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Diagnostic Guide for Evaluating Surface Distortions in Veneered Furniture and Cabinetry

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Abstract

Manufacturers and installers of wood-veneered furniture and cabinetry sometimes find that their products eventually develop surface distortions, characterized by either buckling or cracking of the surface finish. The veneer itself sometimes buckles or cracks. Most surface distortions are caused by moisture changes in the product. This guide is a diagnostic tool for locating or narrowing down the source of the problem. By describing the many ways in which moisture changes can become a problem, the guide provides information for avoiding or minimizing surface distortions. Although the guide focuses on veneer, the information presented here should be useful for other wood products as well.

Keywords: diagnostic guide, veneered furniture, cabinets, surface cracks, moisture content, finish buckling

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Diagnostic Guide for Evaluating Surface Distortions in Veneered Furniture and Cabinetry

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Introduction

In the context of furniture and cabinetry, veneer is a thin sheet of fine wood that is glued to a solid wood or reconstituted wood product to improve its appearance. This solid or reconstituted wood is called the substrate or core stock, and the veneer is laminated onto it by means of an adhesive. Decorative veneer ranges in thickness from 0.20 to 1.7 mm (1/125 to 1/16 in.); the thinnest veneer is about twice the thickness of a sheet of paper.

Very thin veneer is so thin that it is supported by and adhesively bonded to a thin paper sheet so that it may be handled without breaking. This combination of veneer and paper is bonded to the substrate by another adhesive, which attaches the paper side to the substrate. The paper inhibits penetration of water from the adhesive into the veneer.

Most surface problems are initiated by shrinking or swelling of the wood. Changes in wood moisture content cause dimensional changes that can produce buckling or cracks in the surface finish or the veneer. Buckling and cracks of finish can occur on solid wood as well, but to a lesser extent.

Swelling and shrinkage are affected by how the veneer is cut and what kind of substrate is used. Figure 1 shows the effects of moisture absorption and drying on peeled veneer laminated to composite board and sawn veneer laminated to solid wood. Peeled or flat-sliced veneer is subject to high swelling and shrinkage. When laminated to a more dimensionally stable surface like fiberboard or particleboard, the veneer swells and may buckle as moisture is absorbed. In drying, the veneer shrinks, which may result in the opening of checks.

Quarter-sawn or quarter-sliced veneer is more dimensionally stable than peeled veneer. For sawn veneer laminated to flatsawn solid wood, the substrate swells when moisture is absorbed (Fig. 1). The veneer cannot stretch to adapt to that increased dimension, and cracks open in the veneer. In drying, the wood substrate shrinks but the veneer does not, resulting in buckling of the veneer.

In general, surface distortion will not occur if (1) both veneer and substrate have similar swelling and shrinkage rates, (2) moisture contents of veneer and substrate are similar at the time of bonding, and (3) only minimal changes in moisture content occur over time. It may be possible to violate one of these conditions, but violating more than one will likely result in surface failure.

Diagnostic Guide

The checklist of diagnostic questions was assembled to help manufacturers and installers track down likely causes of surface distortions in veneered wood. The associated comments should increase understanding of the many factors that lead to such problems. This list can also be used to anticipate possible problems. To help analyze problems that may arise later, we suggest that the manufacturer or installer keep records of relevant construction details, multiple sales, or installations of similar production runs to different customers or in different manufacturing locations. If the problem is not encountered at other locations, perhaps it is attributable to something specific at that site.

As this diagnostic guide indicates, moisture change is the predominant variable that affects wood surface quality in veneered cabinetry or furniture, once appropriate materials and processes have been put into place. Changes in moisture content need not be extreme to have a visible negative effect on fine woodwork.

Resources

Hardwood Plywood and Veneer Association. A good source of information on checking of face veneers and warping of plywood panels, including panels that contain particleboard or medium density fiberboard (MDF) cores, is the Web site of the Hardwood Plywood and Veneer Association (http://www.hpva.org). Under the Publication link are relevant publications that can be purchased at minimal cost. See “Moisture Management for the Control of Checking and Warping in Hardwood Plywood Panels” and Ply-Tips #2, “Preventing Checking and Warping on Wood Veneered Panels.” The Hardwood Plywood and Veneer Association also provides information on product certification and inspection, standards, and accredited dispute settlement.

Wood Handbook. 1999. Wood as an Engineering Material. FPL–GTR–113. Madison, WI. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. See Chapter 9, Adhesive Bonding of Wood Materials; Chapter 10, Wood-Based Composites and Panel Products; Chapter 12, Drying and Control of Moisture Content and Dimensional Changes; and Chapter 15, Finishing of Wood. For wood shrinkage values, see Tables 3–5 and 3–6 (green to ovendry) and Table 12–5 (6%–14% moisture content) and accompanying text and equations. The *Wood Handbook* is available at http://www.fpl.fs.us. Look under Notable Publications.

Public Forum. For a public forum, go to http://www.WOODWEB.com. This forum is devoted to questions from consumers about working with wood. It also includes information on common problems associated with wood moisture content.

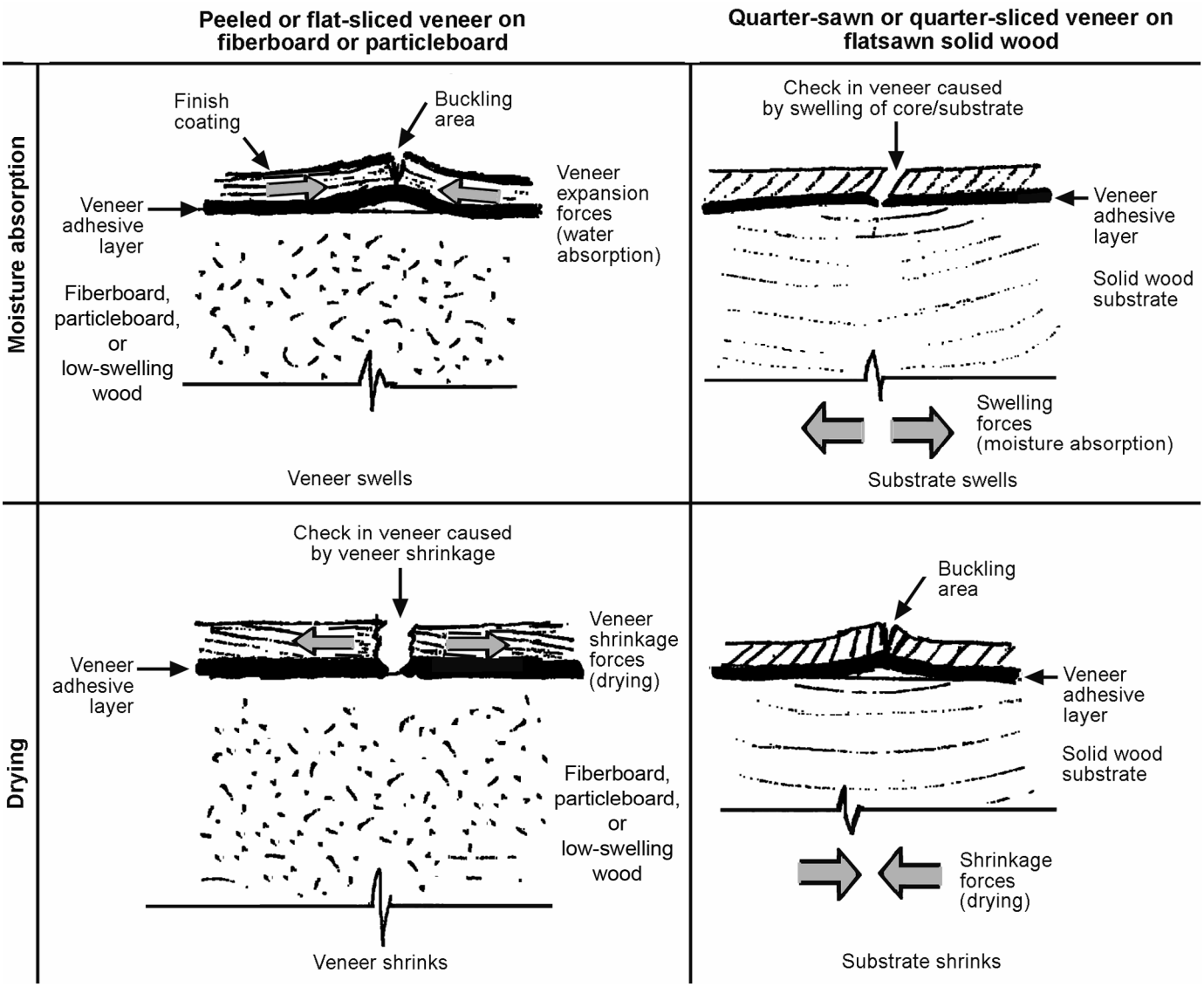

Figure 1—Differences in swelling or shrinkage characteristics can cause surface distortions and/or cracks in veneer-faced panels.

Diagnostic Guide for Evaluating Surface Distortions in Veneer

Question	Comment
Preliminary Questions	
• Where in the process (manufacturing to customer) was the problem discovered or brought to attention?	Pinpointing the stage at which the problem occurred will indicate where to examine the process for problems.
• If the problem occurred after installation, how much time had elapsed between manufacture and installation?	If the problem only occurred after a delay of a few months, environmental factors at the installation site may have changed the moisture content, promoting wood expansion or contraction, which produced the visual problem.
Parallel Experience	
• Did the problem occur while using this process in the past? Has the problem occurred in other facilities?	Can the problem be localized to a particular plant or facility, rather than to the process or the materials in general?
• Have any of the components (substrate or core stock, veneer, paper backing, adhesives, finish) been changed recently?	If the process was operating adequately before the change, then the change should be evaluated to determine if it might be part of the problem.
• Is the same substrate (core material) and varnish or finish used on other wood veneer laminates without problem?	The substrate or finish may be incompatible with the veneer. Some veneer species, such as American beech and some tropical species, "move" (expand perpendicular to the grain) to a great extent with increasing moisture content (relative humidity).
• Has the problem occurred with other items from the same lot or other lots from the laminator, cabinet or furniture maker, or installer?	If the problem has not occurred in other lots, then the specific lot, or its last environment before the problem was noticed, is implicated in the problem. Association with a single lot may indicate the problem occurred after shipping.
• Has the problem occurred in other installations (rooms or buildings) of the same type of components?	If other installations are all right, the problem may be the environment in which the item has been placed.
• What differences in environment (moisture or temperature) are there between problem and non-problem situations?	
• Have any other instances of this type of failure occurred?	The answer to these questions might help narrow down the cause of the problem.
• If so, are there any parallels in experience?	
lnspections[a]	
• Was a quality control (QC) inspection conducted by the veneer manufacturer? By the laminator?	General quality, diving grain, thickness uniformity, moisture content.
• Was a QC inspection conducted by the cabinet maker or furniture manufacturer and/or the finisher?	Cracks in or delamination of veneer, checks or blisters in the finish, uneven flat surfaces.
• Was a QC inspection conducted by the installer of cabinetry or furniture retailer?	Cracks or blisters in the finish, uneven surfaces, delamination of veneer.
• Was a QC inspection conducted by the consumer at the time of purchase or just after installation?	Cracks or blisters in the finish, uneven surfaces.

[a]Questions about QC inspections help indicate whether the problem occurred after the last positive inspection, although prior conditions could have generated the problem.

Diagnostic Guide for Evaluating Surface Distortions in Veneer—con.

Question	Comment
Materials	
• What is the type of core stock or substrate (solid wood, plywood, particleboard, medium density fiberboard (MDF), etc.)? If the core stock is solid wood or plywood, what is the wood species?	Solid wood shrinks and swells less uniformly than does reconstituted wood. Species with high swelling and shrinking coefficients are more likely to experience problems; these are often the harder (denser) hardwoods. Some exotic species are not only dense but have other problems; for example, Santos rosewood (*Machaerium scleroxylon*) has a tendency to have drying checks, interlocked grain (makes machining difficult), high oil content (complicates gluing), occasional trees with high silica content (dulls blades quickly), and sawdust that can be highly irritating and cause dermatitis. A few low-density domestic species (e.g., cottonwood) tend to warp.
• Is the finish buckling away from the veneer?	Buckling of the finish indicates the veneer may have dried and shrunk since the finish was applied.
• Is the veneer buckling away from the substrate?	Buckling of the veneer indicates that it may have swelled (absorbed moisture) or that the moisture content of the core was higher than that of the veneer when the veneer was applied. Since then, the core may have dried and shrunk.
• If the substrate is a reconstituted panel, what adhesive was used to make it? Is the panel uncommon in some way?	Some adhesives adhere to wood surfaces better than others. Panels made with unconventional materials or complex shapes can be difficult to bond with some adhesives.
• How thick is the substrate or core stock?	A thin core stock is more likely to bend if the dimensions of the veneer change. On the other hand, if the substrate is thick, the affected veneer is more likely to crack or buckle.
• Is the construction balanced through the thickness of the finished piece? That is, equal thickness of face layers, same species or materials arranged in the same order from the surfaces, equal moisture content on both sides during bonding, same finishing on both sides.	Unbalanced constructions are more likely to deform if moisture conditions change. Moisture-impervious coatings on one side mean the other side can swell to a greater extent as humidity rises, causing it to cup around the non-swelling side. Stiffer wood (higher density, thicker pieces) will cup around less stiff pieces as humidity falls.
• In the application, is there restraint on one face (e.g., the face is fastened to something) but not on the other face (e.g., decorative molding around a door panel or a cleat on the bottom of a table)? Is moisture content frequently higher on one side than on the other (e.g., bathroom vanity panel, exterior door)?	Unbalanced construction causes problems.
• How far is the defect from the edge? Is the edge finished or covered (laminated)?	Edges are less restrained than is the rest of a surface, so that this region swells or shrinks more easily. In addition, moisture often can move in or out of the edges of wood more easily than in or out of the larger faces of the material. However, the problem can be reduced by covering the edges with an impervious plastic layer.

Diagnostic Guide for Evaluating Surface Distortions in Veneer—con.

Question	Comment
Veneer	
• Is the veneer made of wood?	Unlike plastic, wood shrinks and swells with moisture changes. Plastic laminates, commonly called "Formica," are resin-treated laminated paper. These laminates also shrink and swell with changes in moisture content—quite often more than does particleboard or MDF.
• Is the veneer simple (raw)? Or is the veneer complicated, e.g., twice-sliced (peeled or sliced, glued in stacks, and re-sliced)?	In general, paper-backed veneer does not bond strongly to the substrate. Twice-sliced veneer is more stable than veneer that has only been peeled or is plane sliced, because it is glued and randomized.
• What is the wood species?	Specific gravity, tendency to swell, anatomy, and pH (acidity) vary with species.
• How was the veneer cut (peeled, sliced)?	Cutting affects wood grain orientation, which in turn affects resistance to deformation, particularly with changes in moisture.
• If the veneer is peeled, do the checks (small cracks along grain produced during peeling) face the core or the surface?	If the checks face the core, they are less likely to open the surface as the core or veneer changes dimension with changes in moisture.
• How thick is the veneer? Is the thickness uniform?	Thin veneer has less strength to resist changes in the substrate layer. However, checks will be larger in thick peeled veneer than in thin veneer.
• Is the defect parallel to veneer grain or wood rays?	Wood swells and shrinks perpendicular to the grain. Rays can initiate problems during wood expansion and contraction, especially in oaks.
• Was the veneer sanded after bonding? • How much wood was removed? • What grit size of abrasive paper or belt was used?	Sanding removes material, making the veneer thinner and less resistant to dimensional changes; it may expose checks on the glued face. Large grits for sanding cause more damage to the veneer, especially crushing of surface wood cells. An increase in moisture may "raise" these cells, which have less strength for good bonding. The raising of cells crushed by various processing steps can lead to "telegraphing" (small bumps) on the surface.
• If the core material is solid wood, in which direction is its grain oriented relative to the grain direction in the veneer?	If the grain of the veneer and substrate run perpendicular to each other, then swelling and shrinking could play a factor in surface problems. Reconstituted wood panels usually have low dimensional movement in both directions of the plane, whereas veneer and solid wood tend to move perpendicular to the grain direction.
• Does the veneer have a paper backing?	Paper has more uniform dimensional change than does a solid wood substrate. Consequently, paper backing may reduce surface distortion if the veneer and substrate have different grain orientations. Paper is often used to hold thinly cut veneer together during handling and preparation of the piece for bonding.
• What adhesive was used to bond the veneer to the paper backing? Contact adhesive (solvent- or water-based), hot melt (type), PVA (polyvinyl), or urea (plastic) resin?	Solvents and heat can drive moisture from wood, and water-based adhesives add moisture to wood. Some adhesives are weaker or more forgiving than others when stresses are created by wood swelling or shrinking.
• Has the veneer been filled (to fill pores and gaps) before finishing?	Unfilled cracks in the surface are aggravated by dimensional changes.

Diagnostic Guide for Evaluating Surface Distortions in Veneer—con.

Question	Comment
Laminate	
• What is the climate where (city, country) the veneer was made?	
• How much time elapsed between shipping and application?	
• In what form (sheet, roll) was the veneer supplied to the plant?	
• What were the storage conditions? Was the veneer exposed to moisture and/or cold?	
• Where was the woody core material made? What were the storage conditions?	It may be necessary to recondition the veneer or substrate before bonding. For veneer that can be exposed on both sides, conditioning time could be as short as a day. If the product will be shipped to a dry climate, consider conditioning all wood to lower moisture content.
• In what region (or climate) was the veneer bonded to the substrate (core stock)?	
• What are the conditions (especially humidity) in the veneering facility? Do the conditions vary by season?	
• How was the veneer layer laid onto the core (manually, press process, automated process)? Was the veneer pressed into place by nip rolls or a veneer scraper?	An important variable is the kind of force used to press the veneer flat against the substrate for good contact. More contact means a better bond, although excessive pressure can also be a problem.
• Was the laminating adhesive applied to one or both surfaces? Which surface was the adhesive applied to first?	This may influence whether the veneer or substrate has insufficient bonding.
• For the failed piece, did the adhesive adhere well to one surface but not the other (delaminated) in all cases?	Compare this to the previous answer to determine a possible correlation.
• What kind of adhesive was used to bond the veneer to the core (e.g., contact adhesive, hot melt, PVA, polyurethane, urea formaldehyde (or plastic) resin)?	Adhesives vary in strength and compliance (flexibility). The example adhesives are listed in approximate order of flexibility; however, greater flexibility means less resistance to difficult environments.
• Was any hot pressing used? What were the pressing conditions (temperature, pressure, time)?	Heating reduces moisture content overall, but more so at the surfaces.
• How were the veneered pieces stored?	The issue is moisture control.
• For shipment, was the material wrapped or sealed to protect against moisture changes? Was protective wrapping in good condition when the item was received?	

Diagnostic Guide for Evaluating Surface Distortions in Veneer—con.

Question	Comment
Cabinet/Furniture Manufacture	
• Under what conditions (moisture and temperature) were the panels stored before manufacture into cabinets or furniture? After manufacture?	
• What finishes were applied to the surface? Were both a primer and topcoat applied?	Low-quality primers and lacquer frequently cause problems.
• Was the finish water-, gel-, or solvent-based?	Water-based finishes will supply some moisture to the veneer, which may promote short-term swelling perpendicular to the grain and promote buckling.
• Were the veneer and substrate at an appropriate moisture content before the first finish was applied?	Manufacturing procedures may fail to take into account unanticipated climate conditions in product application.
• How long was each layer of finish allowed to dry before the next layer was applied?	If excess moisture is not allowed to dissipate, dimensional changes will be greater.
• How thick was the applied finish?	If too much finish is applied, then the finish may be unable to move with the natural expansion and contraction of the wood.
• Were the finished pieces shipped long distances (or long times) between manufacture and installation or final delivery, during which moisture content of the pieces could change?	
Product Installation	
• At what time during the year were the products installed? Was humidity controlled?	Humidity usually dictates to what moisture content level the piece will equilibrate.
• Is the State or region where the problem occurred a new market or use area for this product?	The manufacturing moisture equilibration procedures may not have taken into account unanticipated climate conditions.
• If the problem occurred in a new region, is the humidity in this region different from that in the previous use region?	There is a huge difference between Arizona, where 15% relative humidity produces an equilibrium wood moisture content of 3%, and Mississippi, where 80% relative humidity produces 16% moisture content. A difference of only a few percentage points in moisture content can significantly affect dimensional change. Continual interior climate control reduces such changes.
• Was the product (e.g., cabinet) installed or brought to the job site in cool or cold weather before the permanent heating system of the building was operational?	The relative humidity of a cool unheated area may have been high before the heating was turned on, so the product may have absorbed moisture and expanded significantly.
• If so, were unvented job-site heaters (“salamanders”) used in the structure after the wood units were delivered?	A job-site heater raises air temperature and thus lowers humidity and moisture content near it; areas farther from the heater, which are cooler, gain moisture content and swell.
• What strategy (if any) was followed to dissipate construction moisture in a new building?	The largest source of construction moisture is usually a poured concrete foundation. Humidity conditions in the first year after construction can be significantly higher than those in subsequent years.
• Was the problem piece a door or a lid?	The door or lid of a product may be thinner than other sides of the piece and are less restrained from warping. The construction of a door or lid may not be balanced if the exposed face is contoured. In cabinetry, the door may separate areas that differ greatly in humidity.

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Question	Comment
Conditions After Installation	
• Were products in a room that might be cooler or more humid (bathroom, kitchen, unventilated basement) than the rest of the building, in front of a humidifier, or near an unvented gas fireplace?	See Product Installation for comment on effects of job-site heater.
• To what extent has condensation occurred on the inside surfaces of windows?	Condensation on inside surfaces could indicate a humid room (although in a cold climate condensation can occur with relatively low humidity if the windows are not insulating well).
• Was the cabinet or furniture cleaned with water or ammonia cleaning solution?	Absorption of water or ammonia could cause swelling of veneer.
• In warm–humid and hot–humid climates, does the air-conditioning compressor run fairly steadily or does it cycle on and off repeatedly?	Cycling suggests that the equipment is oversized, a common occurrence that results in poor humidity control. Steady running of the air handler fan does not necessarily indicate that the compressor is running steadily.
• Were the products stored in a room that might be hotter or drier than others? • Is the product situated in direct sunlight or heat (vent, radiator, fireplace, wood-burning stove)?	Sunlight shining on a surface within a room may raise the surface temperature by 11°C (20°F) or more, which decreases relative humidity and moisture content and can cause shrinkage at the surface.
• After the product was installed, did the air conditioning or heating system of the building fail? • Was it shut off for any significant time? • In what season did the problem occur? • If cabinetry units were built in place, were they allowed to come to moisture equilibrium before the finish was applied but after the building was enclosed? • Did the finished pieces gain or lose moisture?	Failure of electrical, ventilation, and air conditioning systems can affect humidity.
• To what extent have the problem units been exposed to temperature extremes?	Clear line-of-sight to an east- or west-facing window or to a skylight can result in solar-induced surface temperatures appreciably higher than the indoor air temperature. This is also true if the sunlight falls on wood with a dark surface. Localized heat sources can also cause temperature extremes. Heating duct surface temperatures usually range from about 43°C to 71°C (110°F to 160°F). Furnace limit switches are not uncommonly set at around 82°C (180°F), which can lead to extensive localized overheating should mechanical malfunction occur. Radiant heat for wood flooring is set to a relatively low temperature, such as 26°C (80°F), to prevent a great reduction in moisture content.