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FIRE-RETARDANT COATINGS

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FIRE-RETARDANT COATINGS

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Fire-Retardant Coatings*

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Livermore, California

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Introduction

During a Laboratory fire in the Fall of 1960, it was observed that a strippable wall coating became involved. The material apparently flashed, burned, and gave off copious quantities of an acid-smoke. As a part of the subsequent investigation, samples of the strippable material, enamel systems, and enamel over a fire-retardant intumescent paint were evaluated for fire retardance.

Examination by ASTM E-162 (The Radiant Panel Test, developed by the Bureau of Standards) showed that the strippable material, particularly when applied in thick layers, increased the flame spread index of the base material. Enamel over an intumescent base paint reduced the flammability. However, this latter system was not easily strippable.

Since mechanically strippable coatings are desirable to provide easy decontamination of a surface, the Research and Development Section of the Hazards Control Department was asked to try to find paint systems which were both fire retardant and easily removable.

Investigation

Twenty-three coating systems were examined. Of these, five were mechanically strippable, nine were enamel and intumescent systems, seven were chemically strippable or specialized cleanable coatings, and two were aluminum-silicone formulations.

All materials were tested for fire retardancy by the method noted above, and were also subjected to service tests: scrubbability, flexibility, chemical resistance, and strippability (these tests are detailed in Appendix I). In addition the materials were evaluated for toxicity both in regard to usage and to that of potential combustion products.

Results

Of the five mechanically strippable systems tested, only two were satisfactorily fire retardant. One of these, "AK,"[†] is a vinyl spray-coat system; the other is an enameled wall-cloth. The "AK" material passed the service tests satisfactorily, and is therefore recommended for use in high-hazard areas. The wall-cloth is not resistant to chemicals, and hence should not be used in areas where chemical attack is a problem.

All of the enamel-intumescent and other fire-retardant coating systems showed good to very good fire retardance when applied to flammable substrates. These systems were chemically removable; none was mechanically strippable. Other service characteristics varied from very good to poor.

The chemical strip and specialized coating group showed fair to good fire retardance. All were chemically removable. Manufacturers' claims that two of these were mechanically strippable were not substantiated, probably because the top coats were too thin. Mechanical and chemical properties of coatings in this group were good or better.

Both of the silicone enamel systems were very good fire retardants; one was unusually resistant to the spread of flame. They were both chemically removable, and showed good mechanical and chemical properties.

All coating systems except three were rated Satisfactory in regard to toxicology; that is, they could be used if reasonable precautions — adequate ventilation and protective equipment, customarily employed in handling paints and lacquers — are observed. This rating also implies that the products of combustion are estimated to be at worst only slightly more harmful than those of ordinary paints.

Two of the three exceptions noted were rated as questionable, because in the Radiant Panel Test they evolved moderately heavy amounts of smoke. Examination of the paint formulation indicated that the smoke would be acid-like in character.

The other exception, rated Fair toxicologically, evolved a noticeable amount of smoke in the flame spread test; this smoke is also likely to be acid.

The evaluations of the coating systems are summarized in Table 1 (see also Figs. 1 and 2). Four typical data sheets are shown in Appendix II. It should be noted that the fire retardance of a coating system depends upon the film thickness.^{1, 2} Care should therefore be used to apply coating thicknesses indicated in the data sheet, to obtain the fire retardance related thereto.

The assistance of the Industrial Hygiene Section in evaluating the toxicology of the coatings investigated is gratefully acknowledged.

References

*Work performed under the auspices of the U. S. Atomic Energy Commission.

[†]All systems tested were assigned a code designation; see Table 1.

¹Flame Spread Properties of Building Finish Materials - D. Gross and J. J. Loftus, ASTM Bulletin No. 230, May 1958, pp. 56-60.

²Data Sheet No. D-1 (this report).

Table 1. SUMMARY — DATA ON FIRE-RETARDATION COATINGS — EVALUATION

Coating sys- tem code	Fire retardance	Chemical resistance	Mechanical properties	Strippable Mech. Chem.		Toxicology	Recommendations
A — MECHANICAL STRIP COATS							
AK	Very good throughout	Very good	Very good	Yes	Yes	Satisfactory	OK for high hazard areas
WT	Very good throughout	Poor	Good	Yes	--	Satisfactory	OK except for chemical resistance
PF	Poor	Good	Fair	Yes	--		Do not use in fire hazard areas
SL	Very poor	Very good	Very good	Yes	--		Do not use in fire hazard areas
PA	Very poor	Good	Very good	Yes	--	Satisfactory	Do not use in fire hazard areas
B — ENAMELS AND INTUMESCENT SYSTEMS							
MNO	Good	Very good	Very good	No	Yes	Unsatisfactory	Do not use in fire hazard areas ^a
21	Very good throughout	Poor	Poor	No	Yes	Satisfactory	Corridors, halls, offices
E	Good	Poor	Poor	No	Yes	Satisfactory	Corridors, halls, offices
A	Very good	Poor	Poor	No	Yes	Satisfactory	Interiors, attics, warehouses
EA	Very good	Fair-good	Poor	No	Yes	Satisfactory	Interiors — moderate chem. resist.
DX	Very good	Fair	Poor	No	Yes	Satisfactory	Interiors — attics, warehouses
DX13	Very good throughout	Poor	Poor	No	Yes	Satisfactory	Corridors, halls, offices
PFE	Very good	--	--	No	Yes		Interiors
DT	Good	Fair	Fair	No	Yes		Moderate hazard labs.
S	Very good throughout	Very good	Poor	No	Yes	Satisfactory	Mod.-high hazard labs.
ABC	Good	Very good	Satisfactory	No	Yes	Unsatisfactory	Do not use in fire hazard areas ^a
C — CHEMICAL STRIP COATS AND SPECIALIZED SYSTEMS							
GMB	Fair	Very good	Very good	No	Yes	Satisfactory	Equipment in low-mod. haz. areas
GO	Fair	Very good	Very good	No	Yes	Fair	Equipment in low-mod. haz. areas
2	Fair	Very good	Very good	No	Yes	Questionable	Walls low haz. areas
3	Fair	Very good	Very good	No	Yes	Questionable	Walls low haz. areas
P53	Good	Good	Good	No	No	Satisfactory	Base sealer-remote cells
P23	Good	Very good	Very good	No	Yes	Satisfactory	Remote cells mod-high haz.
PSC	Good	Very good	Very good	No	Yes	Satisfactory	Remote cells mod-high haz.
D — ALUMINUMIZED-SILICONE SYSTEMS							
G53	Excellent	Good	Very good	No	Yes	Good	Hot equipment — furnaces, stacks
5	Very good	Good	Very good	No	Yes	Satisfactory	Warm equipment — ovens, stacks

^aSmokes excessively on burning.

H-SL

H-PA

H-PF

H-P53

H-PSC

H-GMB

H-P23

H=HARDBOARD
G=GYPSUM } SUBSTRATE

H-GO

H-3

H-ABC

H-DT

H-2AK

G-PF

H-5

GLB-621-27929A

4.5 MILS

Fig. 1. Photographs of coating specimens after fire-retardance test.

H-PFE

H-DX13

G-1

G-2

H-I-AK
8.5MILS

H-G6-53

G-P23

UNCOATED GYPSUM BOARD

G-AK
3 MILS

G-PSC

G-P53

G-ABC

G-MNO

G-DT

H=HARDBOARD
SUBSTRATE

G= GYPSUM
BOARD

GLB-621-27930A

Fig. 2. Photographs of coating specimens after fire-retardance test.

APPENDIX I

Evaluation Tests

Fire Retardance — Fed. Interim Std. 00136 (Com-NBS); ASTM E-162 (60T)

A 6 × 18-in. coated hardboard or gypsum board panel, inclined about 30° from vertical is exposed to the heat of a gas-fired radiant panel maintained at a blackbody temperature of 670°C (1238°F). The top face of the test piece is ignited with a pilot light and the spread of flame across the surface is timed and measured. Additional heat generated by the burning of the test piece is measured. Smoke evolved by the burning test piece is collected by a flue sampler. The smoke sample is weighed and also tested for light transmission.

The flame spread rating is calculated in such a way as to refer the flammability to a value of 100 for uncoated red oak, and zero for asbestos cement board.

A set of standards from the same shipment as the test piece — tempered hardboard, gypsum board, plywood, etc. — is usually run in conjunction with the tests so that fire retardance of the coatings can be compared with the uncoated substrate.

The following ratings — modified by excessive smoke generation, flashing, running, dripping — are applied to the coatings:

<u>Classification</u>	<u>Range of flame spread indices</u>	<u>Description</u>
I	0 - 15	No flame spread to limited.
II	16 - 30	Limited to slow flame spread
III	31 - 75	Slow to moderate flame spread

<u>Classification</u>	<u>Range of flame spread indices</u>	<u>Description</u>
IV	76 - 200	Moderate to rapid flame spread
V	Over 200	Rapid and greater flame spread

The flame spread index I_s is calculated as follows:

$$I = F_s Q,$$

where $F_s = 1 + 1/t_3 + 1/(t_6 - t_3) + 1/(t_9 - t_6) + 1/(t_{12} - t_9) + 1/(t_{15} - t_{12})$

and $Q = 0.1\Delta\theta/\beta$.

In the above equations,

F_s = flame spread factor,

Q = heat evolution factor,

t_3, t_6 , etc. are elapsed time (minutes) from specimen exposure to arrival of flame front at 3-in., 6-in., etc. gage marks,

$\Delta\theta$ = rise in stack temperature over that with asbestos board specimen in place,

β = maximum stack temperature rise for unit heat input to calibration burner in °F/min/Btu.

At least four samples are tested and the average of the results is reported. Results in this report are given as a series of ratios plus an overall judgment of the fire retardance of the coating system. For example,

<u>Coating</u>	<u>Rating</u>	<u>Coating thickness (in.)</u>	<u>Base material</u>	<u>Flame spread index</u>	<u>Flame travel (inches)</u>	<u>Smoke (mg)</u>
ABC	Very good	0.008	Hardboard	120/20	18/9	2.6/2.8

The first number in the ratios is the value obtained for bare substrate; the second number is that obtained with the substrate coated with 0.008 inch of ABC coating. Thus the index was reduced from 120 to 20, the total flame travel from 18 in. (the entire sample) to 9 in., and the smoke increased from 2.6 to 2.8 mg.

In the example given, the flame spread index was reduced by a factor of 6, and the total flame spread by a factor of 2, all with a negligible increase in smoke. The rating is, therefore, very good.

If the flame spread index and total flame travel should be reduced significantly, but smoke evolution were increased appreciably, then the overall rating would not be so good. In this case the estimated quality of the smoke would be brought into question. Smoldering fires producing a large amount of acrid smoke present hazards to the fire fighters; such fires can also damage equipment in the area because of the acid content.

Scrub Test - Federal Specification TT-P-26a, Par. 4.3.5

In this test a 3-mil coating, applied to a frosted glass plate with a draw-knife, is scrubbed for 1000 strokes with a standard brush impregnated with Bon Ami. The scrubbing is done using a mechanical device (Gardner Washability Machine); the machine is stopped every 250 strokes to re-impregnate the brush with abrasive.

After testing, the coating is examined by reflected and transmitted light for marring, streaking, break-throughs or failure.

The test is a measure of the coating's resistance to mild scrub cleaning.

Bending Flexibility - ASTM D-522

This test measures the stretchability of a coating; it is also indicative of its adhesion to a steel substrate. A sheet steel test panel coated on one

side is bent over a cone whose diameter varies from 1/8 in. to 1-1/2 inches. A knife scratch is then made on the coating along the bending axis, and the coating is inspected for flaking, peeling, or cracking. The results are given the following, rather than the standard ASTM rating:

<u>Rating</u>	<u>Numerical value</u>	<u>Observed result</u>
Excellent	10	Coating sound over 1/8-in. bend
Good	7-9	Coating sound in bending range of 1/8 to 1/2-in. radii
Fair	3-7	Coating sound in bending range of 1/2 to 1-1/8-in. radii
Poor	1-3	Coating sound in bending range of 1-1/8 to 1-1/2-in. radii
Inflexible	0	Coating fails on 1-1/2-in.-radius bend, without scratch

Impact Flexibility

This test measures the brittleness of coatings which fail in impact by shattering, or the flexibility failure where the substrate stretches beyond the yield point of the coating.

The coating applied to 28-gage steel is backed up with 5/8-in. gypsum board and tested using a Gardner G. E. Variable Impact Tester: a 5/8-in. round-nose impactor is driven into the surface by dropping a known weight from a measured height. The coating is then examined under a lens or pocket microscope for incipient failure. The results are expressed in inch-pounds at which such failure occurs.

<u>Rating</u>	<u>Impact — for no failure (in.-lb)</u>
Excellent	+100
Good	80
Fair	60
Poor	50 or less

Vapor Corrosion Test

This test measures the resistance of a coating to exposure to acid or solvent vapors.

A coated round-nose steel rod (1/2 in. diam × 4- 1/2 in. long) is suspended in a beaker over the test reagent at room temperature and examined once a day for several days or until failure.

<u>Test reagent</u>	<u>Composition</u>
Acid	37% hydrochloric acid
Mixed solvent	Equal parts by volume of toluene butyl alcohol methyl ethyl ketone butyl acetate Stoddard solvent

<u>Test rating</u>	<u>Days exposure without failure</u>
Poor	Less than 1
Satisfactory	1 - 2
Fair	2 - 3
Good	3 - 6
Very good	6 - 10

Mechanical Strippability — Modification of ASTM D-903

In this test a piece 1 in. wide is cut from a sample of 16-gage sand-blasted steel coated with the material to be tested. A small portion of the coating is peeled by hand and inserted in one of the grips of a vertical tensile-testing machine. The stripped end of the steel sample is placed in the opposite grip. After suitable adjustment the machine is turned on at a standard rate of pull, and the maximum peeling tension observed and recorded. In the tests of the coatings under investigation, a Scott L-6 machine was used with a head travel rate of 2 inches/minute. The results are given in pounds pull per inch of coating width.

<u>Rating</u>	<u>Value obtained (lb/in. of width)</u>	<u>Remarks</u>
Very easy	0 - 1	Too easy — not enough adhesion
Easy (excellent)	1 - 2	
Good	2 - 4	
Satisfactory	< 5	
Poor	> 5	

Chemical Strippability

In this test a proprietary paint stripper or selected solvent (ketones, chlorinated hydrocarbons, esters, or alcohols) are applied to the coating under test and allowed to react for periods up to one-half hour. At frequent intervals, the surface is rubbed with a cellulose tissue to determine the removability of the coating. Alternately, the surface is scraped with a putty knife. Ratings are as follows:

- Easily removable: Coating comes off within five minutes of application of stripping agent.
- Removable: Coating comes off within 30 minutes of application of stripping agent.
- Not Removable: Coating does not come off, or is removed with difficulty after one-half hour of soaking.

Application and Use Hazards

Hazards related to the storage, use, and possible combustion products of dried films of coatings investigated in this report were estimated from manufacturers' data.

Each coating supplier was sent a form letter and asked to fill out a data sheet. From the information obtained, an evaluation was made relating to the handling precautions and the labeling required according to the California Division of Industrial Safety, Article 85, Par. 4201-4206.

In addition, an estimate was made of the possible products of combustion or pyrolytic degradation over and above those found in commercial paints not containing lead.

It should be noted that combustion products will vary in kind and concentration depending upon reaction temperature, available oxygen, and degree of ventilation. It would be advisable to check coatings of particular interest by burning them under some standard conditions and analyzing the combustion gases.

APPENDIX II

Data Sheets

Notes on Use of Data Sheets

Because of space limitations only the most significant information is shown on the data sheets. Information given on the summary sheet is even more generalized. Furthermore, the usual precautions regarding precision of measurements should be observed. For example, flame spread data are the average of four tests. Data obtained with hardboard and gypsum board substrates show an average coefficient of variation of ~30 %. Toxicological information has been compressed into three statements:

1. A caution as to use handling;
2. The signal word(s) to be used in the label;
3. A comment as to possible decomposition hazards.

The precautionary label should conform to the safety orders of the California Division of Industrial Safety, Article 85, paragraphs 4201 - 4206.

Thus it should contain:

The product name;

A signal word — danger, warning, caution, etc.;

A statement of the hazard — causes burns, vapor harmful; and

Precautionary measures — keep away from heat, avoid breathing
vapor, etc.

Other test data are rated as follows:

<u>Test</u>	<u>Excellent</u>	<u>Good</u>	<u>Satisfactory</u>	<u>Fair</u>	<u>Poor</u>
Scrub test	Little or no marring		Slight mar- ring	Few streaks	Notice- able breaks
Impact flex- ibility (in.-lb)	100	80	--	60	< 50
Bending flex- ibility	10	7-9	--	3-7	1-3
Chemical vapor resistance (days)	6-10	3-6	1-2	~1	< 1
Mechanical strip- pability (lb)	1-2	2-4	<5	--	>5
Chemical strip- pability	Easily re- movable		Removable		Not re- movable

DATA SHEET - WALL, CEILING, AND EQUIPMENT COATINGS

MATERIAL:

Code: G-53 Name(s) _____

General Description: Silicone enamel with aluminum pigment and ceramic frits

Supplier(s): _____

Application Methods: Spray or brush - methyl ethyl ketone solvent - followed by low temperature bake between coats. Final cure at 350°F.

PROPERTIES:

Fire Retardance
(ASTM E-162)

Fl. Spr. Index 120/10 =
120 for bare substrate;
10 for coated sample.
Red oak = 100;
Asbestos millboard = 0

Scrubbability
(TTP-26a)

Impact Flexibility

(GE Var. Impact Test)

Bending Flexibility
(ASTM D-522)

Chemical Vapor Resist.

Mixed Solvent

Hydrochloric Acid

Strippability

Mechanical

Chemical

RATING	TEST DATA				
	Coating thickness	Base material	Fl. spr. index	Flame travel	Smoke (mg)
Excellent	0.0052 in.	Hardboard	120/9	18/5	2.6/1.8
Fair	Noticeable marring				
Excellent	>100 in.-lb				
Excellent	Score of: 10 on scale of 0 - 10 maximum				
Good	Resisted exposure 3+ days				
Fair	Resisted exposure 1-2 days				
Poor	Not strippable				
Good	Removable with proprietary supplier.				

APPLICATION & USE HAZARDS: Use same precautions as for paints and enamels.

Label: WARNING: FLAMMABLE - VAPOR HARMFUL. No unusual decomposition products to be expected.

RECOMMENDED FOR: Hot equipment: furnaces, mufflers, exhaust pipes, stacks and fire doors.

REMARKS: Remarkable fire retardance, good mechanical and fair chemical properties.

DATA SHEET - WALL, CEILING, AND EQUIPMENT COATINGS

MATERIAL:

Code: PSC Name(s)

General Description: Fire-retardant vinyl strip coat over modified phenolic

Supplier(s):

Application Methods: Spray preferable; brush or roller may be used.

PROPERTIES:

Fire Retardance
(ASTM E-162)

Fl. Spr. Index 120/10 =
120 for bare substrate;
10 for coated sample.
Red oak = 100;
Asbestos millboard = 0

Scrubbability
(TTP-26a)

Impact Flexibility
(GE Var. Impact Test)

Bending Flexibility
(ASTM D-522)

Chemical Vapor Resist.

Mixed Solvent

Hydrochloric Acid

Strippability

Mechanical

Chemical

RATING	TEST DATA				
	Coating thickness	Base material	Fl. spr. index	Flame travel	Smoke (mg)
Good -	0.0069 in.	Hardboard	146/87	18/14	5.5/6.6
Good	0.0068 in.	Gypsum bd.	14/4	15/5	0.6/0.6
Satisf.					
Good	~80 in.-lb				
Excellent	Score of: 10 on scale of 0 - 10 maximum				
Very good	Resisted exposure for 10 days				
Very good	Resisted exposure for 10 days				
Poor	Claim of mechanical strippability not substantiated.			not sub-	
Good	Top coat removable with ketones				

APPLICATION & USE HAZARDS: Regarding top coat use same precautions as for lacquer. May cause dermatitis. Label: WARNING: FLAMMABLE - VAPOR HARMFUL. Decomposition products may contain Cl, HCl, phosphorus oxides.

RECOMMENDED FOR: Coating hot cells - where fire hazard is moderate.

REMARKS: Good cleanability, chemical and mechanical resistance.

DATA SHEET - WALL, CEILING, AND EQUIPMENT COATINGS

MATERIAL:

Code: AK Name(s) _____

General Description: Vinyl copolymer system with intumescent fillers

Supplier(s): _____

Application Methods: Brush or spray. Thin with methyl ethyl ketone, toluene, or 2-nitropropane

PROPERTIES:

Fire Retardance
(ASTM E-162)

Fl. Spr. Index 120/10 =
120 for bare substrate;
10 for coated sample.
Red oak = 100;
Asbestos millboard = 0

Scrubbability
(TTP-26a)

Impact Flexibility
(GE Var. Impact Test)

Bending Flexibility
(ASTM D-522)

Chemical Vapor Resist.

Mixed Solvent

Hydrochloric Acid

Strippability

Mechanical

Chemical

RATING	TEST DATA				
	Coating thickness	Base material	Fl. spr. index	Flame travel	Smoke (mg)
Very good	0.0085 in.	Hardboard	120/ 14	18/ 6	2.6/ 2.8
Good	0.0045 in.	"	120/ 36	18/ 13	2.6/ 3.0
Very good	0.003 in.	Gypsum bd.	17/4	14/ 5	0.0/ 0.7
Satisfactory					
Excellent	100 in. -1b				
Excellent	Score of:	10 on scale of 0 - 10 maximum			
Very good	Resists exposure for 10 days				
Very good	Resists exposure for 10 days				
Easy	1.0 - 1.3 lb/ in. of width				
--	--				

APPLICATION & USE HAZARDS: Same precautions as for handling lacquers

Label: WARNING: FLAMMABLE - VAPOR HARMFUL.

Decomposition products may include chlorine, HCl and phosphorous oxides

RECOMMENDED FOR: Walls and ceilings where fire and contamination hazards are high.

REMARKS: Film thickness important for optimum fire retardance.

DATA SHEET - WALL, CEILING, AND EQUIPMENT COATINGS

MATERIAL:

Code: PF Name(s) _____

General Description: Peelable vinyl plastic

Supplier(s): _____

Application Methods: Spray or dip - cannot be brushed

PROPERTIES:

Fire Retardance
(ASTM E-162)

Fl. Spr. Index 120/10 =
120 for bare substrate;
10 for coated sample.
Red oak = 100;
Asbestos millboard = 0

Scrubbability
(TTP-26a)

Impact Flexibility
(GE Var. Impact Test)

Bending Flexibility
(ASTM D-522)

Chemical Vapor Resist.

Mixed Solvent
Hydrochloric Acid

Strippability

Mechanical
Chemical

RATING	TEST DATA				
	Coating thickness	Base material	Fl. spr. index	Flame travel	Smoke (mg)
Poor	0.005 in.	Hardboard	120/118	18/16	2.6/4.6
Poor	0.006 in.	Gypsum bd.	17/34	15/11	0.0/0.7
Satisf.	Slight marring				
Fair	30 in. -1b				
Excellent	Score of: 10 on scale of 0 - 10 maximum				
Good	Resisted exposure 6 days				
Satisf.	Blistered in 6 days				
Excellent	1.2 lb/in. of width				
--	--				

APPLICATION & USE HAZARDS: Data not available from manufacturer. Solvent probably contains ketones.

RECOMMENDED FOR: Protection of equipment against corrosion and contamination.

REMARKS: Should not be used where there is a significant fire hazard.

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