Hot Dip Galvanized Information Sheet No.4
Effect of Silicon and Phosphorous in Steel

The quality and surface finish of hot dip galvanized carbon steels are directly related to the chemistry of the components being processed. Fundamentally, two elements, being Silicon (Si) and Phosphorous (P) within carbon steel, influence the surface finish in terms of uniformity, colour (shiny or matt dull grey) and relative smoothness.

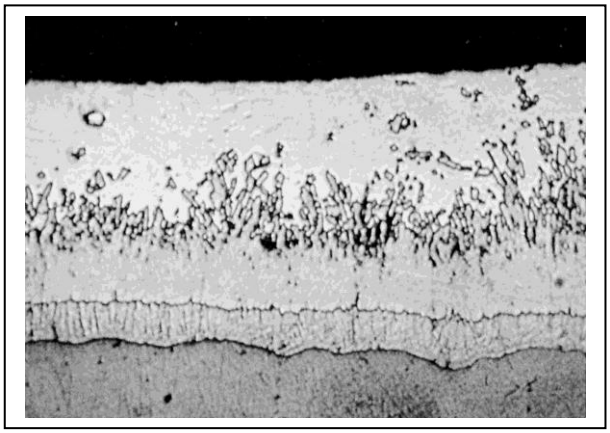
Carbon steels fall into two broad categories, viz,

- Aluminum killed steels, < 0.03% Si, or
- Silicon killed steels, > 0.03% Si

The term “killed steels” relates to degassing and de-oxidizing of carbon steels during their manufacturing process..

Zinc coating thickness and appearance, produced by hot dip galvanizing; at normal molten zinc temperatures of between 445 to 455°C is a function of Si% and in certain circumstances, but less frequently, by P% content within the carbon steel.

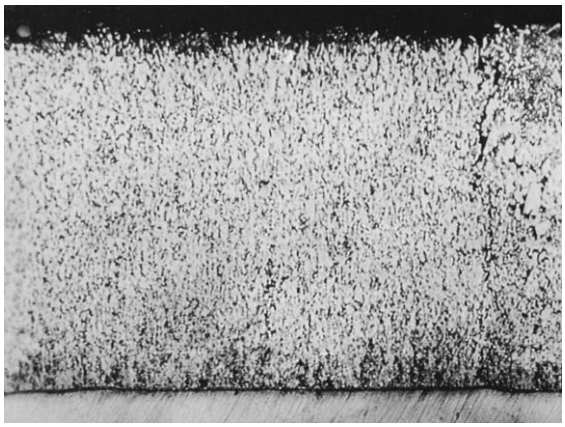
Micrographs of Hot Dip Galvanized Coatings (magnification of 150 to 200x)



Typical micrograph of a hot dip galvanized coating using “aluminium killed” carbon steel (Silicon < 0.03% and zinc temperature 450°C)

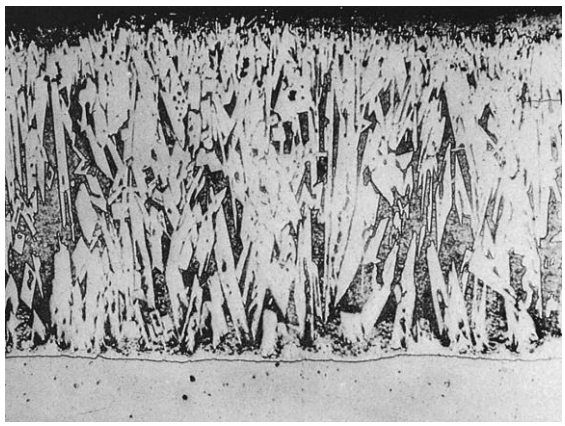
Zinc coating thicknesses range between 50µm to 65µm

Coating surface finishes are usually a bright silvery shine, which in time (3 to 4 months) will become a dull matt grey uniform finish of $ZnCO_3$, refer to Information sheet No. 11 “How does zinc protect?”



Cross-section through zinc coating on silicon-killed steel with 0.06% Si

Zinc coating thicknesses range between 150µm to 300µm and illustrated in the photograph



Coating structure of hot dip galvanized coating produced using “silicon killed” steel within the silicon range of 0.15% to 0.25% and a zinc temperature 450°C

Coating thicknesses range between 120µm to 200µm, and illustrated in the photograph

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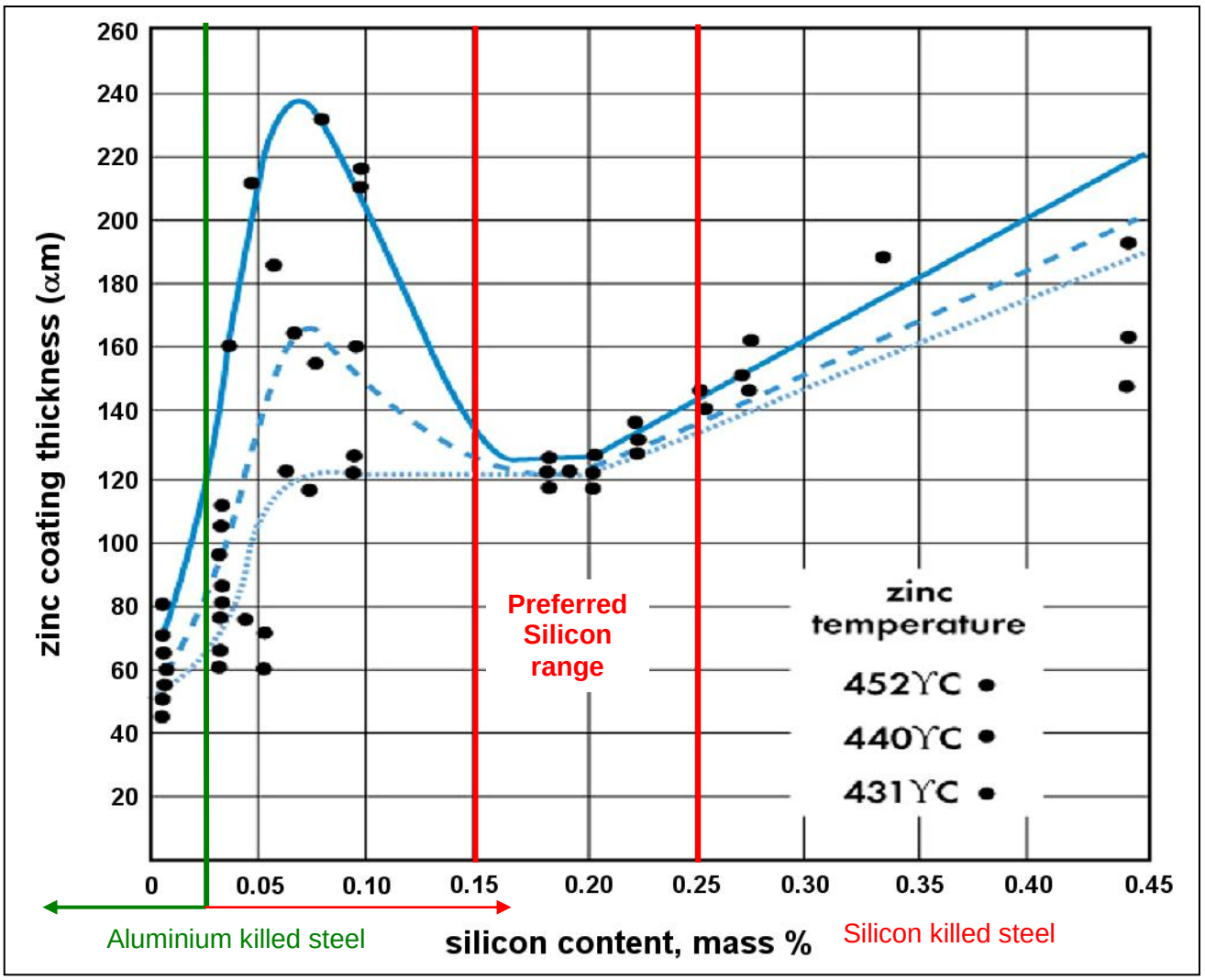
The influence of Si in the steel chemistry, is illustrated by the following Sandelin Curve, with Al killed steels to the left on the green line (Si <0.03%) and Si killed steels >0.03%.



In the steel making process aluminium or silicon is used to remove oxygen and contaminants from the steel. This is referred to as “aluminium killed” or “silicon killed” steel. The effect is that aluminium killed steel will have low amounts of silicon and more aluminium. With silicon killed steel the reverse applies. Aluminium killed (Si range of 0.008% to 0.03%) and is less reactive when immersed in molten zinc. Silicon killed steel, Si >0.03% is more reactive and hence should be controlled by way of the steel specification with a specified Si range. Aluminium in steel has little effect on the reactivity with molten zinc.

Phosphorous in the steel chemistry has an additional effect on its reactivity within molten zinc. In order to control coating thicknesses and surface finish, phosphorus should be specified <0.02% and if possible <0.01%. Phosphorous content above 0.02% will cause coatings to be excessively thick (> 200µm), brittle and subject to chipping and / or flaking due to mechanical damage. A steel chemistry analysis certificate should be obtained from steel suppliers, particularly when large quantities of material are to be hot dip galvanized.

Surface appearance of reactive “silicon killed” steel with a phosphorous content > 0.02%

Corrosion Protection of Hot Dip Galvanized coatings

Zinc is a “sacrificial material” that retards the rate of corrosion. Therefore the thicker the zinc coating the longer the service life of the carbon steel. In the case of “aluminium killed” steel (60 to 80µm) the service life is less than that of “silicon killed” steel. However too thick a coating (>200µm) there is a greater potential for mechanical damage. It is advisable, particularly on large contracts, to specify the chemical analysis (silicon and phosphorous) of the steel.

An ideal steel chemical analysis specification should be stated as follows;

“Aluminium Killed Steel”

Silicon (Si) = 0.01 to 0.03%, Phosphorous (P) = 0.015% maximum (50 to 65µm, more flexible and “short term shiny finish)

Or

“Silicon Killed Steel”

Silcon (Si) = 0.15 to 0.25% and Phosphorous (P) <0.02% maximum (normally >120µm with a dull grey surface finish, but brittle when over 200µm)

Corrosion rates and ultimate service life of hot dip galvanized carbon steel structures are not only dependent on zinc coating thickness, but the environmental conditions in which a structure is located. Refer to Information sheet No.8 “Corrosion of Zinc – Corrosivity of Atmospheres” and Information sheet No.6 “Corrosion Control by Hot Dip Galvanized Steel in Water”.