I discussed the effect of water on coatings in the July 2015 issue of *CoatingsTech*. Blistering was mentioned briefly there, but covered in more detail in the October 2005 issue. I am returning to that subject. Blisters are dome-shaped defects that may occur when a coated object is immersed in water, when water lies on a horizontal coated surface (as during and after a rain), or upon exposure to high humidity. Blisters often occur on coatings inside water tanks and in other water immersion situations. They occasionally appear on new automobiles left out in the rain or in high humidity. Corrosion often produces blisters, especially along a scribe or other damage to the coating.

Blisters can form whenever there is water-soluble material (salts, soluble impurities in pigments, or residual solvents) in or under a coating. Such materials act as water collectors when the coating is exposed to liquid water or water vapor. If water permeates the coating and dissolves the water-soluble species (and the species is absent in the water outside of the coating), then an osmotic cell is created. The cell consists of a semi-permeable membrane (the paint film), separating a solution of relatively high concentration (the dissolved material) from a solution of low concentration (the water on the surface). This non-equilibrium situation provides a strong driving force to make the two concentrations equal. More water will pass through the coating in an attempt to dilute the concentrated solution. This results in a liquid-filled blister.

Liquid water must be present for a blister to form. Water that is truly dissolved in a coating will not cause blisters. However, many coatings will dissolve additional water at elevated temperatures (such as in a rainstorm on a hot day or rainfall on a hot car hood) and will exude or trap excess free water when the film is cooled. Water trapped by this process can cause blisters, microcavities, and even delamination [C.M. Hansen, *Prog. Org. Coat.*, 26, 113-120 (1995)].

Optical microscopy is a useful tool for examining blisters as shown in the two figures. It often is possible to determine the location of the blister-causing agent by examination of a broken blister or a cross section through the defect. The automotive blisters in *Figure 1* were in the clearcoat and involved lifting from the basecoat. The root cause eventually was found to be a solvent in the basecoat. The blisters in the industrial coating in *Figure 2* were found to be within the topcoat itself, but I do not recall the root cause. Corrosion blisters rise up from the coating-substrate interface and are caused by water, electrolytes, and corrosion products in that area. Steps to prevent blistering include:

- limiting the use of slow (low evaporation rate) water-soluble solvents, especially in air-dry coatings,
- controlling ovens to ensure evaporation of any such solvents that are used in baked coatings, and
- making sure that cleaning processes before coatings are applied remove all salts from substrates.

Corrosion blisters are more difficult to prevent because the salts come from external sources and the corrosion process, but primers that have excellent adhesion (particularly wet adhesion) will minimize them.

There are a number of different ASTM tests or practices for water resistance of coatings, all of which may produce other effects, such as loss of gloss and loss of adhesion, in addition to blisters:

- D 870—water immersion
- D 1735—water fog
- D 2247—100% relative humidity
- D 4585—controlled condensation

I recall tests consisting of 40ºC, 100% relative humidity for 240 hours, and 40ºC water soak for 240 hours being used. Any blistering was taken as failure. These tests seemed to be reliable predictors of field failures.