Zinc-Rich Primers in High Heat

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Low alloy steels are used in steam power plants and gas turbines to allow operation at elevated temperatures. The elevated temperatures, above 650 F (343 C), provide greater efficiency as the temperature increases. Resistance of steels to degradation of properties at elevated temperatures usually increases with alloy content. Most low alloy steels contain no more than 10% total alloy content. This low alloy content should not impact coating performance.

The generally accepted temperature limit for most untopcoated inorganic zinc-rich primers is 750 F (399 C). When inorganic zinc is used as a primer with a silicone topcoat, protection can be provided up to 1,000 F (538 C). However, there are two other theories regarding the temperature limitations of untopcoated inorganic zinc.

One theory is that without topcoats, inorganic zinc coatings oxidise rapidly at temperatures above 750 F (399 C). The application of a silicone topcoat prevents contact with the air, which activates the zinc and causes rapid failure.

The second theory is that the melting point of zinc (787 F [415 C]) limits the use of zinc to 750 F (399 C). However, there are some indications that as the zinc melts, it forms a better bond to the substrate, which provides protection at higher temperatures.

Some other factors to consider in the success or failure of untopcoated inorganic zinc are the environment surrounding the high-temperature applications and the total thickness of the zinc film.

The use of untopcoated inorganic zinc in areas of high or low pH can cause premature failure. Therefore, the use of zinc should be limited to environments with a pH between 6 and 10. Outside of these parameters, zinc will fail rapidly.

Excessive film build can cause two problems at elevated temperatures. Mudcracking is always a potential problem with inorganic zinc. But the problem is amplified in high-heat applications. In some laboratory cool water quench tests conducted, there was a tendency for some of the untopcoated zinc to pop off. The topcoated zinc did not pop off. Although lab tests can provide valuable data, it may be hard to duplicate the severity of this test with field conditions.

As with any paint system, there are always several factors to consider when deciding what paint to apply and how to apply it. One of the greatest challenges to the paint specifier is to provide the most value while reducing the risk of failure. Understanding all the parameters affecting the application can help limit the risk.

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film thickness in the range of 75–125 micrometres (3–5 mils) over an abrasive blasted surface. In contrast, organically based paints are only serviceable to much lower temperatures, typically to about 180 C (356 F).

However, inorganic zinc silicates are not serviceable above 400 C (752 F) unless they are overcoated. This is because as the melting point of the zinc (412 C [774 F]) is approached, the rates of oxidation and carbonation increase markedly, and the finely divided zinc in the siliceous binder is rapidly consumed to render the coating ineffective.

To retard this oxidation, topcoats can be applied that inhibit oxygen from reaching the zinc. Two types are common:

• silicone aluminium applied as a one- or two-coat system to a nominal dry film thickness of 175 micrometres (7 mils), and
• butyl titanate applied as a two-coat system to a nominal dry film thickness of 50 micrometres (2 mils).

These will extend the serviceability of the inorganic zinc silicate primer to about 540 C (1,004 F).

Two asides are relevant to the use of inorganic zinc silicates.

Application of untopcoated inorganic zinc silicates outside the range of 65–125 micrometres (2.6–5 mils) is likely to risk under-protection and film cracking, respectively. Thus, the application of film thickness needs to be carefully controlled.

In the author’s experience, there is a tendency for specifiers to overstate the maximum temperature that surfaces will reach. This can result in the use of more expensive and sophisticated coating systems than are required.

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The melting point of pure zinc is generally quoted as being 419.6 C (787 F). This causes concern with many users of zinc-based coatings regarding the performance of the zinc at high temperatures above this figure, giving them a vision of the coating “melting” away. (Commercial grades of zinc used in making zinc dust for coatings often have very slight levels of impurities that make the melting point slightly lower still.)
The problem of melting away is clearly not the case, for zinc silicates are commonly used at temperatures in excess of 500 °C (932 °F). In zinc silicates, the matrix is composed of silica and, consequently, the individual zinc particles that may soften cannot flow because of the rigidity of the inorganic “polymer” matrix, which is basically unaffected by heat up to temperatures of 1,500 °C (2,732 °F). This is apparent when studying the coating under an SEM before and after heating to 600 °C (1,112 °F). There is no apparent change in the appearance of the film or the individual zinc particles.

There are many instances where zinc silicates are specified for use at temperatures up to 400 °C (752 °F), presumably because of concern with zinc melting, but also presumably for one of the other reasons often quoted for not using zinc silicate untopcoated at temperatures above 500 °C (932 °F), i.e., that oxidation of the zinc dust will occur, destroy metal-to-metal contact, and, hence, prevent galvanic protection. In some instances, zinc silicates are recommended at these temperatures under silicone aluminium, which prevents oxidation reaction. Together with carbonation and other reactions, the oxidation reaction gives zinc salts of various composition, occurs at all temperatures, and is only accelerated by increasing temperature. In practice, at any temperature, all zinc silicate coatings cease to protect galvanically after relatively short periods and function only as a barrier. The situation here is no different. (It is worth asking about the likelihood of electrolyte being present to allow galvanic protection—this will only occur when the plant is not operating, and the zinc in practice will be functioning only as a barrier.) In terms of resistance to mechanical damage, impact will still tend to smear the zinc over the surface, giving temporary anti-corrosive protection as normal.

Instances where zinc silicates have “failed” under high temperature conditions can generally be traced to poor surface preparation or over-application. Temperature cycling with over-applied zinc silicate (> 100 microns dft [4 mils]) can lead over time to accentuation of fine surface mud-cracking to greater defects and, eventually, flaking.

The use of single coats of zinc silicates at temperatures in excess of 500 °C (932 °F) is now recognised in the NACE “Guidelines to High Temperature Coatings,” which comments that these have been used successfully in a number of instances at temperatures well in excess of 500 °C (932 °F).