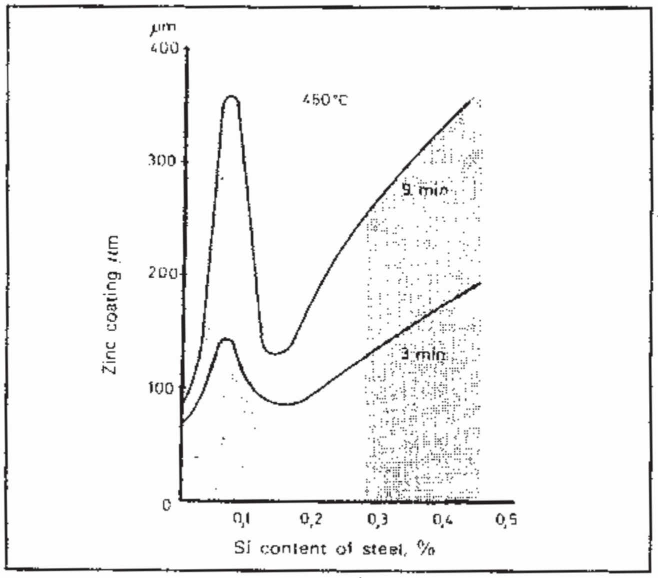
ASK DR. GALV

Q. Dear Dr. Galv: What is the correct formula for determining steel reactivity when I have silicon and phosphorous in the incoming steel?

A. This is a very tricky question. The original authority on the subject of silicon reactivity was Robert W. Sandelin who found that the rates of enhancement of reaction diffusion peaked at a silicon concentration of about 0.10 wt%. The graph below shows the relationship between zinc coating thickness and silicon content of the steel as researched by Dr. Sandelin.



Silicon changes the diffusion reaction between zinc and iron. When low silicon material is galvanized, the diffusion reactions take place in the first few minutes of immersion in the galvanizing bath. The process slows rapidly after about six or seven minutes and the coating will not increase in thickness even with much longer immersion times.

The high silicon steel continues to pick up zinc in a linear fashion as the coating time increases. This can cause some very thick coatings on steel parts. The silicon is acting as a catalyst to promote the interdiffusion of iron and zinc which leads to the formation of a very thick layer of intermetallic. The layer that grows is the delta intermetallic, which is 90% zinc and 10% iron. The thick intermetallic layers tend to be more brittle and have a greater likelihood of experiencing handling damage. If the silicon is not evenly distributed in the base steel, there can be significant thickness differences in the galvanized coating. Intermetallic crystals may reach the surface of the coating and result in a dull gray surface or even a mottled surface that may be asthetically unacceptable.

The presence of intermetallics at or near the coating surface and their relatively open coating microstructure can lead to premature staining — a rust colored stain which often leads to the erroneous conclusion that the part is failing.

Research carried out by the University of Cardiff in Wales for an ILZRO project took an in-depth look at the problem of silicon reactivity and included phosphorous as a reactive element, also. The researchers varied the weight percentage of silicon and phosphorous and then assessed the reactivity of the steel at different galvanizing temperatures. This work has led to a new table of reactivity classifications for silicon and phosphorous content. One interesting finding is that even when the silicon content is low, steel class 3, if the phosphorous content is high the steel is very reactive. The last column of the table indicates that the coatings with high phosphorous, >0.035, have the greatest tendency to flake off of the steel.

Steel Class	Silicon Content Weight %	Phosphorus Content Weight%	Steel Reactivity	Coating Appearance
1	0—0.035	0—0.025	Generally normal	Few defects
2	0—0.04	0.025—0.035	Normal	Localized defects due to zeta outbursts
3	0—0.04	>0.035	High, especially with high phosphorus content	Pronounced surface defects such as "tree bark", high tendency to flake
4A	0.04—0.135	>0.01	Moderate, increased with silicon content	Few defects
4B	0.04—0.135	>0.01	High	Few defects
5A	0.135—0.35	>0.03	High, but generally produces thinner coatings than 5B	Few defects
5B	0.135—0.35	>0.03	High	Tendency to flake especially with high phosphorus content
6	>0.35	>0	High, increases with silicon content	Tendency to flake with increasing phosphorus content