NATIONAL BUREAU OF STANDARDS REPORT

7816

FIRE ENDURANCE OF STEEL
COATED WITH FIRE-RETARDANT PAINT

by

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and

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Report to
Office of the Chief of Engineers
Bureau of Yards and Docks
Headquarters, U. S. Air Force

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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ABSTRACT

Sheet steel specimens were coated with three commercial fire-retardant paints to determine to what extent such treatment would increase the fire endurance of the metal. Tests were made with specimens coated with zinc chromate primer, and one test with asphalt primer on the sheet. Two of the paints were incompatible with the asphaltic materials. The results of the tests indicated that, while there were some differences in the performance of the paints, no significant increase in fire resistivity would accrue from the use of any of them.

1. Introduction

A series of tests was performed to determine if the fire endurance capacity of otherwise unprotected structural steel building members or sheet steel surfaces in buildings could be increased to an acceptable level by the application of simple (nonreinforced) coatings of commercial fire-retardant paints. If such were possible, comparatively low cost fire protection could be provided for buildings constructed with open steel framing members. These are often used in warehouses, hangars, storage sheds and others, many of large size and involving a considerable investment in the building and its contents. The results also would be applicable to sheet metal structures and to metal cladding of wooden elements of a building.

As the cost of large-scale testing, such as of columns or floors, was considered excessive in the preliminary stage of the investigation, the tests were confined to an examination of the results obtainable with the paints applied to moderate-size sheets of metal. The original program outlined for the work comprised several recommendations not subsequently performed. It was apparent as the work progressed that these parts of the program would add little or nothing to the data forming the basis of the conclusions. Such time as had been allotted for the omitted tests was expended in efforts to overcome difficulties arising in the preparations for and conduct of the tests completed.

2. Description of Materials and Specimens

The test specimens consisted of 24-in. square steel panels cut from hot-rolled sheet of 0.075 to 0.078 thickness (14 ga). Combinations of metal primers and fire-retardant paints were applied to one side of the panels. Before application of the paint, thermocouple wires (No. 24 ga chromel-alumel) were attached at the center of each panel by swaging around the wires inserted in holes about 1 in. apart in the metal. The junctions formed on the face of the plate were filed flush with the surface. The thermocouple leads were placed on the back or unpainted face.

To simulate actual conditions in construction, where steel columns and beams may have zinc chromate or other metallic primer, and steel joists a bitumen coating, 12 test panels were given a single spray coat of commercial zinc chromate yellow primer and another 12 panels were similarly treated with an asphalt-base material.

Fire-retardant paints were chosen with the criteria that they should have achieved an Underwriters'Laboratories, Inc. flame-spread rating of not more than 25, and smoke developed not to exceed 50 (with the paints applied to Douglas fir compared to uncoated red oak rated 100). For practical purposes, a requirement that the paints be listed as scrubbable was also established. Three paints, designated A, B, or C in this report, were found to meet the requirements. All three could be applied by brush in a single coat at a rate of 150 to 175 ft^2/gal, the coverage recommended by the manufacturers, while the specimen was horizontal. Two of the paints were reported as scrubbable as applied in a single coat; one was reported as requiring the use of a thin overcoating to achieve some degree of resistance to wet abrasion.

In preparing the test specimens, an initial drying time of 48 hrs was allotted to the prime coats. This was usually adequate for the zinc chromate although in some cases puckering and blistering occurred when the fire-retardant coating was applied. It was possible, however, to prepare satisfactory samples with each of the three paints. Care was taken to apply the paint evenly at the specified rate. The sheets so treated were dried under ordinary interior ambient conditions for a minimum of 30 days before testing.

Considerable difficulty was encountered with the bitumen primer. While paint C could be applied with reasonably good coverage over the asphalt-base undercoat, the solvents present in the other two paints proved to be entirely incompatible with the use of the primer. The volatiles in the fire-retardant materials very quickly acted on the asphaltic paint to form a soft and sometimes running conglomeration of the coatings. Longer curing of the primer, up to 1 week, was tried in an effort to secure a stable base for the fire-retardant paints. The effect, however, was the same, and the effort was abandoned as the use of further drying time was considered both impractical and not likely to lead to a different result. Two samples of the effect of applying fire-retardant paints over bitumen are shown in Fig. 1.

In the absence of specific instructions on the manufacturer's label, the samples requiring a finish coat to impart the desired washable quality were allowed to dry 2 days before being so treated. Additional specimens were prepared by application of the materials not compatible with asphalt primers, paint A and B, over bare metal sheets at the recommended rates of coverage. For purposes of comparison, some of the sheets were also prepared for test with coverings of zinc-chromate or asphaltic primers only. With no rate specified in the instructions, these were applied to give complete coverage as evenly as possible over one side of the specimens.

3. Test Method and Equipment

The tests were conducted in a small furnace having a top opening 23-3/8 in. square. This opening is closed by the test specimen, which is thus exposed, on its underside to the heat supplied by six gas burners in the furnace. Temperatures in the furnace are determined from four thermocouples distributed within the chamber. The average temperature is automatically controlled to conform as closely as possible to the ASTM Standard Time-Temperature Curve for Fire Tests of Building Construction and Materials (ASTM E119-61).

The steel specimens were placed horizontally over the furnace opening with the paint-protected side forming the fire-exposed surface. The unexposed surface was heavily insulated in an effort to simulate the most severe condition of possible exposure, which would approach the state of bar joists or columns in a surrounding fire. This was accomplished by placing a frame of 4-in. steel channel stock, 26 in. square on the inside, over each specimen under test, and filling the square with 3-in. of perlite. As a check on the insulating effect, five thermocouples were placed in the perlite at different distances above the thermocouple at the center of the test specimen.

The response of the thermocouples, those in the furnace as well as the one in the specimen and those in the insulating layer, was recorded at 1-min intervals with automatic equipment. The test exposures were continued somewhat beyond the time required to attain a temperature of 538°C (1000°F) on the steel, which was taken as the criterion of failure in these tests.

4. Results of Tests

The several combinations of paints used are shown in Table 1 together with the results of the tests. There appear to be some small differences in the effectiveness of the three fire-retardant paints. In addition to showing the times at which failure occurred (col. II), an attempt is made in the table to demonstrate differences existing in the paints by indicating the average of the furnace temperatures at the time of failure (col. III). It should be noted that where the protection afforded the steel sheet is small or nonexistent, it is quite possible that the lag in the furnace thermocouples, which are encased in iron pipe, will be greater than that of the thermocouple attached to the specimen.

Columns IV and V of the table show the average furnace temperatures at 5 min (nominally 538°C or 1000°F) and the temperatures in the steel at the same time. To indicate the degree of exposure and compensate for any departures from normal in the temperatures in the furnace, the sum of steel temperatures in each test, taken each minute and including the whole minute immediately following failure are related to the similarly observed average furnace temperatures for the same time interval (col, VI-VIII).

It can be seen from the table that paint B applied to bare metal had the longest endurance (Test 1) followed by paint C over zinc chromate (Test 3) and paint B over zinc chromate (Test 4). A very rapid rise in temperature occurred in the sheet treated with asphalt primer only (Test 6), and this was but little improved by additional coating with paint C (Test 7). Specimens coated with paint A had the same endurance whether prime coated with zinc chromate or not (Tests 8 and 2); however, the exposure was somewhat greater in the test without the primer, as can be seen in the steel-to-furnace temperature ratios. It would appear that the use of a primer tends to reduce the fire endurance imparted by the paint, possibly because the primer itself contributes heat to the exposure. A point to remember in comparing the ratios of col. VIII is that the lag in the response of the pipe-encased furnace thermocouples may contribute greatly to the differences in temperature which determine the ratios.

Although the fire tests were made under conditions approaching those of greatest severity, as indicated by a high temperature gradient through the perlite insulating layer (Table 2), the increments of fire resistivity resulting from the use of the paints were so small as to be of practically no significance. The test specimens were prepared with care, and only those appearing to have the best coverage were used. The results of the tests, falling far below any acceptable standard of protection, serve as an indication of the ineffectiveness of applying simple fire-retardant coatings to metallic building elements or structures. The test program, it should be noted, was for the purpose of determining what insulating effect, if any, the paints may have, and was not an examination of their flame-spread properties, nor was any correlation observed between the results of these tests and the UL flame-spread ratings.

5. Summary and Conclusion

Three commercially available fire-retardant paints were applied to sheet steel specimens to determine if by such means the fire endurance of steel could be materially increased. The paints were applied over zinc chromate primer, and one was used with an asphalt-base undercoat. Two of the paints were found to be incompatible with the asphaltic material, and tests were made with these paints applied over bare metal.

The tests were conducted in a small furnace regulated to follow approximately the standard ASTM time-temperature curve for tests of building materials and constructions. To secure as severe conditions as posssible, the unexposed side of the specimens was heavily insulated to prevent heat loss.

Although the paints were carefully applied, following the manufacturers' instructions, the gain in heat resistivity of the steel sheets was at best insignificant, and far below that required for a meaningful fire endurance rating. There appeared to be some small differences in the effectiveness of the several paints. Application over primers tended to give lower increases in endurance than when used on bare metal, with the asphalt primer having a greater deleterious effect than the zinc chromate. The tests were not an investigation of the flame-spread properties of the material, and no correlation was noted between the results and the flame-spread classifications listed by the Underwriters' Laboratories, Inc.

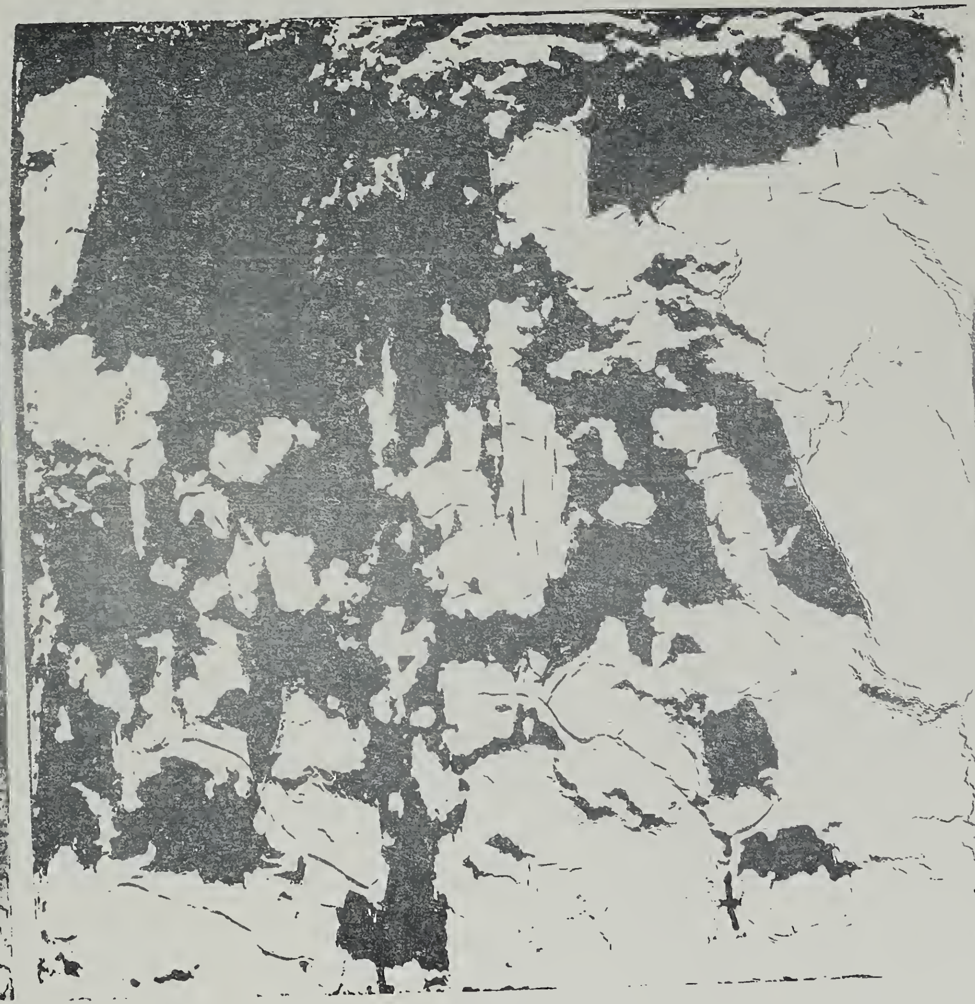
Table 1. Results of Tests

Column	I	II	III	IV	V	VI	VII	VIII
Test No.	Material	Time to Failure (538°C) min:sec	Avg. Furn. Temp. at Failure °C	Avg. Furn. Temp. at 5 min. °C	Steel Temp. at 5 min. °C	Deg.-min. Furnace	Deg.-min. Steel	Ratio VII:VI
1	Paint B no primer	8:50	670	491	360	3962	3263	0.82
2	Paint A no primer	4:30	544	583	577	2216	2324	1.05
3	Paint C and Zn Chromate	7:30	591	532	497	3440	3486	1.01
4	Paint B and Zn Chromate	6:30	600	517	468	2714	2762	1.02
5	Zn Chromate (primer only)	3.45	428	540	618	1192	1799	1.51
6	Asphalt (primer only)	2:50	362	539	655	688	1298	1.87
7	Paint C and asphalt primer	3:30	406	538	661	1238	1833	1.48
8	Paint A and Zn Chromate	4:30	468	515	583	1612	2072	1.29

Table 2. Temperatures in Perlite Insulating Layer

Test No.	Time of Observation	Temp. of Steel	Temperatures in Perlite Distances above Steel Specimens				
			3/8 in.	3/4 in.	1-1/2 in.	2-1/4 in.	2-5/8 in.
	min.	°C	°C	°C	°C	°C	°C
1	9	547	266	162	62	37	32
2	5	577	238	81	49	32	30
3	8	587	330	193	63	45	38
4	7	569	309	173	71	42	37
5	4	549	212	105	-	33	36
6	3	548	209	75	41	35	32
7	4	566	209	96	46	35	33
8	5	583	295	156	30	26	32

PAINT A



PAINT B

Fig. 1. Fire retardant paint applied over bitumen primer.

The following paints were used in the tests described in National Bureau of Standards' Report 7816:

Zinc chromate yellow primer and asphalt base primer, both "Paint Pot Products" manufactured by Jerry Bachman, Inc., Washington, D. C.

Paint A, Albi-107A, Albi Manufacturing Co., Rockville, Connecticut; one coat, no primer or overcoat; density 10.79 lb/gal; UL ratings on Douglas fir (basis, uncoated red oak 100), flame spread 20, fuel contributed 20-25, smoke developed 0-5.

Paint B, Ocean No. 900, Ocean Chemicals, Inc., Niagara Falls, N. Y.; one coat, no primer or overcoat; density 10.71 lb/gal; UL ratings, flame spread 25, fuel contributed 25, smoke developed 45.

Paint C, Sāf 303, Alim Corporation, New York; resin base two component paint; one coat, no primer or overcoat (following overcoat required for washable finish); density 11.76 lb/gal; nonflammable solvent; UL ratings, flame spread 15, fuel contributed 15, smoke developed 5.

Sāf 202, Alim Corporation; overcoat for Sāf 303; coverage 500 ft^2/gal; density 11.90 lb/gal; UL ratings (over Sāf 303), flame spread 10, fuel contributed 15, smoke developed 0.

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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WASHINGTON, D. C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research. Crystal Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Microscopy and Diffraction. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Far Ultraviolet Physics. Solid State Physics. Electron Physics. Atomic Physics. Plasma Spectroscopy.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering Laboratory. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

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