that should be folded and inserted between the canvas and crossbar(s).
- Once the fabric is unfolded and correctly positioned, attach fabric along the edges to the back face of the stretcher.
- Stretch the fabric while attaching it. (See Figure 1.)

See example on following page.
Figure 1 — Example of stretcher lining.

NOTES


FOR FURTHER INFORMATION, SEE:


T. Green, "Shock and Vibration-Test Results for Framed Paintings on Canvas Supports" ICOM Committee for Conservation 8th Triennial Meeting, Preprints, Sydney (September 1987), 585-596.


Section 8

PACKING CASES

Topics

- Case Construction—Structure
- Handles
- Skids
- Chemical Stability of Packing Materials
- Soft Packing
- Sample Packing Case No. 1
- Sample Packing Case No. 2
- Sample Packing Case No. 3
- Sample Packing Case No. 4
- Sample Packing Case No. 5
- Sample Packing Case No. 6
- Sample Packing Case No. 7
- Case Labels—English, French, Spanish, German, Italian
CASE CONSTRUCTION — STRUCTURE

For a packing case to be fully effective, it must fulfill a variety of functions. They include:

- Support the painting, insulation, and cushioning foams
- Protect the contents from impact and puncture without serious distortion
- Maintain a sealed environment
- Protect against intrusion of rain and snow
- Provide handles for lifting and moving
- Survive a multi-venue tour without compromise of any of the above functions

There are several aspects of case dimensions, materials, and construction that should be considered for successful performance.

CASE DIMENSIONS AND SIZE LIMITATIONS

If there is a question as to size accommodation available, establish the transport possibilities prior to building the case. The size of the case depends on the size and number of the paintings to be packed, thickness of thermal insulation, and thickness of the cushioning materials used. The type and amount of foam materials to be used in the packing case must be determined prior to case construction. Once the dimension of the case is determined, material selection and construction techniques may proceed.

Keep in mind that there are limitations to the size case that can be accommodated by transport vehicles. In the United States, cases up to 290 cm (114 in.) in the vertical dimension can be shipped fairly easily.

Cargo is carried on both passenger aircraft and air freighters. The aircraft specializing in air cargo can hold fairly large cases, up to 292-302 cm (115-119 in.) in the vertical for pallets and up to 159 cm (62 in.) in containers. The different aircraft types such as the L-1011, B-747, and DC-10 are flown by different companies serving different areas.
**CASE MATERIALS**

There are several different packing case designs available to the user. While the majority are still constructed from plywood, there are commercially manufactured aluminum and fiber glass cases available. Plywood has inherent advantages over the other building materials. It has a high strength-to-weight ratio, provides some insulation, provides some relative humidity buffering, is relatively inexpensive, and no special tools or equipment are needed to construct a case from this material. Commercially available cases constructed from aluminum or fiber glass usually function best for smaller cases. A large packing case constructed from these materials and having the puncture resistance and stiffness of an equivalent plywood case would probably weigh considerably more than the plywood case and would not have the desirable thermal or moisture properties of wood. The choice of materials of the case is not the only consideration in case construction. The actual construction details of the case are equally important.

**PUNCTURE RESISTANCE**

If plywood is used as a construction material, the thickness of the plywood has a considerable effect on the puncture resistance of the sides of the case. Unfortunately, no reasonable thickness of plywood will stop a forklift tine or a topple onto a sharp object. The thickness will have an effect on the depth of penetration, so the case width and the thickness of the plywood act together to protect the painting from puncture. Plywood thicknesses between 9.5 mm (.375 in.) and 12.5 mm (0.5 in.) are typically found on small-to-medium sized cases, up to 183 cm (72 in.) long. Plywood thicknesses up to 19 mm (.75 in.) are found in the larger cases. Both exterior and interior grade plywood are found in cases though exterior grades tend to have better structural properties as well as better water resistance. In plywood case construction there can be a real economy of scale. If several cases are to be constructed, planning a plywood cutting schedule by predetermining the various case part dimensions and laying those parts out on a minimum number of plywood sheets will prove to be economical.

**IMPACT RESISTANCE AND STRUCTURAL RIGIDITY**

Using of cushioning foams in a packing case assumes that the case will not distort or twist in the event of an impact. If it does, then the cushioning will lose a substantial amount of its effectiveness in protecting the painting and the painting could be
twisted along with the case. The construction methods of the case, particularly where materials are joined, have a significant effect on the strength as well as the rigidity of the case. A case having edges and corners that are well-joined can have over ten times the strength and one-hundred times the rigidity of a case that has corners and edges that are poorly joined. It is recommended that edges and corners be both screwed and glued together. Nails and screws alone perform poorly under impact condition that cases routinely experience. Some examples of both poor and good edge connection techniques are illustrated in Figures 1-3.

Figure 1. A poor joint construction.

Figure 2. A useable joint construction.

Figure 3. The best joint construction.
All cases have lids that are removable. Since the strength and stiffness of the case depends on the firmness of the joints, the lid should be provided with a bolting system that uniformly and firmly secures it to the rest of the case. Bolts or screws spaced every 250-300 mm (10-12 in.) around the edges should be used. Cases with two to three lid hinges and fasteners will not develop the rigidity or strength of bolted cases.

**CASE STABILITY AND TOPPLE RESISTANCE**

Large packing cases containing a single painting can be high and narrow. Consequently they can also be unstable and prone to topple even if slightly jarred. Provisions should be made to prevent such accidents.

**PROVISIONS FOR LIFTING**

For cases light enough to be lifted by one or two people, handholds should be provided on the case. For cases requiring mechanical means for lifting, such as forklifts, blocks (skids) should be provided that allow the tines of the forklift to slide under the case.

**FOR FURTHER INFORMATION, SEE;**


HANDLES

Moving large packing cases without handles can be very difficult and result in rough handling. Many handle styles are commercially available and others are easily made from wood. Careful consideration must be given to the placement of handles on packing cases. Persons lifting or carrying a case should be able to hold it at a comfortable height from the floor without bending their arms. Handles should not be placed too low to the floor because cases become top-heavy when lifted. While there is no single location for handles that is perfect for everyone, experience has shown that a height of 50 cm (20 in.) to 60 cm (24 in.) from the floor works well for most medium-size cases. Larger cases should have one set of handles at the height given above and a second set of handles placed higher on the case to give additional control during handling. The higher handles should be placed at a height between 150 cm (59 in.) and 165 cm (65 in.). It is also advisable to place additional handles along the sides of very large cases.

METAL CHEST HANDLES

- These handles are readily available and inexpensive.
- Handles are easily attached to packing cases with screws or bolts; however, screws are often inadequate for very heavy cases.
- The weight of a packing case must be considered when handles and methods of attachment are selected. It can be
disastrous when a handle breaks away from a packing case.

- Most handles are designed to fold down flat against the case when they are not being used, therefore, they have little or no effect on the overall dimensions of the packing case.

- Chest handles are useful for removing the lids of large cases.

- Only one person can use each handle, a limitation when moving heavy cases. Additional personnel can provide assistance if a second handle is placed in each location.

- It is important to attach chest handles in the proper orientation. When they are attached upside-down, hands are pinched between the handle and the case.

**WOODEN HANDLES**

- Glue and screws **must** be used to attach wooden handles. Handles attached only with screws frequently pull out or
break when lifted. To achieve an optimum hold, attach screws from the inside of the case going outward into the handle, and place additional screws on the outside going into and through the handle toward the case interior.

- Wood handles on large cases can usually accommodate more than one person, an advantage when cases are heavy and difficult to control because they are top-heavy.

- Wood handles slightly increase the case dimensions.

- Wood handles are more vulnerable to damage because they protrude from the side of the case.
**SKIDS**

Forklifts, hydraulic pallet trucks, and other equipment are frequently used to move large packing cases. To provide easy access for the fork prongs on this equipment, skids should be attached to the bottom of large cases. Various skid designs are used and no single design is ideal for all circumstances, as it depends on the size, shape, and weight of the packing case and the handling techniques that are employed during transit. All skids should be attached with carpenter's glue and screws that pass from the case interior into the skid. The glue adds considerable strength to the joint, greatly reducing the likelihood that the skid will be knocked off when slid across the floor. When cases are painted, attach the skids before painting to ensure good adhesion. Painted skids are desirable as they are less vulnerable to long-term exposure to water.

Whenever possible, openings should be left between skids for the prongs of forklifts and hydraulic pallet trucks. The width of the prongs on forklifts is usually adjustable but the prongs on hydraulic pallet trucks are fixed. The figure below depicts a hydraulic pallet truck frequently found in museums, warehouses, and airports. While various styles and sizes are available, the maximum width of most pallet trucks used in North America are either 53 cm (21 in.) or 69 cm (27 in.). Typical dimensions of pallet trucks are provided in the drawings below.

![Diagram of hydraulic pallet truck](image)

- **Length** - Several sizes are available between 91 cm (36 in.) and 183 cm (72 in.)
- **Height** - Two typical fork heights are 8 cm (3 1/4 in.) and 5 cm (2 in.)
- **Width** - Two typical fork widths are 53 cm (21 in.) and 69 cm (27 in.)
Another consideration in the design of skids is the placement of mover's dollies under packing cases. Dollies are frequently used in museums and on loading docks. Skids can create problems when their spacing does not allow packing cases to rest on dollies in a reasonably stable manner. It is also important to ensure that the underside of the packing case is strong enough to support its weight when it is placed on only one or two dollies. One can never predict exactly where dollies will be positioned unless the skid design restricts their placement to a few locations. This is complicated further by the wide variety of mover's dollies that are commercially available. A few of the most common sizes used in North America are 46 x 66 cm (18 x 26 in.), 46 x 76 cm (18 x 30 in.), and 61 x 91 cm (24 x 36 in.).

**SKID 1**

- The long dimension of the skid is aligned with the long dimension of the packing case.
- Cases having skids attached in this orientation are more
easily slid across the floor and onto or off a truck. This skid design is also less vulnerable to damage than skids that are oriented perpendicular to the long dimension of the case.

- Cases having skids with chamfered edges (see drawing) slide more easily and the skids are damaged less often.

- Skids should be at least 9 cm (3.5 in.) high to allow easy access for forklifts and pallet trucks.

- An opening should be left in the center of the packing case to allow easy access for forklifts and pallet trucks.

- An opening on each end of the packing case should be left between skids to allow easy access for a lever dolly or pry bar. These are often required to lift the ends of heavy cases.

- Extremely heavy packing cases should have hardwood battens, for example, oak, on the bottom of the case because of the localized pressure exerted on the wood by lever dollies and pry bars.

**SKID 2**

- The long dimension of the skid is oriented perpendicular to the long dimension of the packing case. This approach
is often necessary with smaller cases.

- It is more difficult to slide heavy cases having skids attached in this orientation. The skids are also more easily damaged.

- Skids should have chamfered edges.

- Skids should not be attached at the outer edge of the case because room should be left for the use of lever dollies or pry bars.

- Extremely heavy packing cases should have hardwood battens, for example, oak, on the bottom of the case because of the localized pressure exerted on the wood by lever dollies and pry bars.

- It may be necessary to attach additional skids to support the center of long, heavy cases.
CHEMICAL STABILITY OF PACKING MATERIALS

In packing for the transport of art, the emphasis is placed on the physical protection of the object as it during this time that it is most vulnerable. Other factors are also important and must be considered. It has been known for some time that many materials release chemical compounds such as acids that can damage objects near or enclosed with them. Unfortunately, there are many examples of this in the museum field where materials used to construct display or storage cases have caused damage to enclosed objects. In general, damage from internal pollution accumulates over a period of time, but there are examples where such damage has occurred quickly enough to indicate that the same requirements of chemical stability applied to materials used in permanent storage should also be applied to materials used for transport containers. Several approaches can be used, either together or separately, to prevent such damage.

- By far the most preferable is to use only materials known to be chemically stable and suitable for use.
- Physically separate suspect materials from the object.
- Use absorbents to trap any volatile materials that might cause damage.

CHOICE OF SUITABLE MATERIALS

There are two approaches for the selection of suitable materials for use in packing cases. The first is to use only materials determined by previous testing or evaluation to be safe, and to avoid materials that are untested or known to cause damage. The following are updated lists of material known to be either generally safe or unsafe.¹

MATERIALS REGARDED AS GENERALLY SAFE FOR MUSEUM USE

- metals
- ceramics
- glass
- inorganic pigments (those that do not contain sulfur)
- polyethylene and other polyolefins such as polypropylene
- polycarbonate
- polystyrene
- acrylics
- polytetrafluoroethylene (Teflon™) and other fluorinated hydrocarbon polymers
- polyester (polyethylene terephthalate)
- cotton and linen (unsized and undyed)
- paper and matboard made from rag or lignin-free pulp, especially if buffered or alkali processed

## MATERIALS KNOWN TO CAUSE PROBLEMS

- wood (Contrary to some sources, no wood can be regarded as acid free.)
- noncollagenous proteins (Most proteins contain sulfur, and can cause tarnishing and discoloration. Highly refined gelatin is free of sulfur.)
- nitrocellulose (Problems with early manufacturing processes resulted in a variable, often highly unstable product. Though the modern product is more consistent, it still cannot be recommended for use in conservation.)
- cellulose acetate (Some samples may be stable, but others have been known to release acetic acid. Test before use.)
- polyvinyl chloride (PVC) (This and other chlorinated hydrocarbons can release hydrochloric acid, and often contain volatile additives.)
- polyvinyl acetate (Some samples may be stable, but others, especially some emulsions, release acetic acid. Test before use.)
- polyvinyl alcohol (Prepared from polyvinyl acetate, and is subject to the same provisions.)
- polyurethanes (Inherently thermally and photolytically un-
stable and always contain additives.)

- dyes (Many dyes contain sulfur or other reactive groups.)

Many commercial materials are variable, and cannot reliably be assigned to either list. Often a term such as “paint" or “adhesive" is used to refer to a group of materials of widely varying chemistry. When a material of unknown, untested, or variable composition is considered for use, thorough testing is required to verify that it is safe.

II TESTING OF MATERIALS

There are many quick tests that can be used to identify or evaluate materials, but the only reliable way to judge its suitability for use is by long-term testing. Most long-term tests are a variant of the method proposed by Oddy. In this test, a sample of the material to be tested is bottled up with copper, lead, and silver strips, and “aged" at an elevated temperature for a period of at least a week. The amount of corrosion on the metal strips is compared to that on metal strips from a control experiment which is identical except for the absence of the material being tested. The presence of excess corrosion on the metal strips enclosed with the material being tested indicates the possibility of damage to objects.

II SEPARATION OF OBJECTS AND PACKING MATERIALS

It is inevitable that untested or unsafe materials will be used in the construction of cases. Often there is no suitable or safer alternative. This is especially true of transport cases where the physical requirements are much more demanding and may rule out materials that are otherwise acceptable. Fortunately, design requirements of packing cases tend to help isolate the object from most of the materials of the case. The air space around the object is generally minimized to reduce the required amount of humidity buffering. The vapor barrier around the object also acts as a pollutant barrier, protecting the object from most of the volatiles that may be emitted by the surrounding materials. Thus, materials such as wood can be used in the exterior sections of appropriately designed transport cases. All that is now required is to protect the object from unsuitable materials enclosed with it in this inner chamber and from the small amount of pollution that may get through.
OTHER CONSIDERATIONS

Transport cases should be prepared as far ahead of shipment as possible so that they can be left open to air out.

Ideally, objects should spend only the minimally required amount of time in transport cases. Practically, though, such cases are often used for long periods of time, if not for permanent storage. Allowances for using materials such as wood in transport cases are made precisely because these cases are not intended for permanent use or for storage in enclosed spaces with other objects that might be affected.

NOTES


SOFT PACKING

Protection of a painting in transit depends on several factors: outer case materials, case construction, packing materials, packing procedures, and the condition of the painting. The usual wooden or hard-sided shipping case provides an envelope of protection against shock, vibration, and environmental changes, particularly when unforeseen problems develop during transit. Such protection is reduced when other types of packing materials or packing procedures are used. If one replaces the plywood-sided case with one having cardboard sides, the protection for the painting is reduced. Reduction of the foam in the packing case reduces the thermal insulation and shock protection for paintings.

A museum cannot reduce the quality of the packing and the shipping case without increasing the risk of damage.

That being said, it must be acknowledged that transporting paintings without the protection of a hard surrounding case is commonplace, even in museums, although the practice makes conservators nervous. Soft packing is virtually the norm for graphic works such as prints and drawings, especially if the piece is hand carried. The practice of soft packing has spread from commercial galleries and artists to museums. Originally, soft packing was used to move works of art within a city, but the practice has now expanded to include long-distance shipments. As the cost of exhibitions and the associated shipment of paintings increases, institutions are turning to soft packing to reduce their costs; unfortunately, the practice also reduces the protection of the work of art and increases the risks of damage. No work of art should be soft packed unless the institution is willing to risk a major damage. Some shippers have reported greater incidence of damage to works that were soft packed. While experience in soft packing is extensive, there has been almost no scientific research into how to provide the best protection at the least cost. Excluding case design and construction, there is very little increase in packing convenience and it may actually take longer to properly soft pack a work. There may be a cost saving for packing case storage, however, if new materials are used preparing the work for the return shipment the cost savings may be negligible. Handling by airline personnel and extreme environmental variation raise the risks of soft packing paintings for air shipment to an unacceptable level.

Soft packing fails in two critical ways when compared to a hard-packing case.
• There is virtually no protection from physical impact or penetration of the packing.

• There is very little protection against environmental changes.

Most damages that occur during transport are from impact on the packing carton or from a puncture of the carton and painting. The increased risks accompanying soft packing, coupled with the escalating values of cultural materials, make it difficult to justify the use of soft packing for long-distance shipments. In an attempt to keep costs down, it can be appealing to ship works of art long distances soft packed, especially since there is no penalty in insurance cost. This perceived savings may not really be the case if insurance companies look carefully at the circumstances surrounding works damaged in transit.

**IMPORTANT CONSIDERATIONS FOR SOFT PACKING**

During transit it is important to keep a stable moisture content in paintings. Wrapping paintings in plastic, or other moisture barrier materials, and minimizing temperature variations is the simplest way to reduce moisture content changes in paintings. Even with climate-controlled vehicles, the absence of proper insulating materials in soft-pack systems makes it difficult to maintain a stable temperature, especially when the trucks are repeatedly opened and closed in extreme weather conditions during the summer and winter months. It is also important to reduce shock and vibration transmitted to the work of art; soft packing offers minimum protection, especially from impact and puncture damage. Considering the risks involved, few conservators, if any, will endorse soft packing for long-distance shipments. Museums should resist the attraction, perceived or real, of reduced cost through soft-packed shipments. The pressures to save money have resulted in the expanded use of soft-pack systems without regard to the increased risks to cultural treasures. Many museums have developed their own systems for soft packing works of art. Shipping companies may have special containers for soft packed paintings, which can be provided upon request.

**RECOMMENDED GUIDELINES FOR SOFT PACKING**

• Restrict the use of soft packing to local moves.

• Use a wooden collar (travel frame) attached to the reverse of the painting or frame to protect ornate frames and con-
temporary unframed paintings. Sheets of cardboard, corrugated plastic, or foam board may be attached to the front and back faces of the wooden collar.

- Wrap the painting in a nonabrasive material, for example, soft tissue paper or glassine.

- Wrap the painting with plastic, which may be completely sealed with tape, unless the painting is acclimated to a relative humidity above 70%.

- Do not let anything touch the surface of the painting.

- The wrapped painting should be containerized in a stiff cardboard carton (cartons can be made of cardboard sheets or from foam core sheets and the joins taped to add strength).

- Foam should be used around the painting to offer temperature insulation and shock protection. (Unfortunately, it has been noted that few museums line their cartons with foam padding.) Some shippers attach the sheet of foam to the inside of the cardboard or other stiff paper board used for the construction of the carton.

- The truck floor should be padded with clean moving blankets or more foam before strapping the soft-wrap carton against the wall of the vehicle.

- A shelf may be built beside the wheel well of the vehicle to make a flat surface. Smaller soft-wrap cartons should be packed against the wall of the vehicle first. Larger soft-wrap cartons can be placed on the floor and against the first layer.

- The soft-wrap cartons should be securely tied against the wall of the vehicle.
SAMPLE PACKING CASE NO. 1

CASE CONSTRUCTION

Constructed of 12 mm (0.5 in.) or 19 mm (0.75 in.) plywood, reinforced with wooden battens.

The painting should be wrapped before it is placed in the case to protect the frame from abrasion. (Refer to Section 4 for further information on wrapping materials.)

FOAM CUSHIONING MATERIAL

All inner surfaces of the packing case are covered with a 5 cm (2 in.) piece of polyester urethane foam. The density of the foam selected is between 25 and 33 kg/cm² (1.5-2 lb./ft²).

Polyether urethane foam could also be used but a polyester urethane foam is recommended.
The bottom side of the case is covered with a second layer of 5 cm (2 in.) piece of polyester urethane foam. A 10 cm (4 in.) layer on the bottom provides improved protection from shock and vibration.

**ADVANTAGES OF THIS CASE DESIGN**

- It is simple to build.
- Both poly(ether) and (ester) urethane foams provide acceptable shock protection for typical paintings over a broad range of static loads.
- Polyurethane foam is a very good insulating material, therefore, the same layer of foam provides both thermal protection and shock protection.

**DISADVANTAGES OF THIS CASE DESIGN**

- The static load on the reverse of the painting is probably too low because the painting's reverse contacts such a large surface area of foam. If the packing case topples or is dropped onto that face, a high shock level will be transmitted to the painting.
- The static load on the front face of the painting and the four narrow sides depends on the shape of the frame. **While the static load falls within an acceptable range for many paintings, it will be unacceptable for some.**
- In very large packing cases, the large pieces of foam will bow in toward the painting, possibly pushing against it, unless they are firmly adhered to the inside of the case.
SAMPLE PACKING CASE NO. 2

CASE CONSTRUCTION

Constructed of 12 mm (0.5 in.) or 19 mm (0.75 in.) plywood, reinforced with wooden battens.

The painting should be wrapped before it is placed in the case to protect the frame from abrasion. (Refer to Section 4 for further information on wrapping materials.)

FOAM CUSHIONING MATERIAL

All inner surfaces of the packing case are covered with a 5 cm (2 in.) piece of polyester urethane foam. The density of the
foam selected is between 25 and 33 kg/cm² (1.5-2 lb./ft.²).

On the two large faces of the packing case, polyester urethane foam corner pads are adhered to the 5 cm (2 in.) piece of polyester urethane foam. This is done to improve the static load on the foam. Corner pads can be adhered with hot-melt glue or a strong, double-sided tape. Foam manufacturer information should be consulted for recommendations on adhesives that work well with their products.

Polyether urethane foam could also be used but a polyester urethane foam is recommended.

The bottom side of the case is covered with a second layer of 5 cm (2 in.) piece of polyester urethane foam. A 10 cm (4 in.) layer on the bottom provides improved protection from shock and vibration.

**ADVANTAGES OF THIS CASE DESIGN**

- It is simple to build.
- Both poly(ether) and (ester) urethane foams provide acceptable shock protection for typical paintings over a broad range of static loads.
- Polyurethane foam is a very good insulating material, therefore, the same layer of foam provides both thermal protection and shock protection.
- The corner pads attached to the two large sides of the packing case alter the static load on the foam. The increased static load, especially on the reverse of the painting, improves the shock protection if the case topples or is dropped on that face.
- The corner pads usually improve the static load on the front face of the painting. It depends on the shape of the frame.

**DISADVANTAGES OF THIS CASE DESIGN**

- In very large packing cases, the large pieces of foam will bow in toward the painting, possibly pushing against it, unless they are firmly adhered to the inside of the case.
- The corner pads can fall off if they are not firmly adhered.
SAMPLE PACKING CASE NO. 3

CASE CONSTRUCTION

Constructed of 12 mm (0.5 in.) or 19 mm (0.75 in.) plywood, reinforced with wooden battens.

The painting should be wrapped before it is placed in the case to protect the frame from abrasion. (Refer to Section 4 for further information on wrapping materials.)

FOAM CUSHIONING MATERIAL

Polyethylene corner pads, approximate density of 33 kg/cm² (2 lb./ft.²) are used to cushion the painting on all sides. The corner pads are 10 cm (4 in.) in thickness. The thickness could be reduced to 5 cm (2 in.) but the shock protection is lessened considerably. It is possible to attain better than 60 G's shock protection for a 75 cm (30 in.) drop height but the static load must be accurately calculated for the case design.
ADVANTAGES OF THIS CASE DESIGN

- It is simple to build.
- Polyethylene foam will provide acceptable shock protection for typical paintings if the proper static load is placed on the foam.
- Polyethylene foam is a chemically stable material.

DISADVANTAGES OF THIS CASE DESIGN

- It is easy to use too much foam for the corner pads, yielding an improper static load.
- A packing case having only corner pads has no thermal insulation.
- The corner pads can fall off if they are not firmly adhered.
SAMPLE PACKING CASE NO. 4

CASE CONSTRUCTION

Constructed of 12 mm (0.5 in.) or 19 mm (0.75 in.) plywood, reinforced with wooden battens.

The painting should be wrapped before it is placed in the case to protect the frame from abrasion. (Refer to Section 4 for further information on wrapping materials.)

FOAM CUSHIONING MATERIAL

All inner surfaces of the packing case are covered with 5 cm (2 in.) of polystyrene foam. This foam is used as a thermal insulating material. **It is not intended to be a cushioning material.**

Polyethylene corner pads, approximate density of 33 kg/cm² (2 lb./ft.²) are used to cushion the painting on all sides. The corner pads are 10 cm (4 in.) in thickness. The thickness could be
reduced to 5 cm (2 in.) but the shock protection is lessened considerably. It is possible to attain better than 60 G shock protection for a 75 cm (30 in.) drop height but the static load must be accurately calculated for the case design.

**ADVANTAGES OF THIS CASE DESIGN**

- The polystyrene foam adds additional thermal protection for the painting, increasing the temperature half-time of the packing case.

- Polyethylene foam will provide acceptable shock protection for typical paintings if the proper static load is placed on the foam.

- Polyethylene foam and polystyrene foam are usually chemically stable materials.

**DISADVANTAGES OF THIS CASE DESIGN**

- It is easy to use too much foam for the corner pads, yielding an improper static load.

- It can be difficult to adhere materials to certain types of polystyrene foam. Care must be taken to ensure that the corner pads cannot fall off.
SAMPLE PACKING CASE NO. 5

CASE CONSTRUCTION

Constructed of 12 mm (0.5 in.) or 19 mm (0.75 in.) plywood, reinforced with wooden battens.

The inner case is constructed from plywood, foam board, and/or heavy cardboard.

It is recommended that the inner case be wrapped with polyethylene after placing the painting inside to waterproof the inner box. (Refer to Section 4 for further information on wrapping materials.)

FOAM CUSHIONING MATERIAL

The painting should be held firmly in the inner case. This can be done with foam but the foam should be thin and firm. The painting should not be free to move in the inner case.

All inner surfaces of the packing case are covered with a 5 cm (2 in.) piece of polyester urethane foam. The density of the foam selected is between 25 and 33 kg/cm² (1.5-2 lb./ft.²).
Polyether urethane foam could also be used but a polyester urethane foam is recommended.

The bottom side of the case is covered with a second layer of 5 cm (2 in.) piece of polyester urethane foam. A 10 cm (4 in.) layer on the bottom provides improved protection from shock and vibration.

**ADVANTAGES OF THIS CASE DESIGN**

- The inner case reduces the risk of abrasion to the frame.
- The inner case will slightly improve the temperature halftime of the case.
- The inner case improves the protection of the painting from accidental puncture should an accident occur.
- Both poly(ether) and (ester) urethane foams provide acceptable shock protection for typical paintings over a broad range of static loads.
- Polyurethane foam is a very good insulating material, therefore, the same layer of foam provides both thermal protection and shock protection.

**DISADVANTAGES OF THIS CASE DESIGN**

- The static load on two large faces of the inner case, i.e. the front and back faces of the painting, is almost certainly too low because the inner case contacts such a large surface area of foam. If the packing case topples or is dropped on either of the two large faces, a high shock level will be transmitted to the painting.
- Additional work is required to construct the inner case and to pack the painting.
SAMPLE PACKING CASE NO. 6

CASE CONSTRUCTION

Constructed of 12 mm (0.5 in.) or 19 mm (0.75 in.) plywood, reinforced with wooden battens.

The inner case is constructed from plywood, foam board, and/or heavy cardboard.

It is recommended that the inner case be wrapped with polyethylene after placing the painting inside to waterproof the inner case. (Refer to Section 4 for further information on wrapping materials.)

FOAM CUSHIONING MATERIAL

The painting should be held firmly in the inner case. This can be done with foam but the foam should be thin and firm. The painting should not be free to move in the inner case.

All inner surfaces of the packing case are covered with a 5 cm (2 in.) piece of polyester urethane foam. The density of the foam selected is between 25 and 33 kg/cm² (1.5-2 lb./ft.²).
On the two large faces of the packing case, polyester urethane foam corner pads are adhered to the 5 cm (2 in.) piece of polyester urethane foam. This is done to improve the static load on the foam. Corner pads can be adhered with hot-melt glue or a strong, double-sided tape. Foam manufacturer information should be consulted for recommendations on adhesives that work well with their products.

Polyether urethane foam could also be used but a polyester urethane foam is recommended.

The bottom side of the case is covered with a second layer of 5 cm (2 in.) piece of polyester urethane foam. A 10 cm (4 in.) layer on the bottom provides improved protection from shock and vibration.

**ADVANTAGES OF THIS CASE DESIGN**

- The inner case reduces the risk of abrasion to the frame.
- The inner case will slightly improve the temperature halftime of the case.
- The inner case improves the protection of the painting from accidental puncture should an accident occur.
- Both polyester and polyether urethane foams provide acceptable shock protection over a broad range of static loads.
- The corner pads attached to the two large faces of the packing case alter the static load on the foam. The increased static load on the two large faces of the inner box, i.e. the front and back faces of the painting, improves the shock protection if the case topples or is dropped on one of the large faces.
- Polyurethane foam is a very good insulating material, therefore, the same layer of foam provides both thermal protection and shock protection.

**DISADVANTAGES OF THIS CASE DESIGN**

- Additional work is required to construct the inner case and to pack the painting.
SAMPLE PACKING CASE NO. 7

CASE CONSTRUCTION

constructed of 12 mm (0.5 in.) or 19 mm (0.75 in.) plywood, reinforced with wooden battens.

The inner case is constructed of plywood, foam board, and/or heavy cardboard.

it is recommended that the inner case be wrapped with polyethylene after placing the painting inside to waterproof the inner case. (Refer to section 4 for further information on wrapping materials.)

FOAM CUSHIONING MATERIAL

The painting should be held firmly in the inner case. This
can be done with foam but the foam should be thin and firm. The painting should not be free to move in the inner case. A polyester urethane foam is recommended, but polyether urethane foam could also be used.

All inner surfaces of the outer packing case are covered with polyester urethane foam having a thickness of 5 cm (2 in.). The density of the foam selected is between 25 and 33 kg/cm$^2$ (1.5-2 lb./ft.$^2$).

Polyester urethane foam pads are adhered in all corners of the case interior. This is done to improve the static load on the foam. Corner pads can be adhered with hot-melt glue or a strong, double-sided tape. Foam manufacturer information should be consulted for recommendations on adhesives that work well with their products.

**ADVANTAGES OF THIS CASE DESIGN**

- The foam is 10 cm (4 in.) thick on all sides of the case. The size of the corner pads can be adjusted to provide the optimum static load on the foam. This improves the shock protection for the painting.

- The inner case reduces the risk of abrasion to the frame.

- The inner case will slightly improve the temperature half-time of the case.

- The inner case improves the protection of the painting from puncture should an accident occur.

- Both polyester and polyether urethane foams provide acceptable shock protection over a broad range of static loads.

- Polyurethane foam is a very good insulating material, therefore, the foam provides both thermal protection and shock protection.

**DISADVANTAGES OF THIS CASE DESIGN**

- Additional work is required to construct the inner case and to pack the painting.

- Thick foam pads increase the size of the packing case.
CASE LABELS

PACKING INSTRUCTIONS — FRENCH

Fragile - FRAGILE
Keep dry - TENEZ A SEC
Face up - FACE EN HAUT
Remove screws - ENLEVEZ VISES
Remove lid - ENLEVEZ COUVERCLE
Lift lid - LEVEZ COUVERCLE
Remove artwork - ENLEVEZ TABLEAU
Do not remove this box - N'ENLEVEZ PAS CETTE CAISSE
Save all packing materials - GUARDEZ TOUT EMBALLAGE
Lift out - SOULEVEZ
Lift tape tags - TIREZ RUBAN DE FIL
Remove tape carefully - ENLEVEZ RUBAN DE FIL AVEC SOIN
Pull off tape from lid - TIREZ RUBAN DE FIL DU COUVERCLE
Open folds - OUVREZ LES PLIS
PACKING INSTRUCTIONS — SPANISH

Fragile - FRAGIL
Keep dry - MANTENGASE SECO
Face up - MANTENER ESTE LADO HACIA ARRIBA
Remove screws - REMUEVA LOS TORNILLOS
Remove lid - REMUEVA LA TAPA
Remove artwork (painting) - REMUEVA PINTURA O CUADRO
Do not remove inner box - FAVOR NO REMOVER CAJA ADICIONAL POR DENTRO
Save all packing materials - FAVOR GUARDAR TODO EL MATERIAL DE EMPAQUE
Repack using same method and material as received - RE-EMBALAR CON EL MISMO SISTEMA Y MATERIAL CON QUE SE RECIBIO
This side up - MANTENGA ESTE LADO HACIA ARRIBA
Lift tape tags - LEVANTE LAS CINTAS
Pull off tape from lid - REMUEVA LA CINTA DE LA TAPA
Lift lid - LEVANTE LA TAPA; Lift out - LEVANTE Y SAQUE
Do not remove this box - NO REMUEVA ESTA CAJA
Remove tape carefully - REMUEVA LA CINTA ADHESIVA CON CUIDADO
This end up - ESTE LADO ARRIBA
Packed and shipped by - EMBALADO Y ENVIADO POR
Flight direction - DIRECCION DEC VUELO
Do not turn - NO VOLTEAR
Empty - VACIO
Glass - VIDRIO
PACKING INSTRUCTIONS — GERMAN

Fragile - ZERBRECHLICH
Face up - VORDERSEITE NACH OBEN
Remove lid - DECKEL ENTFERREN
Remove painting - GEMALDE ENTFERREN
Save all packing materials - GESAMTES VERPACKUNGSMATERIAL AUFBEWAHREN
Lift tape tags - KLEBESTREIFENENDE HOCHZIEHEN
Pull off tape from lid - KLEBESTREIFEN VOM DECKEL ABZIEHEN
This side up - DIESE SEITE NACH OBEN
Keep dry - TROCKEN AUFBEWAHREN
Remove screws - SCHRAUBEN ENTFERREN
Lift lid - DECKEL ANHEBEN
Do not remove this box - DIESE KISTE NICHT WEGNEHMEN
Lift out - HERAUSHEBEN
Remove tape carefully - KLEBESTREIFEN VORSICHTIG ENTFERREN
This end up - DIESES ENDE NACH OBEN
Repack using the same method and materials as received - WIEDERVERPACKUNG UNTER VERWENDUNG DESSELBEN PACKVERFAHRENS UND VORHANDENUM PACKMATERIALS
Empty - LEER
Packed and shipped by - VERPACKT UND VERLADEN
Flight direction - FLUGRICHTUNG
Shockmaster - SCHOCKMASTER
Glass - GLAS
PACKING INSTRUCTIONS — ITALIAN

Fragile - FRAGILE
Face up - FACCIA IN ALTO
Remove lid - TOGLIERE IL COPERCHIO
Remove painting - TOGLIERA IL DIPINTO
Save all packing materials - CONSERVARE TUTTO IL MATERIALE D'IMBALLAGGIO
Life tape tags - TIRARE IL NASTRO DALL'ESTREMITÀ
Pull off tape from lid - TOGLIERE IL NASTRO DAL COPERCHIO
This side up - ALTO
Keep dry - TEME L'UMIDITÀ
Remove screws - TOGLIERE LE VITI
Life lid - SOLLEVARE IL COPERCHIO
Do not remove this box - NON RIMUOVERE QUESTA SCATOLA
Life out - SOLLEVARE
Remove tape carefully - TOGLIERE IL NASTRO CON CAUTELA
This end up - ALTO
Repack using the same method and materials as received - REIMBALLARE USANDO LO STESSO SISTEMA E MATERIALI.
Open this side - LATO DA APRIRE
Do not turn - NON CAPOVOLGERE
Section 9

ROLE OF THE COURIER

Topic

- Role of the Courier
ROLE OF THE COURIER

**OVERVIEW**

The following are general guidelines for couriers escorting works of art. There is a variety of shipments that require couriers such as:

- Local transits to another museum, a historic house, private residence, or the airport.
- Long-distance shipments that require aircraft, long over-the-road shipments, or train journeys.
- Combinations of the above, which may require several days and deliveries to differing institutions or homes.
- Fragile works of art or complex installation problems may require a courier.
- Objects of high value or politically sensitive may require a courier.

While perceived as a wonderful adventure, some of these shipments may try the courier's patience, endurance, and creative problem solving.

Many museums have developed their own courier guidelines as has the Registrar's Sub-Committee for Professional Practices of The American Association of Museums. These museums have also developed courier training programs to inform couriers of their responsibilities and role during the transit. A novice courier should develop experience with local courier trips. Only after developing local experience should an individual be used for an international shipment. In most museums the courier pool is made up of curators and their assistants, conservation staff, registrars, art handlers, packers. Most museums exclude non-art technical assistants and clerical staff from the courier pool. The courier must be diplomatic yet assertive, flexible to meet the developing situation, and able to cope with unusual, stressful demands.
COURIER TRAINING

Each individual assuming the responsibility of courier for a work of art should be trained for their role. A typical training session might cover the following agenda:

Paperwork
- Travel tickets
- Condition report with photograph
- Letter of introduction to airline/trucking firm
- Air waybill
- Trucker's bill of lading
- Pro-forma invoice
- Customs documents for international shipment
- List of names, telephone numbers, and addresses
- Incoming/outgoing receipt
- Terms of the loan (loan agreement form)

Hand-carried shipments
- Security checks
- Placement on the plane

Cargo shipments
- Conservation considerations
- Environmental concerns
- Examination reports
- Packing and handling

Frame conservation issues

Packing and unpacking procedures

Installation procedures and concerns

TRAVEL ACCOMMODATIONS

Generally the borrowing institution makes arrangements for lodging for the courier and provides them with a per diem allowance to cover their meals, tips, and other expenses. Some museums prefer to invoice the borrower for the per diem expense at the end of the loan. Hotel and per diem rates should be agreed upon in advance so the courier knows the limits allowed.

Airlines require that couriers hold a regular ticket whether they are on a passenger flight or cargo shipment. The ticketing arrangements for the courier are usually made by the museum registrar or shipping agent.
PAPERWORK

The following is a list of the usual paperwork associated with a shipment:
- Receipt from lending museum
- Receipt from borrowing museum
- Condition report and photograph
- Letter of introduction to airline or shipping firm
- Airline waybill
- Bill of lading for truck shipment
- Pro-forma invoice
- Custom documents (varies with country)
- List of contacts
- Terms of loan (loan form, borrowers agreement)

RESPONSIBILITIES OF THE COURIER

The courier has the authority to act on behalf of the owner in the protection of the work of art until the object is officially released to the borrowing museum. The courier must have an understanding of the construction and condition of the work of art and its special requirements. If necessary, the courier should be prepared to oversee the installation of the work of art, assuring that necessary environmental and security requirements are met.

- The courier should know exactly where the work of art is going, the contact at the borrowing institution, by what carrier, by what agent, and the route.
- The courier is responsible for protecting the work of art while expediting its movement.
- The courier should be aware of special handling or instructions for the work of art, including all security requirements.
- The formal condition report may have been prepared by a conservator or registrar and the courier must understand the report. The condition report may be sent with the courier or it may be packed with the work of art in the shipping case. After examination of the work of art, the courier must oversee the packing. Upon arrival at the borrowing museum, the courier must supervise the unpacking and reexamine the work of art for any change in
condition. Upon conclusion of the condition examination, both the courier and registrar (or other agent as appropriate) must sign the report. A copy of the condition report should be delivered to the registrar of the lending institution upon the return of the courier.

- **The courier has the responsibility for the security, safety, proper handling, and the general environment of the work of art in its case.** The courier must physically stay with the shipment or be in contact with agents in control of the shipment. With air cargo shipments, legal restrictions may prohibit the presence of the courier in the warehouse or at planeside and control of the shipment must be delegated to an appropriate authority. The courier may be prevented from following the shipment planeside onto the tarmac to see the case loaded aboard the aircraft. Or the courier may be required to board the aircraft as the shipping case is being loaded. This may be overseen by the shipping agent.

- **It is the responsibility of the courier to secure and carry the necessary paperwork, documents, letters, condition reports, and receipts** for the work of art. Upon delivery of the case to the borrowing museum, the courier should receive a signed receipt. Should the courier not be returning to the lending museum directly, the receipt must be airmailed or faxed to the registrar of the lending museum within twenty-four hours.

- **In the event of damage, problems, or questions, the courier should immediately notify the lending institution** by telephone or fax to obtain further instructions. Complete detailed notes should be taken in the event of damage and the condition report updated and signed by both the courier and the borrower's representative. The damaged work of art should be photographed immediately.

- **Couriers must have no conflicting professional or personal obligations** that would hinder fulfilling their courier obligations.

- **Unless there is an accompanying museum staff member, the courier must travel alone.** If the courier plans to meet family or friends for a vacation following their courier responsibilities, they must travel independently. It is unprofessional for the courier to expect the borrower to make travel/hotel arrangements for accompanying family or friends.
• **Information regarding the trip and shipment should not be volunteered to anyone.** For security reasons, information should be given on a need-to-know justification only.

**ADDITIONAL INFORMATION SPECIFIC TO CARGO SHIPMENTS**

Over-the-road truck shipments are the most common modes of transportation. The information contained here applies to local and long-distance shipments by truck.

• **The courier must observe the loading into the truck,** assuring that the case is properly secured in the vehicle with straps.

• Assure that **someone stays with the truck** at all rest stops.

• Periodically **call in** to verify progress or alert receiving institution.

• **Assure that unloading can be safely done** away from traffic or pedestrians, at a loading dock, or with proper personnel and equipment.

Air cargo shipments are the next common modes of transportation. The information contained here applies to shipments by airplane. Shipments by boat are rare but would have similar applications.

• **Accompany the shipment to the airport** and observe the unloading at the airport. Stay with the shipment and observe the loading of the case onto the pallet or airline container. Be sure that there are no hazardous materials or liquids included on the pallet or in the container and that the shipping case is securely strapped into the container/pallet. If a pallet is used, assure that the work of art case is covered with plastic sheeting. Make note of the pallet/container number containing the shipping case. If allowed, observe the loading of the shipment aboard the aircraft, noting the pallet/container's position within the aircraft. If the courier cannot personally observe the loading onto the aircraft, have the shipping agent verify that the shipment was loaded. The courier must travel on the same flight as the shipment.
- The courier must be prepared for any changes in routing or schedule. The airline may reroute the flight through a third city or may change aircraft requiring the unloading of the shipment. If known in advance, arrangements will have been made for other agents to oversee the transfer. Otherwise, the courier must follow through on the transfer with the cargo manager and airline crew.

- At the departure airport, obtain a copy of the air waybill and the pro-forma invoice from the shipping agent or customs broker.

- Be alert to shipment events such as dropped cases, forklift hazards, major temperature and humidity changes, container or pallet problems. Do not allow containers or pallets to be left outdoors in the weather for extended periods. The container should be checked for damages and potential leaks. Carry a camera with you.

If there is a delay in the shipment schedule, stay with the shipment or arrange to have it safeguarded in your absence.

Upon arrival at your destination, you should be met by an agent of the borrowing museum. The borrower's agent must be at planeside to supervise the offloading. The courier should be present as well but this is often prevented by restrictions.

The courier should supervise the unloading of the pallet or container, assuring that if a forklift is necessary that it is used carefully.

The borrower's agent should expedite the incoming customs clearance so the case is not delayed or opened for inspection. If it can be avoided, the courier should not allow the shipping case to be opened for inspection until safely within the destination museum.

The borrowing museum must provide suitable vehicles to transport the courier and work of art case from the airport to the museum.

The courier must supervise the unloading of the van and the placement of the case into secure storage at the borrowing museum. Often the shipment may require a layover that necessitates storage of the case in an agent's secured warehouse overnight. Do not leave the shipping case and work of art until you are satisfied with the security of the storage.

- Arrangements should be made between the courier and borrowing museum to unpack and inspect the work of
art. The packing case should be allowed to stand for twelve to twenty-four hours before opening. Packing cases often become cold during winter transport or in the cargo hold of aircraft and this waiting period allows the contents to warm up to room temperature. If the contents are cold when the case is opened, condensation may form on the work of art.

It must be made clear to the borrowing museum's staff that the courier must be present at the unpacking.

After unpacking, the courier must complete the condition report with a representative of the borrowing museum, co-signing the report. A copy of the report should be retained by the borrower and a copy returned to the lending institution.

The courier should inspect the exhibition site where the work of art will be installed. This inspection may include confirmation of the temperature and relative humidity ranges. The lending institution may have the courier oversee the installation or actually install the work of art, and with some lenders, this is one of the main duties of the courier.

The courier has complete authority over the work of art until satisfied with its disposition and a signed receipt has been received from the borrower. A copy of the receipt must be sent to the lending museum within twenty-four hours.

**ADDITIONAL INFORMATION SPECIFIC TO HAND-CARRIED SHIPMENTS**

- If traveling by a private automobile with a hand-carried shipment, the courier must be accompanied by a second individual at all times so the case is never left unattended.

- When traveling by train or plane, the courier must be escorted to and from the plane or train by museum personnel or a designated agent. It is helpful if the courier has the name of the individual in advance.

- The courier must be familiar with the appropriate areas on the aircraft or place for the hand-carried case. The recommended locations are under the seat in front of you or strapped into the seat next to you. Do not place the case in an overhead storage bin as it may shift during the flight or fall out when the bin opens.
• **The courier must never surrender the case to a baggage handler** or allow the case to be included as checked baggage.

• **Keep the hand-carried case with you and within sight at all times.**

• **Keep personal baggage to a minimum** or check luggage so as not to interfere with the hand-carry case.

The registrar should always check the under-the-seat size for the hand-carried case since they differ with each aircraft type. Purchasing a seat for the case is an option and usually a larger case can easily be accommodated, especially in the larger seats of first or business class.

## PEOPLE AND THEIR ROLES

The roles of museum staff and shipping agents differ throughout the world. Many of the functions described below may be interchanged between museum staff and the shipping agent.

**The lender's art handlers and packers or agent**
Will move and pack the work of art
Loads the shipping case into van/truck

**The lender's registrar or agent**
Will accompany the courier to the airport
Assists the cargo personnel with loading the container or pallet
May escort the shipping case to planeside if the courier is required for boarding or prohibited from being on the tarmac
Ensures the safe departure of courier and the shipment

**The airline personnel at the cargo terminal**
Will receive the shipment
Draw up the shipment waybill
Load the shipment into the container or onto the pallet, securing it from movements and rain
Move the container/pallet to the plane and load into the aircraft cargo hold
May accompany the courier (or other representative) to planeside
May ensure the courier's boarding of the aircraft from planeside
The airline personnel at the passenger terminal
Will assist in the safe storage of hand-carried cases in the aircraft cabin
May arrange for early boarding of a courier with a hand carried case
May notify airline personnel at the arrival terminal to ensure smooth operations at the courier's deplaning
May assist the courier through customs

The customs broker, shipper, or forwarding agent
Will be present at the airline warehouse for international shipments
Will book cargo shipments
Will prepare the necessary customs documents and arrange customs clearances
Will provide for supervision of the shipping case and container/pallet
Will accompany the courier while at the airport, arranging for passenger boarding
Will arrange for the storage of a hand-carried case on board the aircraft
Will ensure the safe loading and departure of the shipment
May arrange transport to and from the destination museum

The borrowing museum's representative
May be any member of the museum's staff or their agent (ask for identification)
Will meet the courier at the plane (or after immigration inspection)
Will assist with custom clearance for the work of art
Will arrange to expedite the removal of the shipping case from the container/pallet

The truck driver and assistant (almost always two people)
Are responsible for the vehicle and its maintenance
Will load the shipping case onto the van/truck
Are responsible for the safe transport to the destination museum
Will safely unload the shipping case at the destination

The security personnel
May be present on long-distance overland trips
May use a follow car in which the courier can travel
Are responsible for the constant security of the shipment
FOR FURTHER INFORMATION, SEE:

A Code of Practice for Couriering Museum Objects
The Registrar's Sub-Committee for Professional Practices (1986)
The American Association of Museums
Washington, DC

NGA Courier Information
Office of the Registrar
National Gallery of Art
Washington, DC

Loans from the Tate Gallery
Second Edition, April 1984
The Tate Gallery
London, UK

Conditions for Loans to Exhibitions
British Museum
London, UK

Responsibilities of Couriers
The Metropolitan Museum of Art
New York, NY

"International Exhibitions"
Mary Kay Zuravleff
Museum News, February 1987
American Association of Museums
Washington, DC

"The Courier's Art"
John Buchanan
Museum News, February 1985
American Association of Museums

Responsibilities of a Museum Courier
Philadelphia Museum of Art, 1979
Philadelphia, PA

Conservation Policy
National Museum of Science and Technology
Ottawa, Canada

Conservation Policy
National Archives of Canada
Ottawa, Canada
Section 9 - Role of the Courier

Environmental Guidelines for the Loan of Objects from the National Gallery of Canada Ottawa, Canada

"A Draft Code of Practice for Escorts and Couriers"
Peter Cannon-Brookes
The International Journal of Museum Management and Curatorship, 1982
Section 10

GLOSSARY

Topics

- Glossary
- Biographical Sketches
GLOSSARY

**Abrasion**, Damaged areas of paint, resulting from the scraping, rubbing, and grinding away of the upper paint layers.

**Accretion**, Accidental deposit of a foreign substance on the surface of a work of art. In paintings, often fly specks.

**Aging**, In the context of this publication usually refers to the physical and chemical changes occurring to materials over time; i.e. alteration or degradation over periods of time.

**Air-conditioned**, Ideally the control of temperature, relative humidity, and ventilation of the air in an enclosed environment. Often this term is used only to mean control of the temperature.

**Alligator crackle**, A pattern of crackle produced by shrinkage in a rapidly drying upper layer of paint lying over a slow drying still plastic lower layer. The pattern of traction crackle is a characteristic complex branching in which apertures are abnormally wide and disfiguring.

**Batten**, A wooden strip attached to the reverse of a wood panel painting for the purpose of providing additional structural support. Battens can be found attached to the panels either parallel or perpendicular to the grain of the panel. Several battens with sliding cross members constitute a cradle.

**Blanching**, Pale milky cast on an old coating of varnish or paint, indicating the change that occurs in an aged coating after a solvent has been applied and then has evaporated, leaving a milky appearance, usually irregular in distribution.

**Blister**, A convexity or bulge in the paint surface indicating cleavage of paint and/or ground layers, either from each other or from the support.

**Bloom**, A hazy, bluish white cloudiness that appears on parts or all of the surface of some varnish films, resulting from the breakdown of the consistency of the coating by moisture or other pollutants.

**Bole**, A fine, earthy clay of white, yellow, or red, used in gilding and sometimes in artists' grounds. When ground with diluted egg white and applied to a wood surface, it makes a smooth ground for the laying of gold leaf. In early times
terre verte (a pale green earth) was ground in this way and used as bole. The purpose of the red-orange bole is to give brilliance and warmth to the gold.

**Boxes, see also Crate and Case,** The difference between a box (or case) and a crate is that a box (case) is a rigid container with closed faces that completely enclose the contents. A crate is a rigid container of framed construction. The framework may or may not be enclosed (sheathed). (Source: *The Wiley Encyclopedia of Packaging Technology* M. Bakker, ed., New York, 1986, 82-84.) This handbook uses the term “packing case” as defined above.

**Buckling,** (1) The appearance of waves or bulges in a canvas that has slackened on its stretcher. (2) Cleavage from the support in which the ground and upper layers of the painting give way or crumple up under pressure from shrinkage of the canvas support and are pushed up along the edges of cracks.

**Canvas,** A cloth made from cotton, hemp, flax (most common material for canvases of any age) or sometimes silk, traditionally used as a paint support. The term also means a fabric support prepared for painting and the finished painting itself.

**Chalking,** The loss of pigment in a paint layer by powdering off. This effect results from either an insufficient quantity of binding medium in the paint when originally applied or a loss of the binding medium as a result of damage or deteriorating conditions.

**Case, Packing,** See Boxes, Crate.

**Check,** A rupture in wood running along the grain from the edge of a board or panel for a part of its length.

**Cleavage,** Separation between paint layers, paint and ground layers, or ground and support. It occurs where adhesion between layers has deteriorated. Common treatment takes the form of local or total infusion with an appropriate adhesive.

**Climate controlled,** Usually referring to air-conditioning of an internal environment. Climate control of transport vehicles such as trucks usually means heating or cooling. See also Air-conditioned.

**Compression,** The dimensional response of a material subjected to crushing forces as opposed to tensile forces.
which tend to pull a material apart. Materials subjected to compression tend to get smaller.

**Convection crackle**, In a paint surface, a type of age crackle that predominates in areas affected by barriers (e.g. stretcher bars) or bottlenecks (e.g. behind keys) which impede the flow of moist warm air at the reverse of the painting. The crackle will often be less or absent in the areas of the barriers themselves, where a more stable microclimate is maintained.

**Crackle**, The network of fine cracks that develops in grounds, paint layers, and surface coatings of paintings during the aging or drying of the materials. Age cracks usually penetrate both the paint layer and ground. They are caused by strain from movement of the support. Drying cracks or youth crackle are caused by the failure of the film to withstand its own contraction during drying or by the artist's incorrect use of paint. They usually do not penetrate the whole structure from support-to-surface.

**Cracks**, Fissures formed in materials resulting from excessive stress or force.

**Cradle**, A structure on the back of a panel painting consisting of fixed members parallel to the grain of the panel having slots with sliding cross members. The moveable cross members resist the warping of the panel. Designed to prevent warping, with changes in the humidity it often forces the panel to crack.

**Crate**, See Box and Case, Packing.

**Crazing**, A series of tiny breaks in the paint film which do not expose the underlying surface.

**Cupping**, The cuplike deformation observed in the islands of paint formed by cracks in the design layer of a painting.

**Deformation**, The distortion of materials or structures subjected to stresses or forces.

**Double packing case**, A packing technique using an inner case within an outer case.

**Draw**, A system of wrinkles radiating from a corner of a stretched fabric or parallel wrinkles running into a stretched fabric from an edge.

**Ductile**, A material is said to be ductile if it is capable of large plastic deformations. A ductile material requires a
considerable amount of deformation before failure.

**Dynamic**, A system or structure is said to be dynamic if the application of forces results in motion to the system. A vibrating painting is a dynamic system.

**Dynamic cushioning curve**, Curves used in determining the correct amount of cushioning material to optimize the resistance to impact.

**False crackle**, Any pattern resembling that of crackle that is not caused by the normal drying or aging of the materials found in a painting. False crackle may be a deceptive system of ruptures produced mechanically or may be painted on the surface.

**Flaking**, The breaking away or detachment of one or all paint and ground layers from the support in either small particles or larger areas. See Blister, Buckling, Cleavage, Crackle. Flaking is an extreme stage of the cross-referenced terms listed.

**Floating signature**, A name or initials placed on top of the surface coating of a painting or on top of a layer that is not part of the original work.

**Fragility**, A qualitative measure of an object's ability to withstand impact. Fragility is usually measured in G's or acceleration.

**G**, A unitless measure of the magnitude of an impact. The ratio of the acceleration resulting from an impact to the earth's gravitational constant.

**Gesso**, A pale creamy white priming composed of burnt gypsum (plaster of Paris) mixed with glue. Gesso has come to have a wider meaning today and now includes grounds made from chalk (whiting) or other inert white pigments, bound with glue size—usually parchment size, calf skin glue, rabbit skin glue, or isinglass. Gesso in its various combinations provides a ground layer for oil and tempera paintings.

**Glassy**, A description of the mechanical behavior of a materials. A material is said to be glassy if it has a high resistance to deformation, breaks suddenly without ductile deformation, and shows a propensity to brittle cracking. Severe desiccation (drying), cold temperatures, and high rates of loading can cause materials to act in this manner.

**Granular**, A paint structure that consists almost entirely of
pigment particles with little or no vehicle. Used generally in describing the condition of materials that have lost their cohesiveness.

**Grime**, Dirt of any kind. It may be on the surface of an object or buried under a surface coating.

**Ground**, In picture construction, the opaque coating applied to the support after sizing to give it the correct properties for receiving paint or gold leaf. The common ingredients are glue or oil, as a medium, inert fillers, earth colors, white or red lead, and driers. The ground used on commercially prepared canvas is often called priming. See Priming.

**Half-time**, The time required for an internal environment to reach half the difference between the initial internal temperature and the external temperature. The time required for an internal environment to reach half the difference between the initial internal relative humidity and the external relative humidity. Half-time is a useful measurement of the effectiveness of thermal insulation and the effectiveness of buffers used in the control of relative humidity.

**Humidity**, A term relating to the quantity of water vapor present in air. See Relative humidity.

**Impact**, The sudden application of intense forces to a structure. Dropping an object results in a high impact if it hits a hard surface.

**Impasto**, A thick, often opaque, area of paint that protrudes above the surface to which it has been applied.

**Inpainting**, The introduction of new paint material into the areas of loss in an original construction.

**In-plane**, Relating to events occurring in the plane of a structure such as the plane of a painting defined by its edges.

**Interstices**, The crevices between the threads of a canvas support.

**Keying-out**, The expansion of a painting by driving wedges or keys into the inside of the corners of stretchers.

**Keys**, Thin triangular pieces of wood tapped into the corner of a stretcher. The stretcher members are forced apart, thus tightening the canvas.

**Lacuna**, A gap or cavity caused by the loss of a flake of paint or ground from the surface of a painting.

**Lining**, The adhesion of a fabric (traditionally a fine linen
canvas) to the reverse side of a canvas painting. The purpose of lining is to counteract structural weakness in the original canvas and/or to secure cleavage between the paint/ground and canvas layers.

**Mechanical cracks**, Although similar in appearance and character to age cracks, they are often caused by external local pressures.

**Medium**, The material that holds together pigment particles in paint.

**Moisture barrier**, A layer with high water vapor impermeability (such as beeswax) which is often applied as the last stage of treatment to the back of a glue paste relining. Wax-resin linings act as its own moisture barrier. It is also applied to the reverse and edges of panel paintings to protect them from changes in atmospheric humidity.

**Out-of-plane**, Relating to events, such as deformation or vibration occurring out of the plane of a painting defined by the edges. This term usually refers to events occurring perpendicular to the plane of the painting.

**Overcleaning**, Taking off original paint during cleaning a picture or object. Sometimes called “skinning.”

**Overpainting**, Additions that partially or wholly cover original paint.

**Paint**, Finely ground pigment, suspended as discrete particles in a film-forming material or medium, having the property of drying to a continuous adherent film when applied to a surface or ground. Generally, the pigments used to make the various types of paint (watercolor, encaustic, tempera, oil) are the same. The binding media differ in each. Water-soluble gums and glues are used for watercolor, wax for encaustic, egg yolk plus water and/or oil for tempera, and drying oils for oil paints.

**Panel**, A stiff primary or secondary support of wood, metal, or composition board.

**Pentimento**, A phenomenon in paint involving increased translucency of upper layers and emergence of tones beneath, theoretically caused by a progressive change in refractive index of an oil medium. As the index of refraction rises, more light can penetrate through the paint layer, and the drawing and underpaint once concealed show through.
**Priming**, Layer following the ground layer providing modified color base and/or textured surface on which to paint. Priming and primer, meaning a preparation coating for canvas, is synonymous with ground. See Ground.

**PVC**, Pigment volume concentration. The ratio of pigment, by volume, to the total volume of a paint. The same ratio of volume of chalk or filler to the total volume of a gesso. In artists' paints, the pigment is between 40% and 60% of the total volume of the paint.

**Raking light**, Light rays directed parallel to the surface of an object or picture. Used in examination of objects, especially paintings, to indicate buckling and other irregularities of conformation.

**Reforming**, The treatment of blemishes in a surface coating by the application of a solvent that swells the coating and redistributes it on the surface.

**Relative humidity**, The ratio of the partial pressure of water vapor present in the air to the saturation vapor pressure of water vapor at the given temperature. The ratio of the amount of water vapor in the air to the maximum possible at a given temperature.

**Relining**, The lining of a canvas painting that has been lined previously. Removal of the old lining canvas and adhesive and mounting on a new lining canvas and adhesive.

**Resonance**, The effect produced when the amplitude of oscillation of a body is greatly increased by a periodic force at the same or nearly the same frequency. In this case, the periodic force is the vibration from transportation modes.

**Risk assessment**, An evaluation of the potential risk to an object from transport.

**Rubbery**, A material is said to be rubbery when exposed to high relative humidity or high temperature. The material, when tested, exhibits low strength and very high elongation to failure.

**Shock**, A structure is said to experience shock if it is subject to an impact.

**Size**, In its broadest sense, size means any material that is used to seal a porous surface. A term frequently applied to a glutinous mixture of gelatin, skin glue, starch, resin, or gum in water. Raw canvas is normally "sized" before application of the ground or priming.
**Split**, A rupture in wood running along the grain from end to end of a panel or board causing complete separation.

**Static**, Still, restrained from motion. A structure is said to be in static equilibrium when the sum of all applied external forces equals zero.

**Stretcher**, A wooden frame over which canvas paintings are stretched. The corners are jointed but not fixed. By driving in keys or various kinds of springs, the stretcher may be expanded and the canvas tightened.

**Stretcher crease**, The appearance on the paint surface of the form of the stretcher bars as areas of relatively uncracked or uncupped paint (generally in a picture where the surface exhibits crackle). The edges of the stretcher are marked in the paint surface by fairly continuous parallel straight cracks.

**Support**, The physical structure of a painting that holds or carries the ground and paint film. Any material such as fabric, wood, metal, or paper on which a painting is executed.

**Surface coating**, A transparent layer or series of layers applied over the surface of a painting for protection and for a uniform reflection and surface texture. Consists usually of natural or artificial resins, waxes, or oils.

**Tarmac**, Asphalt paved, aircraft parking area, or apron found at airports.

**Transfer (or transposition)**, The removal of the support from the reverse of the paint and ground layers and subsequent mounting of these on a new support. In some cases the ground is removed where it is in poor condition, and a new ground is applied to the reverse of the paint film. This method originated in France in the middle of the eighteenth century when many panel paintings were transferred to canvas.

**Varnish**, A surface coating containing resinous matter either dissolved hot in a drying oil (oil-resin varnish) or cold in a solvent (solvent-type or spirit varnish).

**Vibration**, Rhythmic or random oscillation of an object resulting from transportation vehicles.

**Wedges**, See keys.
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MERVIN J. RICHARD received a B.A. in chemistry and a B.A. in art history from the University of Delaware and an M.A. in conservation from Oberlin College. While a graduate student, he studied the practical and theoretical aspects of conservation at the Intermuseum Laboratory, Oberlin. From 1978-1980, he was employed as a conservator of paintings at the Intermuseum Laboratory. From 1980-1982, he was an assistant conservator of paintings at the Philadelphia Museum of Art. From 1982-1984 he was a conservator of paintings for the Winterthur Museum, and an adjunct professor of the University of Delaware/Winterthur Museum art conservation graduate program. Since 1984, he has been the head of loans and exhibitions conservation at the National Gallery of Art, Washington where he now also serves as deputy chief of conservation. He is the co-chairman of the ICOM working group on the care of works of art in transit.