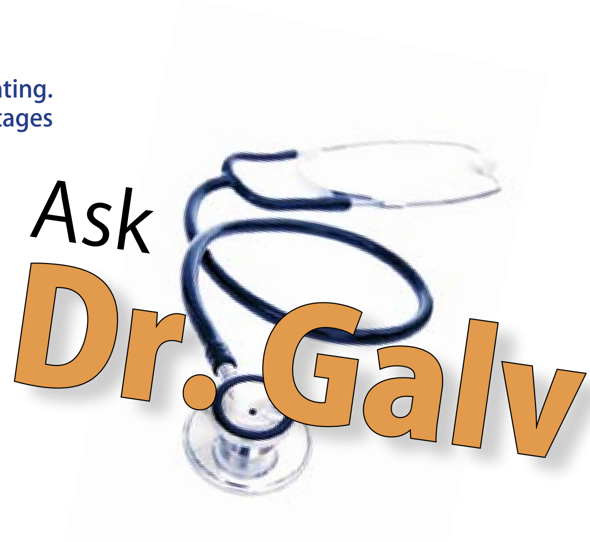

Q: **I know steel chemistry can affect the quality of a galvanized coating. Why does steel chemistry differ, and what advantages and disadvantages do these differences offer?**

A: In order to answer your question I must first define several terms commonly referred to by metallurgists. First, physical metallurgy can be described as the physical and mechanical properties of metals as affected by composition, processing and environmental conditions.[1] Hardness is the measure of a metal to resist deformation by indentation. Hardenability is a measure of the property in a ferrous alloy that determines the "range" of hardness induced into steel by quenching. Tensile strength is the maximum tension that can be applied to a metal without the metal breaking.

The predominant constituent in steel is iron. Iron as an element is soft and ductile. Adding as little as 0.5% carbon by weight to iron can dramatically increase the tensile strength of the steel. Carbon is added to iron in quantities up to 2% by weight to create what is commonly known as "carbon steel." Increasing the hardness of steel can increase brittleness and decrease weldability. Manganese, like carbon, is added to steel to increase its strength. Manganese also increases hot working properties, and increases hardenability and toughness of steel.

In addition to carbon and manganese, several other elements are commonly added to iron. Alloy steels with differing chemistry can have very different material properties. To account for these differences, a formula was devised to compare one alloy steel to another with different elemental additions. This formula is called the carbon equivalent (CE.) There are several different versions of this formula – here is one commonly used:

$$CE = C\% + (Si\%)/25 + (Mn\%+Cr\%)/16 + (Cr\%+Ni\%+Mo\%)/20 + (V\%)/15$$

[1] Glossary of Metallurgical Terms and Engineering Tables.

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Figure 1: **Rough surface due to excessive silicon content**

Figure 2: **Black steel**

Figure 3: **Rough surface due to excessive phosphorus content**

When carbon is added to iron, oxygen in the air reacts with and consumes the carbon. To prevent this, silicon is added to the iron as a deoxidizing agent. This prevents the oxygen from reacting with and consuming the carbon. When silicon is used in this fashion, it is said to "kill" the steel. Silicon can also make steel harder; however, in excessive quantities, silicon can create rough galvanized coatings (see *Figure 1*).

Most steel (*Figure 2*) is made from scrap iron, which can introduce impurities into the steel. In small amounts, impurities usually do not have a detrimental effect on steel properties. Phosphorus, one such impurity, is allowed by many steel specifications in levels up to 0.04%. In levels higher than 0.04%, phosphorus can negatively impact hot-forming operations in the steelmaking process, increase the tendency for steel to crack during welding and create rough galvanized coatings (see *Figure 3*). In amounts up to the specified level, phosphorus can increase the strength and corrosion resistance of steel.

Phosphorus and silicon can act synergistically to cause rapid growth of zinc-iron alloy layers in galvanized coatings. This happens because the two act as catalysts during the metallurgical reaction of zinc and iron during the galvanizing process.

As you can see, elemental additions made to steel are not arbitrary. They help to create steel with specific properties. When these elemental additions are limited to the ranges listed in ASTM A385, they should not negatively impact the quality of a galvanized coating. These recommended ranges include a carbon content less than 0.25%, manganese content less than 1.3%, silicon content less than 0.04% or between 0.15% and 0.22%, and phosphorus content less than 0.04%.