



Primers Beneath Fire-Resistant Coatings

by Douglas Jones, Southern Coatings, Inc.

Active rusting and damaged mill scale on structural steel immediately before fireproofing



Fig. 1

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About the Author: Douglas M. Jones is Research-Engineering Services Manager of the Corrosion Control Group of Southern Coatings, Incorporated.

With more than 10 years experience in the high performance protective coatings industry, Mr. Jones has been with Southern Coatings for three years where his responsibilities include conducting on-site inspections and specification writing.

Mr. Jones has a B.S. in Chemistry from the University of Louisville. He currently serves as Chairman of the Primers Beneath Fireproofing Committee of the Steel Structures Painting council.

FIREPROOFING IS APPLIED to steel in commercial and industrial structures to reduce the rate of temperature increase of the steel during a fire. The thermal mass of the fireproofing tends to prevent the concentration of heat applied to structural members and thereby gives firefighters time to battle the blaze before total destruction results or before the structure collapses, with the attendant results of injury and death.

This paper reviews the arguments for and against the use of primers beneath fireproofing, and takes the position that primers are required in circumstances where normal atmospheric corrosion is accelerated. Issues important to the argument are construction practices, adhesion of the fireproofing material to the primers, and in-service exposure environments.

Construction Practices for Commercial Buildings

For many fireproofing materials used in commercial buildings, such as some in the categories of dense and lightweight concrete and cementitious, surface preparation requirements are minimal. Typical requirements are removal of oil, grease, loose millscale, dirt, and other foreign substances. The Underwriters Laboratories' (UL) *Fire Resistance Directory* indicates that un-primed steel should be "clean and free of dirt, loose millscale, and oil" prior

to application of a fire-resistant coating.

While some manufacturers of fire-resistant material prefer a Near-White Blast Cleaning (SSPC-SP 10) or a Commercial Blast Cleaning (SSPC-SP 6) in the shop, they are satisfied if the steel is lightly rusted at the construction site, and consider the condition of light rusting to be ideal for application of fireproofing so that the appropriate adhesion will result.

It must be taken into account, however, what the conditions of transport and storage will be for the structural steel after it leaves the fabricator's shop and before it is erected and fireproofed. Any number of scenarios are possible, depending upon weather, time of year, the geography, but the following are certainly encountered on a regular basis.

- The fabricated steel, shipped in winter on roads covered with deicing salts, is splashed with roadway slush and contaminated with chlorides.

- The steel is delivered to and stored in a seacoast environment where chlorides again contaminate the surfaces.

- In a heavy industrial environment, such as near chemical or other process plants, chlorides and sulfates are deposited on stored steel.

- In areas of heavy acid rain deposition, the transported and stored steel is contaminated by chemicals.

- Steel is stored for extended durations in the fabricator's yard and/or at the construction site and suffers extensive rusting and damage to millscale.

- Steel is randomly stacked, stacked close to or on the ground, or stacked so that water ponding occurs, with the result that corrosion and pitting take place.

No matter what the conditions of storage, weather, contamination, or jobsite delay, they tend not to be predictable, and therefore planning on the basis of worst case scenarios is in order. Figure 1-3 show the results of some of these conditions.

Presuming the worst case in con-

struction practices as described above, erected structural steel before application of fireproofing is likely to be unevenly corroded and to have cracking, flaking, or totally destroyed millscale if it has not been blast-cleaned. In addition, salt and other chemical contaminants may be present.

In such cases, once the fireproofing is applied, even in the indoor environments of commercial buildings, corrosion is likely to continue, having already established a strong electrolytic process, and having the capability to draw moisture from the water-based fireproofing.

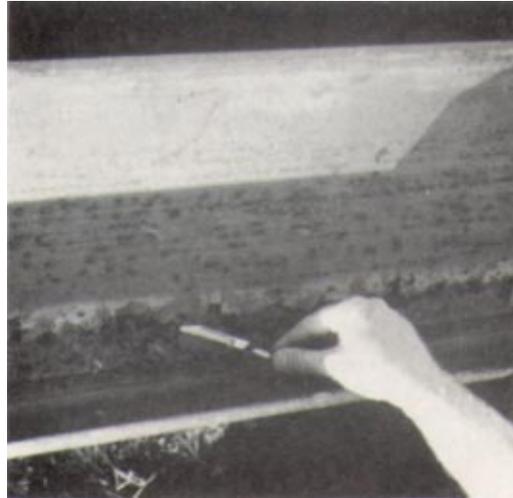
Only a very small amount of moisture is required for active corrosion around millscale and where some pitting has already been initiated. This moisture is entrapped and available from the water-soaked fireproofing when it is applied. Fireproofing before it is enclosed also soaks up moisture from the weather.

Even in an indoor environment, once a building has been enclosed, relative humidity in the range of 40 percent can make moisture available to steel through cracks in the fireproofing that develop from shrinkage, thermal fluctuation, or mechanical damage.

If the corrosion process continues, a buildup of corrosion products can delaminate the fireproofing material. There have been instances when fireproofing has delaminated from steel and thereby failed to protect a structure during a fire. One documented example is described in the New York Board of Fire Underwriters' report, "One New York Plaza Fire."²The fire occurred on August 5, 1970 in a 53-story building within a year of its erection.

Columns, girders, beams, and the underside of floors were protected by sprayed asbestos fiber fireproofing to provide a four-hour fire resistance for columns and a three-hour rating for filler beams and floors. The report advises, in part, as follows:

"Steel beams in the south center and



(top) Fabricated steel has slivers that, without blast cleaning, will become sites for rusting.

(bottom) Corrosion on a beam in a fabricator's storage yard prior to shipment to the job site.

Fig. 2



Fig. 3

west section of the 33rd floor were twisted or deflected several inches and the connecting bolts sheared off or failed, allowing beams in some sections to rest on the flange of the girder."

On the 34th floor of the building, "beams were severely deflected and distorted and the most severe structural damage occurred in the west section of this floor."

The report concludes that "the degree of damage to the steel frame is the result of several factors. It is reported that this steel came from England and became severely oxidized

in transit. As a result the sprayed asbestos fiber did not adhere well in many places and fell off along with the scale shortly after application.”

Further, the report states that “the protection of steel members in a really fire-resistant building must be accomplished by materials that cannot be readily removed or damaged. It is apparent . . . that proper adhesion to steel may not take place.”

The worst-case scenario, in which steel is contaminated and actively rusting when fireproofing is applied, is not always going to take place, particularly in extremely dry and otherwise benign environments such as those found in the Southwest. But where fireproofing is concerned, erring on the

side of caution is more to be recommended than taking unnecessary risks.

The corrective action required to assure that corrosion will not occur beneath fireproofing is application of a suitable primer in the fabricator’s shop under controlled conditions immediately after blast cleaning has taken place.

A rust-inhibitive primer can protect steel during shipping and storage, and it can be easily cleaned before application of fireproofing material.

Adhesion

One argument against the use of primers beneath fireproofing has been that the primed surface will not allow

fireproofing material to achieve a sufficient bond or adhesion to the surface. This position has been advanced by some manufacturers of fireproofing. But laboratory test results show that fireproofing can achieve an adequate bond to primers.

My firm has conducted adhesion tests using our in-house Testing Method #21, "Adhesion of Sprayed-On Fireproofing to Primers." (See boxed item.) This Testing Method was developed before the adoption of ASTM E 736, "Standard Test Method for Cohesion/Adhesion of Sprayed Fire-Resistant Materials Applied to Structural Members,"³ and is similar in its procedures.

Procedures

Five manufacturers of sprayed-on, waterbase fireproofing were listed in Sweet's Architectural File when our testing was begun. These firms were contacted for data on their recommended products, suggested application procedures, and information on proper testing. Four companies responded, and we secured samples of their material for testing.

Material was mixed and applied in accordance with the manufacturers' instructions to bare steel panels and to panels primed with a variety of rust inhibitive primers (allowed to dry 28 days prior to application of fireproofing). Approximately one inch of sprayed-on, waterbase fireproofing was applied and allowed to dry from two to four weeks, as recommended by the manufacturers, under laboratory conditions before evaluating for adhesion.

Observations

Results of the tests demonstrate that selected metal primers afford higher bonding strength than is obtained when the fireproofing is applied directly to unprimed steel. Figure 5 shows two samples of this test. The disc on the right, with the light surface, was applied to steel primed with a zinc chromate primer and produced a bonding strength of 302 lbs/sq. ft. The disc on the left, with the dark surface of heavy

Testing Method #21
September 21; 1984

Adhesion of Sprayed-On Fireproofing to Primers

1. Scope

This procedure sets forth a method for determining the amount of force necessary to remove fireproofing material from a surface.

2. Apparatus

2.1 Wal-Board Hopper Gun, foam insulation, 1 in. thick, metal caps 1¼ in. dia., metal cup hooks, scale calibrated in ¼ in. increments to 30 lbs. maximum and a timer.

2.2 12 in. x 12 in. 16 gauge hot rolled steel panels or as specified.

2.3 Sprayed-on fireproofing material

3. Procedure

3.1 Clean steel panels with xylene and clean rags. Let the solvent evaporate and spray apply the primer to achieve the recommended dry film thickness DFT (normally 2 mils). After the primer has cured seven (7) days minimum, a 1 in. thick frame of styrene foam cut to an outside dimension of 12 in. x 12 in. and inside dimension of 11 in. x 11 in. (for 12 in. x 12 in. hot rolled steel panels). This frame is glued to the primed panel with vinyl-acrylic emulsion (1535-AR). When completely set, the fireproofing material is sprayed-on with the panel inside the frame using a Wal-Board Hopper Gun—with sprayed-on fireproofing mixed according to manufacturers' instructions. The excess is screed off by a straight edge. The panel is then allowed to age 28 days at laboratory ambient temperature.

3.2 After 28 days, a 1¼ in. metal cap with cup hook (cap is made by inserting a threaded cup hook in the center of the cap from the outside and a small piece of wood is attached to the threaded end of the hook—so that the hook will not be pulled out). This assembly is glued near the center of the panel with epoxy glue made of 1501-AR Polyam, Hardener 37-615/1502-AR Epotuf 38-501 in a 35-65 non-volatile weight ratio. This is allowed to set up 48 hours minimum. A scale with ¼ in. increments to 30 lbs. maximum is pulled and held for one (1) minute unless failure occurs at lower weights.

3.3 Calculation: the pounds of force necessary for failure is divided by the area of the cap in sq. ft. Force required for failure is then reported in lbs/sq. ft.

4. References

4.1 ASTM E 736—Cohesion/Adhesion of Sprayed Fire-Resistive Materials Applied to Structural Members

4.2 ASTM E 605—Thickness and Density of Sprayed Fire-Resistive Materials Applied to Structural Members

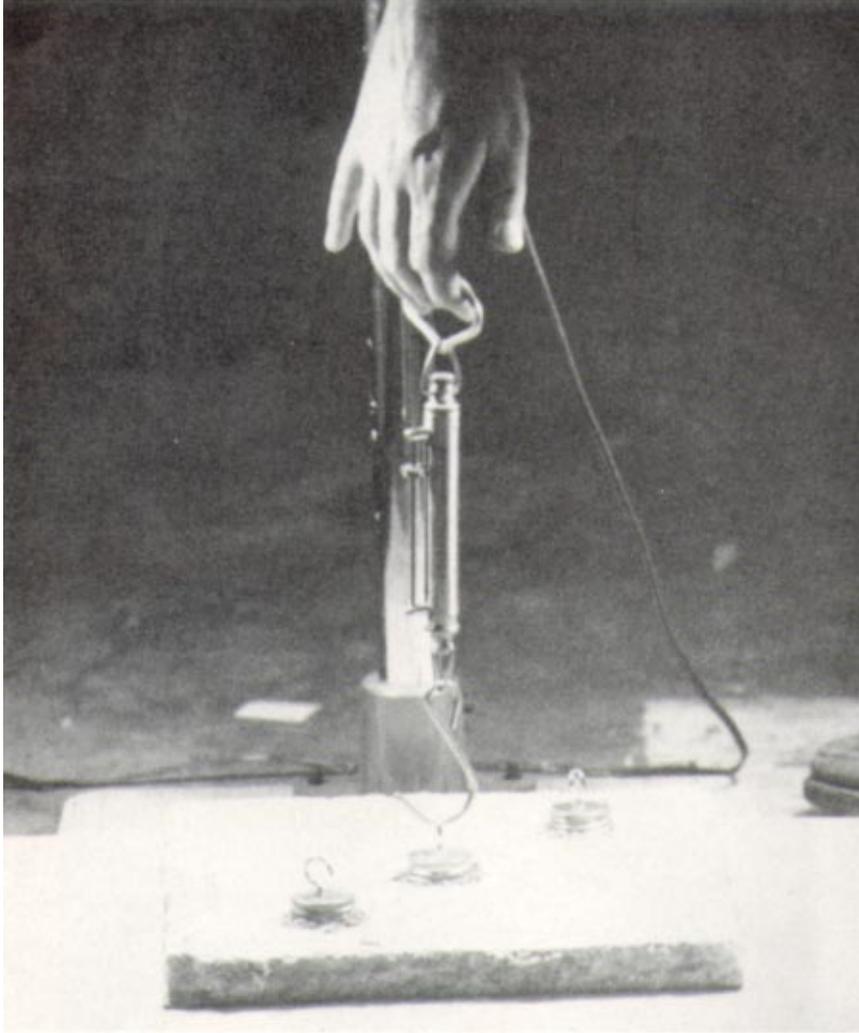
4.3 Instruction pamphlet on Wal-Board Hopper Gun GHG-30

rust stains, was applied to bare steel and produced a bonding strength of only 94 lbs/sq. ft.

An oil-alkyd primer, an alkyd-zinc chromate primer, and a red iron oxide-alkyd primer consistently yielded higher bond strength values than required by General Services Administration and Spray Mineral Fibers Manufacturers' standard. (General Services Administration requires 20 times the weight of the fireproofing for satisfactory bond strength. Spray Mineral Fibers

*Pull test measures
adhesion of
cementitious, spray-
applied fireproofing.*

Fig.4



Manufacturer's Association standard is 36 lbs/sq. ft.) Test results are shown below.

Primers	Adhesion Ratings (lbs/sq ft)*
Oil-Alkyd	128
Red Iron Oxide-Alkyd	105
Alkyd-Zinc Chromate	128

*(Average when testing with fireproofing materials listed in previous reports.)

UL Test

Underwriters Laboratories conducted a fire test in 1987 of the compatibility of primers beneath one manufacturer's cementitious, fiber-filled fireproofing

material. UL reported⁴ that, based on results of the test, "beam, joist, truss and column surfaces may be primed with a coating which complies with any of the following types:

1. Modified Soya Oil Alkyd Resin
2. Red Lead, Iron Oxide, Alkyd Resin-Linseed Oil
3. Alkyd Zinc Chromate
4. Red Iron Oxide-Alkyd Resin
5. Epoxy Polyamide."

In addition, UL's 1989 *Fire Resistance Directory* reflects results of its tests of primers beneath fireproofing.

In the revision, UL states that the following conditions be met before

fireproofing can be applied: (A) the beam flange width does not exceed 12 in., (B) the column flange width does not exceed 16 in., (C) the beam or column web depth does not exceed 16 in., and (D) bond tests conducted in accordance with ASTM E 736 shall indicate a minimum average bond strength of 80 percent and a minimum individual bond strength of 50 percent when compared to the bond strength of the fire resistive coating as applied to clean, uncoated 1/8-in. thick steel plate. The average and minimum bond strength values shall be determined based upon a minimum of five bond tests.

This revision deals specifically with cementitious and sprayed fiber products. Mastic fireproofing material is treated separately.⁵

Industrial service Conditions

The argument already advanced for applying a primer in the shop to steel that will be fireproofed in the field holds for industrial as well as for commercial structures. But with industrial structures, the argument must focus on the service environment of the fireproofed steel once it is applied, which is certain to be more severe than the service environments of commercial buildings.

Delahunt^{6,7} reports severe corrosion beneath fireproofing in refineries and chemical plants at marine and heavy industrial exposure sites. He explains that, although properly formulated concrete fireproofing can prevent corrosion through the passivating effect of (OH-) ions, this effect is negated by the contaminants SO₂, SO₃, and especially, chlorides. These water-borne contaminants can penetrate concrete if it has a high water to cement ratio, if the concrete develops cracks, or if there are exposed junctures with steel. The corrosion process thereby initiated is similar to the more familiar corrosion of reinforcing steel in concrete structures and leads to cracking and spall-

Fig. 5

ing of the concrete, which then intensifies the corrosion process.

Measures for corrosion protection of steel beneath fireproofing, according to Delahunt, include use of concrete with a water to cement ratio of 0.50 or less and application of a suitable primer to the steel. In some cases, he also suggests topcoating of the fireproofing to minimize water diffusion.

Conclusion

Arguments against the use of primers beneath fireproofing can be divided into two main positions: first, that primers are unnecessary since concrete, especially in indoor environments, protects steel from corrosion; and second, that primers diminish the adhesion of fireproofing to steel.

But it has been shown that, in many circumstances, concrete fails to protect steel from corrosion when corrosion has already begun during shipping, storage, and erection; that severe corrosion can occur beneath fireproofing in industrial settings; and that fireproofing can delaminate from commercial buildings where corrosion is occurring.

In addition, tests by my firm and by UL have shown that some primers do provide acceptable adhesion for fireproofing.

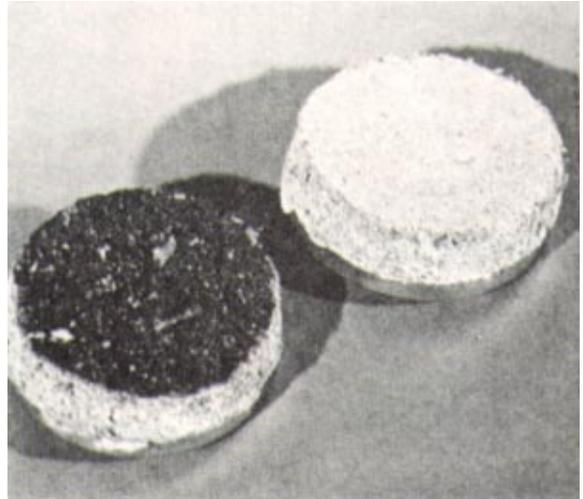
To assure the integrity and service life of fireproofing materials, therefore, and to protect the underlying steel substrate, it makes good sense to shop-prime steel before application of fireproofing in the field.



References

- ¹Underwriters Laboratories, *Fire Resistance Directory*, 1988 Edition. 333 Pfingston Road, Northbrook, IL 60062.
- ²"One New York Plaza Fire," The New York Board of Fire Underwriters, 1971.
- ³ASTM E736, "Standard Test Method for Cohesion/Adhesion of Sprayed Fire Resistant Materials Applied to Structural Member," ASTM,

Fireproofing material above has been pulled from the substrate for an adhesion test. Plug on the left, applied to bare steel, shows rust stain; adhesion measured 94 lbs/sq. ft. On the right, plug was removed from surface primed with zinc chromate adhesion measured 302 lbs/sq. ft.



Philadelphia, PA, 1982.

⁴Private Correspondence from UL to the fireproofing manufacturer, October 16, 1987.

⁵Report on June 22, 1988 Meeting of UL's Ad Hoc Committee for Fire Resistive Coatings, Subject 263, UL, Northbrook, IL.

⁶Delahunt, J.F., "Corrosion Control Under Thermal Insulation and Fireproofing," *Bulletin of The Institute of Corrosion Science and Technology*, United Kingdom, May 1982.

⁷Delahunt, J.F., Collins, P., and Maatsch, D., "Protective Coating System Design for Insulated or Fireproofed Structures," in ASTM STP 800, *Corrosion of Metals Under Thermal Insulation*: Philadelphia, PA, 1983.