

Preparing Steel Surfaces for Thick-Film Intumescent Fireproofing

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ABSTRACT

Thick-film epoxy coating systems are applied at greater dry film thicknesses than conventional protective coating systems, resulting in a greater need for achieving the required level of surface preparation. They also must serve in corrosive and severe environmental conditions and must be capable to withstand hydrocarbon fire exposure and explosions. It is critical that the surface preparation be done in accordance with the manufacturer's written instructions within the application manual. Otherwise, premature failure may occur, often within one year of being placed into service. Inadequate preparation may result in the system not being able to provide the level of fire protection required. Failure of the fireproofing system puts lives, assets, ability to continue operation, and the environment at risk!

Key words: surface preparation, surface cleanliness, surface profile, anchor profile, peak count density, fireproofing, passive fire protection, atmospheric corrosion, thick-film intumescent coating, hydrocarbon fire protection, galvanizing, inspection

INTRODUCTION

The thick-film intumescent fireproofing industry has experienced premature failures globally. Like the failures with conventional protective coatings and linings, a very high percentage of the failures were a result of inadequate surface preparation. Thick-film intumescent coatings are applied at very high film build thicknesses, not surface tolerant, dry quickly, and must be applied to properly prepared bare and galvanized steel. When a premature failure occurs, it presents high financial impacts, disruption of scheduling and production, as well as exposes asset owners to harmful impacts caused by potential fires. By achieving the required level of surface cleanliness and surface roughness, thick-film intumescent coating systems can provide many years of durable fire and corrosion protection.

EXPOSURE

The environment in which thick-film intumescent coatings serve is often worse case scenarios: extreme temperatures, acidic, high levels of moisture, high levels of salinity, chemical exposure, along with endless opportunities for mechanical damage. As a result, Underwriters Laboratory, under UL 2431

Standard for Safety for Durability of Fire Resistive Coatings and Materials, tests passive fire protection materials to various simulated environmental exposures common in hydrocarbon processing facilities. Such exposures include exposing test specimens to simulated sunlight, moisture, heat, air erosion, salt spray, reagent solvents, carbon dioxide, sulphur dioxide, impact, vibration, and a combination of wet, freeze, and dry cycling¹.

The variance in the coefficient of thermal expansion between mild steel and typical epoxy resin requires optimum surface preparation. During sub-freezing conditions, typical epoxy resin materials will contract approximately four to five times more than that of the steel. The flexural and elongation properties of intumescent coatings are reduced during low-temperature exposures. Compromised surface preparation typically becomes evident by detaching, after an intumescent coating goes through a winter season with sub-freezing temperatures, if the required profile is not achieved during the surface preparation process.

Fireproofing must be able to withstand various forms of external forces applied, such as flexing during transportation and construction, mechanical impact during routine maintenance, constant vibration from operating equipment, and explosions before or during a fire. It is imperative for the intumescent coating system to be well bonded to the steel to maintain the level of designed protection.

Hydrocarbon fires subject fireproofed steel members to a rapid rise in temperature. Figure 1 below compares the hydrocarbon heating curve to both uncoated steel and steel coated with an intumescent epoxy coating, using the core temperature of the steel, over time. This rapid rise in temperature results in expedited expansion of the steel and initiates the intumescent reaction. Thick-film intumescent coatings swell when exposed to elevated heat, creating a robust char approximately eight to ten times their initial dry film thickness. It is the char that provides the required level of insulation, preventing the steel from exceeding the limiting temperature deemed necessary within the specified fire rating. Direct hose stream impingement from firefighting equipment may potentially remove the fire protection system, exposing the steel to the fire, if the surface preparation achieved is inadequate and not within the parameters stated in the manufacturer's written instructions.

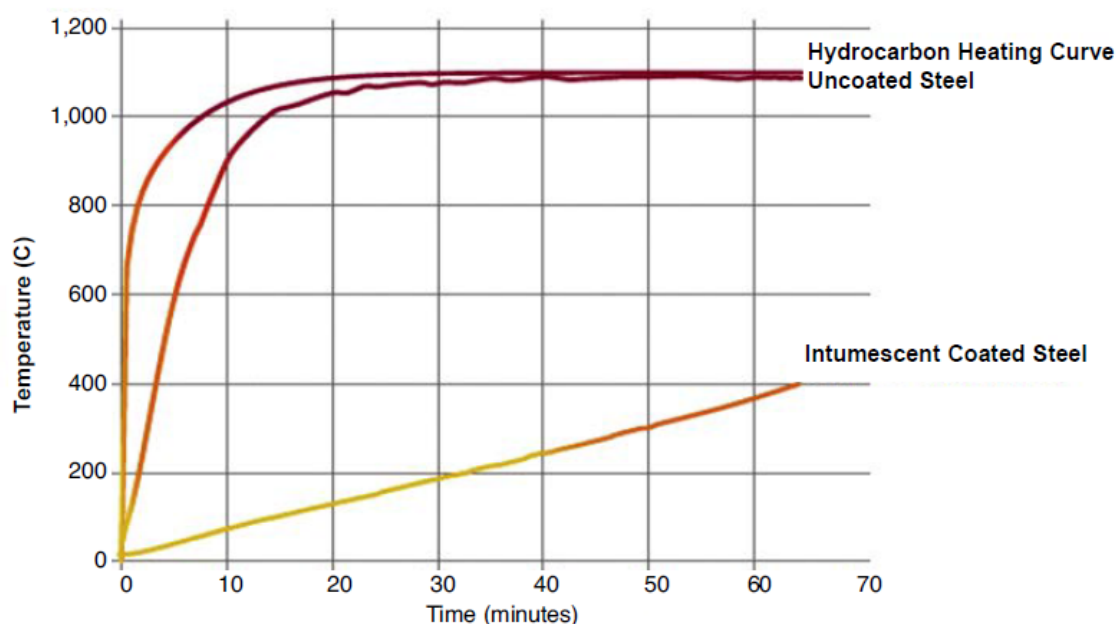


Figure 1: Heat absorption comparison of bare steel to steel protected with a thick-film intumescent coating.

RESULTS AND DISCUSSION

The hydrocarbon heating curve line in Figure 1 illustrates the rate, in minutes, compared to the rise in temperature of the furnace, where both the uncoated and intumescent coated steel members are being fire tested. The curve for the uncoated steel illustrates how quickly the core temperature of the steel reaches that of the furnace. The intumescent coated steel increases at a much slower rate. Limiting temperatures, such as 400 °C (752 °F) and 538 °C (1000 °F), are often deemed necessary by engineers in order for the steel structure to support its load.

SURFACE PREPARATION

There are four key components to the surface preparation of steel surfaces: removing surface imperfections, surface cleanliness, profile height, and peak count. Each component of surface preparation contributes uniquely, working in unison, to ensure the proper bonding of the fireproofing system. Although the method of achieving the required level of surface preparation varies between bare carbon steel and galvanized steel, all four key surface preparation components apply to both substrates.

SURFACE IMPERFECTIONS

Surface imperfections place the fireproofing system at risk of premature localized failure. Surface imperfections should be removed before abrasive blasting. Carbon steel surface imperfections include sharp fins, sharp edges, weld spatter, burning slag, and laminations². Commonly, galvanized steel surfaces must have drainage spikes, lumps, puddles, splatter, dross, ash deposits, and other surface defects removed³. Surface imperfections increase the risk of failure by potentially breaking loose, not allowing proper film build, may conceal porosity, and create an irregular surface, making it difficult to achieve a proper surface profile. It is also important to attain a level surface plane to achieve an optimum bond and to equally distribute stresses within the fireproofing system, such as during flexing, during low thermal cycles, and when exposed to a fire.

There are two galvanizing imperfections, located within the galvanized film, that have proven to be detrimental to an intumescent fireproofing system, being peeling and flaking. Within the four distinct layers of the galvanized film, peeling occurs between the eta layer (100% Zn), or outer pure zinc layer, and the zeta layer (94% Zn, 6% Fe), the second layer from the surface⁴. Peeling leaves a considerable amount of galvanizing on the steel. Flaking occurs at or near the steel surface and most, if not all, of the galvanizing is detached. Peeling and flaking are seldomly obvious and are not consistent throughout the surface of a galvanized steel member. Abrasive sweep blasting does not always reveal flaking and peeling. Therefore, it is imperative to first thoroughly evaluate each galvanized steel member by using the point of a stout knife and exerting force into the galvanizing, attempting to remove it. If not identified and remediated properly, peeling and flaking will result in detachment of the complete system during the application process or when exposed to stresses, such as those previously mentioned.

SURFACE CLEANLINESS

For both galvanized and bare carbon steel surfaces, obtaining a specified level of surface cleanliness requires dividing the task into two categories: dissimilar and similar contamination removal. Dissimilar contaminants are foreign substances that have come into contact with the substrate after the hot-dip galvanizing process is completed or after the molten steel has cooled and has been exposed to the elements. Dissimilar contaminants include, but are not limited to oil, grease, soil, drawing and cutting compounds, welding slag, and annealing slag. Similar contaminants are products that form on the

surface of galvanizing and exposed steel, as a result of reacting with the environment. Zinc oxide, zinc hydroxide, and zinc carbonate are similar product contaminants on galvanized steel surfaces⁴. Similar contamination products of iron include mill scale and oxidation, or rust⁵.

For dissimilar contamination removal, Surface Preparation Specification No. 1 (SSPC-SP 1) *Solvent Cleaning*⁶ is commonly followed. Before wetting the surface, scrapers and stiff fiber and wire brushes are used to remove large deposits of dry contaminants, such as dust and dirt. Heavy deposits of oil and grease are removed by using a scraper. Appropriate cleaning solutions, such as those generically listed within SSPC-SP1 and in the American Galvanizers Association's Guide to Preparing Hot-Dip Galvanized Steel for Paint, are then used to remove remaining contaminants, using clean rags, brushes, or pressurized and steam cleaning equipment. It is best practice to first use non-hazardous solvents to keep hazardous waste to a minimum. The objective of SSPC-SP 1 is to achieve a surface that is free from all visible contamination, as described in section 2.1.

Soluble salts, specifically chlorides, nitrates, and sulfates, are dissimilar contaminants. These, if present in excess, may result in the rapid loss of surface cleanliness following the abrasive blast cleaning process, may produce osmotic blistering, potential degradation of the fireproofing system, and accelerated corrosion of the steel⁷. Soluble salts that remain on the surface following the SSPC-SP 1 solvent cleaning process, should be removed or reduced to an allowable limit. Common guidance provided within the high-performance coating industry limits chlorides to 5 µg/cm², nitrates to 10 µg/cm², and sulfates to 15 µg/cm². Soluble salts are not effectively removed by abrasive blasting⁵. Salts must be removed by using water, steam, or chemical treatments. Considering the initial cost of installing the fireproofing system, having evidence in the coating industry in achieving longer coating life cycles, and that fireproofing serves a critical life-safety role, verifying soluble salt contamination and removing excess soluble salts is well worth the small investment.

Zinc reacts quickly with the environment and immediately begins the process of forming a zinc patina⁸. Within as little as two hours of a steel member being withdrawn from the zinc bath, the galvanizing begins to form a zinc oxide, which is a powdery substance. Then, once exposed to moisture, zinc hydroxide forms. Zinc oxide and zinc hydroxide are commonly referred to as wet storage stain. Wet storage stain, depending on the severity, may require removal using a stiff-bristled brush and cleaning solution, such as those listed in the *Wet Storage Stain*⁹ guide published by the American Galvanizers Association. These similar contaminants compromise the bonding of the fireproofing system and must be removed.

Passivating treatments, also referred to as chromate conversion coatings, are applied by galvanizers onto newly galvanized steel to prevent the formation of wet storage stain. These dissimilar contaminants are detrimental to the bonding of the fireproofing system. Passivating treatments must be completely removed by weathering for prolonged periods of time, sanding, or abrasive blasting. Section 4.3.3 of the Surface Preparation Specification SSPC-SP 16 *Brush-Off Blast Cleaning of Coated and Uncoated Galvanized Steel, Stainless Steels, and Non-Ferrous Metals* describes a procedure for preparing a copper sulfate solution and carrying out passivation testing on galvanized steel surfaces¹⁰. If passivators are present, they must be removed. If fireproofing systems are applied over passivated galvanizing, detachment will typically occur during final curing of the epoxy system, after external stresses are applied, or after being exposed to subfreezing conditions. The amount of passivation present on the surface impacts how quickly detachment will occur. Therefore, it is imperative that testing for the presence of passivators be carried out just before the application of the fireproofing system.

Mill scale is a similar contaminate common to hot rolled steel. If not completely removed from the steel according to the fireproofing manufacturer's requirements, detachment of the fireproofing system will likely occur. The surface of molten steel reacts with oxygen to form mill scale with three general layers,