DEAR DR. G

Q I have a customer questioning the use of galvanized steel in a high temperature environment. Are there any concerns or problems with this situation? Will this lead to failure of the structure?

A There are some concerns with using hot dip galvanized steel in an elevated temperature environment. The industry has recommended the service temperature for conventional coatings to be less than 390 F (200 C) for long-term usage. The problems that arise from long-term use at temperatures above 390 F (200 C) include peeling, some changes in mechanical properties, and obvious reduction in corrosion protection.

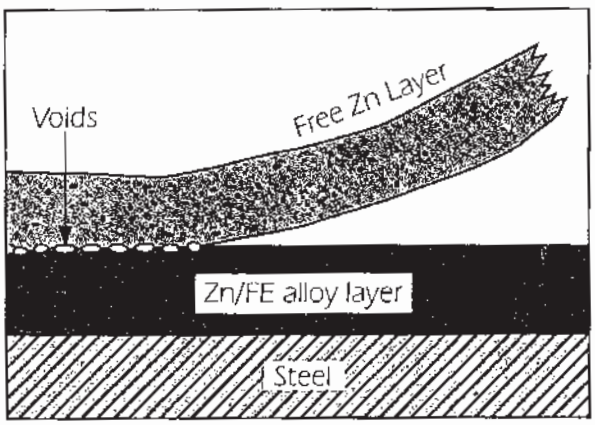

Figure 1: The Kirkendall Effect

Peeling of the free zinc layer (figure 1) is visually unappealing. Peeling is caused by metallurgical changes, which occur within the galvanized coating following solidification of the outer zinc layer. When items are subject to very slow cooling or are heated to temperatures below the melting point, diffusion of zinc from the outer, solid free zinc layer into the inner alloy layer occurs, leaving behind a series of submicroscopic, closely spaced voids at the free zinc/alloy interface. This phenomenon is known as the Kirkendall Effect and results in severe weakening of the bond between the two layers.

In an air environment, conventional galvanized coatings may withstand long-term continuous exposure of up to several months at 390 F (200 C) without separation of the outer zinc layer. The incidence of such failure will depend on the micro-structural characteristics of the coating. Higher temperatures progressively accelerate the separation process to the point where it requires only a few hours at 570 F (300 C) to cause peeling. Continued expo-

sure can result in changes to the zinc-iron alloy layers and even cause them to crack and separate.

Apart from the predominant effect of the time/temperature conditions, the rate of the deterioration process is influenced by coating thickness, the relative thickness of outer zinc and iron-zinc alloy, and by the uniformity of the individual layers. By its effect on the length of the zinc diffusion path or the rate of the iron-zinc inter-diffusion reactions, any of the coating factors can affect the speed and degree of coating deterioration. At or below the industry-recommended limiting service temperature of 390 F (200 C), the coating resists zinc-layer peeling.

At higher temperatures, the resistance to peeling deteriorates. In spite of free zinc peeling at temperatures between 390 F (200 C) and 480 F (250 C), the zinc iron alloy layers protect the steel from corrosion in this temperature range. To what extent this actually would be achieved at this or lower temperature levels would, of course, be dependent on the nature and severity of the corrosive environment in the particular application. Figure 2 depicts a graphical representation of the time/temperature dependence to the zinc diffusion rate.

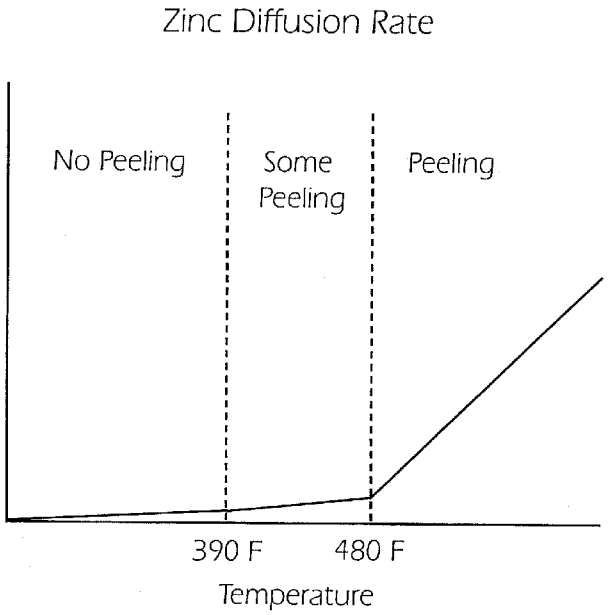

Figure 2: Zinc Diffusion Rate

Another concern is that of changing the mechanical properties of the steel at high temperature. The mechanical properties for samples in the as-received condition and after heating at 750 F (400 C) are as follows. Exposures from two weeks up to 16 weeks produced relatively minor changes, including a decrease in ultimate tensile strength and an increase in elongation. The yield strength was not significantly altered. These structural changes are insignificant and do not affect the design of steel structures.

As discussed, peeling does occur at temperatures above 390 F (200 C) and is dependent on the rise in temperature and the duration exposed. But this does not mean that there is no corrosion protection. During peeling, only the outer free zinc layer has become detached, leaving the zinc-iron alloy layers to provide corrosion protection to the steel.

Mechanical properties change only slightly at elevated temperatures and are not a significant issue. Galvanized product may be used at high temperatures for a limited time with the knowledge that severe peeling may occur. The recommended service temperature of 390 F (200 C) has been a good benchmark for coating protection with no free zinc peeling.