

The Influence of a Fire-Retardant Undercoat on the Burning Characteristics of a Combustible Topcoat

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CONTENTS

Abstract	ii
Problem Status	ii
Authorization	ii
INTRODUCTION	1
EXPERIMENTAL PROCEDURE	2
DISCUSSION	7
SUMMARY	8
CONCLUSIONS	9
FUTURE WORK	9
REFERENCES	9
APPENDIX A - Formula 124/58 MIL-E-17970C	10
APPENDIX B - NRL Semigloss Acrylic Latex Paint (C-60A)	11
APPENDIX C - Combustible, Decorative Topcoat (C-22X)	12
APPENDIX D - Fire Retardancy Test Procedure	13

ABSTRACT

The objective of this program is to develop an interior, fire-retardant submarine paint with special performance requirements not present in currently available paints.

A direct consequence of this investigation has been the development of a general method for the introduction of fire retardancy into a combustible coating system without modification of the paints themselves. This is achieved by use of a thin flame-quenching undercoat in combination with the regular coating system. The fire-retardant undercoat contains high proportions of chlorinated paraffin and antimony oxide which interact under the influence of the heat to produce the powerful flame-quenching intermediate. By concentrating these fire-retardant additives in an undercoat, they are much more effective than when dispersed throughout the whole coating system.

Although these fire-retardant systems will burn under the influence of an extraneous flame or fire, the burning paint film will immediately self-extinguish when this ignition source is eliminated or when that part of the film directly exposed to the fire is consumed. This performance has been obtained even when four or five coats of a combustible paint have been applied over only one fire-retardant undercoat.

However, since these paints will be used only on noncombustible substrates, their burning characteristics have been evaluated only on these types of materials, and their burning characteristics on combustible substrates have not been evaluated.

Although this investigation has been limited to water-based paints to prevent contamination of the submarine's atmosphere with toxic organic solvents, this approach to fire retardancy appears to be applicable to any paint system.

PROBLEM STATUS

This is an interim report; work is continuing on this problem.

AUTHORIZATION

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THE INFLUENCE OF A FIRE-RETARDANT UNDERCOAT ON THE BURNING CHARACTERISTICS OF A COMBUSTIBLE TOPCOAT

INTRODUCTION

It is an objective of this research to develop a highly serviceable, fire-retardant* paint which can be used in nuclear submarines under sealed ship conditions (1-3). Such application demands that the paint evolve no toxic vapors during and after painting. The evolution of toxic gases in case of extreme heat or fire is unavoidable in present state-of-the-art flame-retardant materials. This, coupled with the fact that the gaseous products of almost any burning substance will force a submarine to surface unless their source can be very quickly controlled, eliminates this possible source of toxicity as a significant consideration in this project.

Since the areas to be painted in the interior of a nuclear-powered submarine are nonburning — such as bulkheads, lagging, insulation — the burning characteristics of these paints have been evaluated only on noncombustible substrates, usually asbestos paper. Thus, the fire-retardancy behavior under discussion in this report refers to the burning characteristics of the paint film itself and not to the effect of the paint film on the burning characteristics of a combustible substrate such as wood or plastic. Although these paints might provide some protection for combustible materials, this aspect has not been evaluated, and is not a project objective.

In spite of intensive efforts over an extended period it has thus far been impossible to combine in a single paint all of the properties required of a fire-retardant coating for the interior of nuclear submarines. In many instances lack of success has been attributable to the adverse effect of the fire-retardant additives (mainly antimony oxide and heavily halogenated compounds) on working properties, appearance, and durability of an otherwise acceptable paint. Aside from being fire-retardant (i.e., self-extinguishing) the qualities desired in the paint are good working properties (especially leveling), good appearance and hiding, medium gloss, a low content of volatile organic matter, and sufficient flexibility for application to nonrigid substrates such as foam-type insulation.

As an alternative to the single coat approach it was decided to investigate the possibility of obtaining the desired result from a two-coat system in which the undercoat would impart fire-retardancy, while the topcoat would provide the requisite decorative qualities. In this manner the fire-retardant additives, which were responsible for poor appearance, could be confined to the undercoat, which in turn, would be hidden by the decorative topcoat. Thus, while the topcoat alone might be combustible, in combination with the fire-retardant undercoat the total system would be self-extinguishing.

Although this approach would require application of at least two coats of paint, it is considered practical and, in fact, conforms with general practice. In many common painting systems even three coats, each different, are used to obtain a degree of protection and performance that could not be designed into one or two coatings.

This new approach was attractive also because of its fundamental significance. If successful it would strongly indicate that the method would be generally applicable

*"Fire-retardant," as used in this report, is defined as a significant reduction in burning rate with the ultimate object being self-extinguishment.

regardless of the type paint used, so long as fire-retardancy was imparted to the undercoat by proper additives. Insofar as is known, this concept has not been previously investigated.

EXPERIMENTAL PROCEDURE

The initial problem was to determine what effect, if any, a fire-retardant undercoat would have on the burning characteristics of a combustible topcoat. There was the possibility that the topcoat would burn unaffected by the undercoat. It was convenient to test this concept by using the fire-retardant solvent-based chlorinated alkyd, Formula 124/58,* as the fire-retardant undercoat and an NRL acrylic latex paint† as the combustible topcoat. The test samples were prepared by laying down, with a 10-mil-clearance Dow film caster, a 5-1/2-in.-wide film of Formula 124/58 on a 8×12 in. sheet of asbestos paper. This provides a dry film thickness equal to approximately 1-1/2 brush coats. These undercoats were dried overnight and then overcoated with one, two, three, or four brush coats of the combustible acrylic latex paint, allowing a 24-hour drying period between each coat. The procedure for the fire-retardancy evaluation has been described in a previous report (2); for convenience this description is attached as Appendix D to this report.

The fire-retardancy test results are reported in Fig. 1. The top curve shows the burning characteristics (6-in. burning time) of the NRL acrylic latex paint with no fire-retardant undercoat. None of the samples was self-extinguishing. The burning time reported for these samples is the average of five determinations and is the time required for the sample to burn 6 in. after turning off the ignition torch. The lower curve shows the burning characteristics for a similar series of test samples, but where the acrylic latex is applied over the fire-retardant undercoat as outlined above. None of this second series of test systems burned the full 6 in.; the time reported is the time the samples burned before self-extinguishment after the ignition torch was turned off. With one coat of the combustible acrylic latex over the fire-retardant undercoat, two out of the five samples immediately self-extinguished and the other three burned for approximately 0.8 sec before self-extinguishing. With two, three, or four coats of the combustible topcoat, no samples immediately self-extinguished and the five samples for each series burned for an average of 2.4, 3.0, and 6.2 sec, respectively, before self-extinguishing. These results were encouraging since the chlorine and antimony oxide content of the solvent-based, chlorinated alkyd paint had not been thought high enough to produce this degree of fire-retardancy in combination with the combustible topcoat. The most that had been expected, particularly in the multi-topcoated samples, was a reduction in the burning rate.

Because of this success efforts were directed toward preparing a nontoxic, water-based, fire-retardant undercoat. In order to obtain maximum fire-retardancy, the chlorine and antimony oxide contents were made high. A typical formulation is shown in Table 1. The chlorine source is the Deltvet 65, which is an aqueous dispersion of a chlorinated paraffin that contains 70 wt-% chlorine.

The fire-retardant undercoat was evaluated in combination with two combustible acrylic latex paints developed at NRL: a C-60A acrylic latex paint (Appendix B) which was used in the preliminary studies just mentioned and a C-22X acrylic latex paint

*Formula 124/58 (4) is the fire-retardant paint currently used to paint the interior of nuclear-powered submarines. Its formulation is shown in Appendix A.

†The NRL acrylic latex paint was developed in another program (5) for use as a "touch-up" paint where Formula 124/58 could not be used for toxicity reasons. It is, however, completely combustible. Its formulation is shown in Appendix B and is designated C-60A.

Fig. 1 - Fire-retardant performance of an acrylic latex paint applied over a fire-retardant undercoat

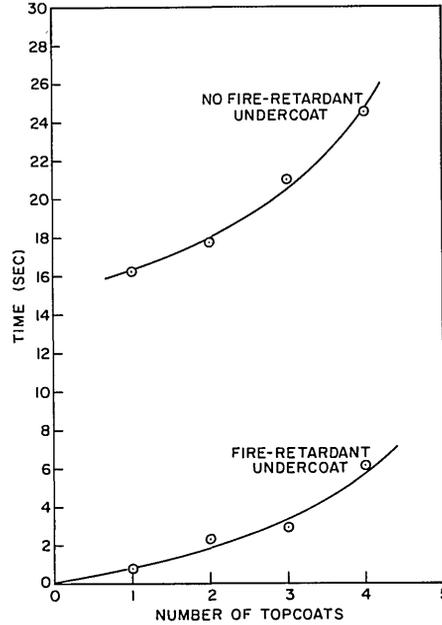


Table 1
Fire-Retardant Undercoat

Ingredients	Wt-%	Function
<u>Premix</u>		
1. Amberlac 165 (21%)	3.08	Grinding vehicle
2. Triton CF10	0.12	Surfactant
3. Tamol 731 (25%)	0.49	Surfactant
4. Nopco NDW	0.12	Antifoamer
5. Water	12.34	Thinner
6. Sb ₂ O ₃	17.29	Fire retardant pigment
7. G-11 hexachlorophene	0.07	Preservative
	<u>33.51</u>	
<u>Letdown</u>		
8. Rhoplex AC22-X (44.5%)	34.94	Vehicle
9. Rhoplex C73 (46.5%)	3.33	Vehicle
10. Eldefoam 2892	0.31	Antifoamer
11. Pine Oil	0.31	Antifoamer
12. Polyglycol P1200	0.31	Drying regulator
13. Acrysol G-110 (22%)	0.68	Thickener
14. Delvet 65 (65%)	26.61	Fire retardant chlorinated paraffin
	<u>66.49</u>	
	100.00	

Constants	Wt-%
Solids in total paint	53.5
Combustible solids in total solids	35.4
Sb ₂ O ₃ in combustible solids	91.4
Cl in combustible solids	64.0
Volatile organics in total paint	0.31
Cl in dried film	22.6
Sb ₂ O ₃ in dried film	32.3

(Appendix C) which was developed in this program specifically for use with the fire-retardant undercoat.

In evaluation with the C-60A acrylic latex paint, 10-mil-thick wet films of the fire-retardant undercoat were laid down, allowed to dry overnight, and then overcoated by brushing with one, two, or three coats of the acrylic latex. With just one coat of this C-60A latex paint, all of the five samples immediately self-extinguished. With two coats, four out of five samples were immediately self-extinguishing, and the fifth sample burned for only 0.7 sec. With three coats of the acrylic paint, four out of four samples were immediately self-extinguishing. A fifth sample, instead of being exposed to the microburner flame for the complete ignition time (15.2 sec average for the other four samples), was exposed to the flame until the burning film was approximately at its maximum intensity (6.0 sec after ignition commenced), and then the microburner flame was extinguished. Under these conditions of ignition, this sample burned for 1.7 sec before self-extinguishing.

With the combustible C-22X acrylic latex paint that was specifically developed to be used in combination with this fire-retardant undercoat, the fire-retardancy performance was investigated in more detail. The initial performance of the system was evaluated using a 10-mil-thick wet film of the fire-retardant undercoat, approximately equal to the thickness obtained with 1-1/2 brush coats, and overcoating with a 20-mil-thick wet film of the decorative topcoat, approximately equal to the thickness obtained with three to four coats. On a relative scale these thicknesses correspond to the ratio of one coat of the undercoat and two coats of the topcoat. Under the usual conditions of the fire-retardancy test all four samples tested immediately self-extinguished.

In another series of tests an attempt was made to define the minimum thickness of the fire-retardant undercoat that would be necessary to obtain a fire-retardant system with a topcoat thickness equal to about two brush coats. In this evaluation 12-mil wet films of the decorative combustible topcoat were laid down over dried films of the fire-retardant undercoat. The wet film thickness of the fire-retardant undercoat was varied from 2 to 20 mils. The fire-retardancy test results are summarized in Table 2. Three replicate samples for each film thickness were tested, and the average is reported. Without the fire-retardant undercoat the decorative topcoat is completely combustible, burning the 6-in. length in 17.7 sec after the ignition torch is turned off. When the wet film thickness of the fire-retardant undercoat was only 2 mils (this corresponds to a dry film thickness of approximately 0.5 mil), the fire-retardancy of the system was surprisingly good. Two of the three samples tested self-extinguished immediately after the ignition torch was turned off, and the third sample self-extinguished after 0.8 sec. At film thicknesses greater than 2 mils (wet) all samples immediately self-extinguished.

In a similar series of tests the fire-retardant undercoat was laid down at wet film thicknesses of 7 mils, 10 mils, and a very heavy brush coat approximately 30 mils. The dried films were then overcoated with three coats of the C-22X decorative combustible topcoat and the fire-retardancy evaluated in the usual manner. This data are summarized in Table 3. Even at these thicker topcoat levels (that is, three coats instead of two as in Table 2) the fire retardancy is quite acceptable. Most of the samples immediately self-extinguished when the ignition torch was turned off, with the remaining samples burning only an average of 0.9 sec before self-extinguishing.

It is curious that as the undercoat thickness was increased no improvement in fire retardancy resulted; in fact, it appears that the fire retardancy performance actually decreased slightly. In addition, it was also observed for the series in Tables 2 and 3 that as the fire-retardant undercoat thickness was increased the size and intensity of the ignition flame also increased.

Table 2
Effect of Fire-Retardant Undercoat Film Thickness on the
Fire-Retardancy Performance of a Combustible Topcoat of
Approximately Two-Brush Coat Thickness
(12-mil-thick wet film)

Wet Film Thickness of Fire-Retardant Undercoat (mils)	Ignition Time (sec)	Six-Inch Burning Time (sec)	No. of Immediately Self-Extinguishing Samples of the Three Tested
0	8.9	17.7	0
2	10.0	self-extinguished	2*
4	11.1	self-extinguished	3
6	10.4	self-extinguished	3
8	10.6	self-extinguished	3
10	11.0	self-extinguished	3
15	14.0	self-extinguished	3
20	15.1	self-extinguished	3

*The third specimen burned 0.8 sec before self-extinguishment.

Table 3
Effect of Fire-Retardant Undercoat Film Thickness on the Fire Retardancy
Performance of Three Coats of the Decorative, Combustible Topcoat

Film Thickness of Fire-Retardant Undercoat (mils)		Film Thickness of Combustible Topcoat		Total Dry Film Thickness as Measured with Micrometer (mils)	Ignition Time (sec)	No. of Immediately Self-Extinguishing Samples	Average Time for Remaining Sample to Self-Extinguish (sec)
Wet	Dry (est)	Wet (brush coats)	Dry (est) (mils)				
7	1.4	3	5.4	6.8	13.2	4 out of 5	0.8 (1 sample)
10	2.0	3	5.4	7.4	14.6	4 out of 5	0.9 (1 sample)
heavy brush	5.6	3	5.4	11.0	18.6	3 out of 5	0.9 (2 samples)*

*Burning behavior abnormal, probably resulting from residual solvents trapped in the thick film.

It should be emphasized that these fire-retardant paints will burn under the influence of an extraneous flame, such as the microburner used in our tests, even though they will self-extinguish when the ignition source is eliminated or the paint immediately exposed to the ignition source is consumed. It is, of course, desirable that these paints burn with as small a flame as possible so that they do not significantly contribute to the overall size or intensity of the fire during this burning period.

Similar behavior has been observed with a fire-retardant decorative coating described in a previous report (2) and to be the subject of a future report. These fire-retardant topcoats are conventional latex paints in which has been incorporated antimony oxide and a halogen additive such as a chlorinated paraffin or chlorinated rubber. While these paints were self-extinguishing, they also exhibited an ignition flame that was larger and more intense than the corresponding halogen-free paints. A similar type of behavior has been observed in a study (6) of the effect of halogenated hydrocarbons on the flame speed of methane. Generally, halogenated hydrocarbons decreased or inhibited the burning rate, but under certain conditions halogenated hydrocarbons promoted or increased the flame intensity when the source of ignition was sustained. It is thought that these inhibitors may act as fuels under certain conditions, with the oxygen reacting more easily with the inhibitor than with the methane. Thus, hydrogen bromide reacts more readily with oxygen than does methane and thereby can provide another mode of chain initiation in the flame propagation process.

It was also of interest to determine the effect of the position of the fire-retardant coat on the burning characteristics of the complete coating system. In these experiments the fire-retardant coating was used (a) beneath the combustible coating (that is, in the conventional manner as discussed above), (b) on top of the combustible coating (that is, reversing the position of the two coatings as discussed above), and (c) completely mixed in with the combustible coating. The fire-retardant coat was used at a wet film thickness of 3 mils, the combustible coat at 20 mils, and the mixture at 23 mils. This mixture was prepared from 20 parts by volume of the combustible coating and three parts by volume of the fire-retardant coating; 6.61 to 1 by weight. The results are summarized in Table 4. Also shown is the burning characteristic of the fire-retardant coating at a 3-mil wet film thickness and the combustible coating (C-22X) at 3 mils and 20 mils wet film thicknesses. The fire-retardancy test was performed in the usual manner.

The data show that the location of the fire-retardant coat is very important. Used in the normal manner, that is, as a thin undercoat beneath the combustible coats, the fire-retardant coating is completely effective. Even with a coating ratio of approximately 1 to 7, i.e., 3 mils (wet) fire-retardant coat to 20 mils (wet) combustible coat, the performance was excellent, with two samples self-extinguishing immediately when the ignition torch was turned off and the third burning for only 1.1 sec before self-extinguishing.

Reversing the position of the two coatings substantially negated the effectiveness of the fire-retardant coating. No sample self-extinguished, and all burned the full six in. after the ignition flame was removed. The 6-in. burning time was, however, slower than that for the combustible coating by itself, 25.6 sec versus 20.0 sec, respectively.

When the two coatings were mixed together and applied as a single coating that had the same total film thickness and volume ratio (3 parts fire-retardant paint to 20 parts combustible paint) of the separately applied coats, the effectiveness of the fire-retardant paint was completely lost. No sample self-extinguished, and the six-inch and total burning times were approximately the same as for the combustible paint by itself.

As discussed earlier this coating system had to meet a number of special requirements because of the application for which it was intended. In particular, it was necessary to keep the volatile organic content as low as possible; thus a number of useful latex paint additives could not be used. Therefore, this fire-retardant undercoat does

Table 4
Effect of Fire-Retardant Coating Position on Burning
Characteristics of Combustible Coating

Type of Coating	Wet Film Thickness of Coating (mils)	No. of Samples	Av Ignition Time (sec)	Av 6-in. Burning Time (sec)	Av Total Burning Time (sec)	No. of Immediately Self-Extinguishing Samples
Fire-Retardant Coating	3	5	6.3	—	—	5
Combustible Coating	3	5	7.0	14.4	21.4	0
Combustible Coating	20	5	11.0	20.2	31.2	0
Fire-Retardant Undercoat/Combustible Topcoat	3/20	3	14.2	—	—	2*
Combustible Undercoat/Fire-Retardant Topcoat	20/3	3	12.0	25.6	37.5	0
Fire-Retardant Combustible Coating Mixture (3 to 20 volume ratio)	23	4	10.2	22.2	32.4	0

*Third specimen burned 1.1 sec before self-extinguishment.

not necessarily represent the optimum formulation that could be developed if less stringent toxicity requirements could be tolerated.

For general interest a few of the properties of this undercoat are described below. The only volatile organic component in the undercoat (formulation — Table 1) is the pine oil at 0.31 wt-%. The polyglycol P1200 is essentially nonvolatile and will not contribute to atmospheric contamination. Because of the absence of coalescing aids, the surface to be painted must be about 50°F, the minimum film-forming temperature calculated for the Rhoplex AC22X/C73 resin mixture to obtain a continuous film. Actually a minimum surface temperature of not less than 55°F, and preferably at least 65°F, is desirable.

The undercoat showed good adhesion to previously painted surfaces. Although its application properties are fairly poor, it gives a receptive surface for the decorative topcoats. The undercoat has little or no hiding power and a leveling value of 6 using the NYPC (7) leveling test blade. The undercoat dries in approximately 1/2 hour and can be overcoated in 2 hours. The undercoat can be used over resilient materials.

DISCUSSION

These observations are consistent with present understandings of the flame-quenching mechanism. It has been known for a long time that a halogen compound and antimony oxide can interact synergistically to form a powerful agent which is much more effective in extinguishing a burning film than the sum of the effects of the individual constituents. Apparently this synergism interfaces with the chain propagation reaction of the combustion process. When the halogen source and antimony oxide are concentrated, as they are in the undercoat, it would be expected that the rate of formation of the flame

inhibitor would be much faster than when the same amounts of these additives are dispersed throughout the whole coating system. It is suspected that when the fire-retardant agents are dispersed through the total film, much of the halogen liberated during decomposition reacts with other fragments of the combustion process before it can interact with the decomposing antimony oxide, thus tending to decrease the availability of the synergistic agent. By producing a large amount of the flame quenching agent very rapidly, as results when the additives are concentrated in the undercoat, synergism and total effectiveness are maximized.

The fact that the fire-retardant paint is almost ineffective when used as a topcoat over a combustible underlayer can be attributed to the loss of flame-quenching agent to the surrounding atmosphere before it can interact and take part in the flame-inhibiting action.

Finally, while these experiments were conducted for the most part with acrylic latex paints, it is believed that the observations are of fundamental significance in that this two-coat, fire-retardant system approach should be applicable generally regardless of the type of paint. Furthermore, the experiments make it appear that this is the most economical and effective means of producing a coating system that is self-extinguishing.

These research studies are continuing with the object of still further improving the working properties of these coatings.

SUMMARY

What we have attempted to do here is demonstrate the feasibility of using a highly potent fire-retardant undercoat to introduce fire retardancy into an otherwise combustible coating system without further modification of the topcoat. This report shows that it has been possible to achieve this objective and that as many as four combustible topcoats can be applied over the undercoat without impairing fire-retardancy of the total coating system.

It was further shown that a very thin coating (2 to 3 mils wet film thickness) of the fire-retardant paint was effective. In fact, it was found desirable to apply the undercoat at minimum effective thickness because the size of the ignition flame (that is, the flame formed when the coating is ignited) increased with the thickness of the fire-retardant undercoat. In actual practice it would be recommended that only one coat of the fire-retardant undercoat be applied and this brushed out as thin as practicable consistent with the viscosity and flow properties of the coating.

Using this method to achieve fire retardancy has several advantages. First, in many paints it is not possible to introduce fire retardancy without adversely affecting other properties that may be important in the performance of the paint, such as gloss, leveling, application properties, and hiding power. By using a fire-retardant undercoat, the unmodified topcoat can be used without any sacrifice in performance and yet the system will meet fire-retardancy requirements. Second, many fire-retardant additives are halogenated organic compounds which are light sensitive. By confining these materials to the undercoat, they are largely protected from light, resulting in an increase in the stability of the coating system. Third, since the undercoat provides the fire-retardant requirement for the multicoat system, any topcoat, whether it be a common household paint or a highly complex, unique, specialty paint, could still be used without further modification. Fourth, this approach minimizes the use of the fire-retardant additives, which is of particular importance in the case of antimony oxide, since it is a relatively costly and strategic material.

It has not been the purpose of this report to provide the reader with a ready-made formulation for use as a fire-retardant undercoat. Although the formulation presented here may be usable in a number of other applications, it was designed for the highly special conditions imposed when application must be made in a sealed ship (submarine). A more general purpose undercoat could be formulated. Without the nontoxic requirement a number of other fire-retardant additives could be used that are not readily suitable for water-based paints, including bromine and phosphorous-containing materials as well as other chlorinated compounds. It would also seem possible, and in some cases desirable, to combine the fire-retardant function of the undercoat with some other function, such as corrosion or rust inhibition.

CONCLUSIONS

These experiments show that a paint system that normally would be combustible can be made fire-retardant (self-extinguishing) by providing a chlorine and antimony oxide source in a thin underlayer. The adverse effect that fire-retardant additives often have on appearance is readily overcome by confining these additives to the undercoat. The experiments also show that this is the most effective way to achieve fire-retardancy of a coating, rather than by dispersal of fire-suppressing additives throughout the total system.

FUTURE WORK

Plans are being made to prepare several gallons of the undercoat for shipboard evaluation. If results from this limited evaluation are encouraging, 100 gallons will be procured from a paint manufacturer for more extensive study and evaluation.

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APPENDIX A

FORMULA 124/58 MIL-E-17970C
 ENAMEL, NONFLAMING (DRY), CHLORINATED ALKYD
 RESIN, SOFT WHITE, SEMIGLOSS

<u>Ingredients</u>	<u>lbs/100 gal</u>
Titanium-Calcium pigment	400
Titanium dioxide	205
Antimony oxide	105
Aluminum stearate	18
Chlorinated alkyd resin solution (Cl-alkyd solids 279 lbs)	465
Petroleum spirits	150
Lead naphthenate	5.9
Cobalt naphthenate	<u>2.4</u>
	1351.3

Pigment in total paint	- 52.6 wt-%
Volatile organics in total paint	- 24.9 wt-%
Cl in total paint	- 4.85 wt-%
Cl in total solids	- 6.45 wt-%
Cl in resin	- 23.48 wt-%
Sb ₂ O ₃ in total paint	- 7.41 wt-%
Sb ₂ O ₃ in total solids	- 10.34 wt-%
Sb ₂ O ₃ in resin	- 47.64 wt-%
Resin in total solids	- 20.7 (22.4) wt-%

APPENDIX B

NRL SEMIGLOSS ACRYLIC LATEX PAINT
(C-60A)

	<u>Wt-%</u>	<u>Function</u>
<u>Premix</u>		
1. Rutile TiO ₂ , R-100	24.70	Pigment
2. Amberlac 165 (21%)	4.41	Grinding vehicle
3. Triton CF-10	0.18	Surfactant
4. Tamol 731 (25%)	0.71	Surfactant
5. Nopco 1407	0.18	Antifoam
6. Carbitol	4.41	Coalescing agent
7. G-11 Hexachlorophene	<u>0.09</u>	Preservative
	34.68	
<u>Let Down</u>		
8. Water	7.06	Thinner
9. Rhoplex B60-A (46%)	31.76	Vehicle
10. Rhoplex C-72 (45%)	22.94	Vehicle
11. WSR-301 (4%)	1.76	Thickener
12. Polyvinylpyrrolidne (20%)	0.48	Thickener
13. Bubble Breaker 746	0.44	Antifoam
14. Pine Oil	0.44	Antifoam
15. Polyglycol P-1200	<u>0.44</u>	Drying regulator
	<u>65.32</u>	
	100.00	

Solids in total paint - 51.8 wt-%

Combustible solids in total solids - 51.5 wt-%

Volatile organics in total paint - 4.85 wt-%

APPENDIX C
 COMBUSTIBLE, DECORATIVE TOPCOAT
 (C-22X)

	<u>Wt-%</u>	<u>Function</u>
<u>Premix*</u>		
1. Amberlac 165 (21%)	4.35	Grinding vehicle
2. Triton CF10	0.17	Surfactant
3. Tamol 731 (25%)	0.70	Surfactant
4. Nopco NDW	0.17	Antifoam
5. Propyleneglycol	2.09	Drying regulator
6. Water	9.23	Thinner
7. TiO ₂ (R-900)	<u>27.15</u>	Hiding pigment
	43.86	
<u>Letdown</u>		
8. Rhoplex AC22-X (44.5%)	48.73	Vehicle
9. Rhoplex C73 (46.5%)	5.22	Vehicle
10. Eldefoam 2892	0.44	Antifoam
11. Polyglycol P1200	0.44	Drying regulator
12. Pine oil	0.44	Antifoam
13. Acrysol G110 (22%)	<u>0.87</u>	Thickener
	<u>56.14</u>	
	100.00	

Solids in total paint - 53.76 wt-%

Combustible solids in total solids - 49.5 wt-%

Volatile organics in total paint - 2.53 wt-%

*0.07 to 0.08 wt-% of G-11 hexachlorophene may be added to the premix as a preservative.

APPENDIX D

FIRE RETARDANCY TEST PROCEDURE

In this test a wet film is laid down with a film caster or brush on an 8×11 in. sheet of asbestos paper (Fisher Catalog No. 1-470) approximately 1/64 in. thick and held flat by a Bird Vacuum plate.

The film is allowed to dry for at least five days, and then the coated area is cut into five 1×11 in. test strips. The test strips are ruled off at 2, 3-1/2, and 9-1/2 in. from the bottom. Since these ruled lines may become covered with soot or smoke or otherwise made obscure during the test, it is convenient to punch a small hole in the test strips at these three locations to facilitate the identification of their position. The test is made in a cabinet whose interior dimensions are 19×13×33 in. It has a glass front door through which the burning sample can be observed. Along the bottom of both sides of the cabinet are several 1/2-in.-diameter holes for ventilation. The top of the box has two 1-in.-diameter holes diagonally opposite each other and one in the center over which a small exhaust fan is positioned to help remove the smoke formed during the test. The cabinet is in a hood, which is kept on during the test to remove the combustion gases. With the cabinet door closed and the hood and small exhaust fan on, there is little or no flame disturbance caused by air currents. The 1×11 in. test strip is suspended vertically in the cabinet by any suitable means. One convenient method is to use two nails held in position by clamps on a 1/2-in.-diameter rod fastened to the top and bottom of the cabinet. The clamps are approximately 10 in. apart, and the asbestos strip is simply pushed onto the nails. To prevent the asbestos from tearing when tightening and aligning the test strip, a small piece of masking tape at the point of puncture is helpful. After the test strip has been positioned, a microburner is aligned with the test strip so that a line passing through the barrel of the burner is perpendicular to the strip at the center of the 2-in. mark and the tip of the barrel is 2 in. from the strip. The torch is lit with the air intake port closed so that a yellow flame is formed that burns straight up and does not reach the test strip. The cabinet door is closed, and the air intake of the burner is fully opened by an external linkage. This produces a hot blue flame which burns straight out and ignites the sample. The time for the paint film to ignite and burn from the 2-in. mark to the 3-1/2-in. mark, at which point the burner is extinguished, and from the 3-1/2-in. mark to the 9-1/2-in. mark is measured with two stopwatches. The time to burn the 1-1/2 in. is called the ignition time and is related to the ease of ignition of the paint. The time to burn the 6 in. after the torch has been extinguished is referred to as the burning time and is dependent on the fire retardancy of the coating.

Ideally, the coating would self-extinguish as soon as the microburner is turned off and, therefore, would have a nonfinite burning time for the 6-in. length. However, depending on the degree of fire retardancy, it may continue to burn for a time before it self-extinguishes, or it may burn the entire 6-in. length at a rate proportional to its degree of fire retardancy. The sum of the ignition and the 6-in. burning time is called the total burning time. For those films which are completely burned, the total burning time appears to be the more useful and reproducible value in correlating the observed effects (data) with paint composition.

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13. ABSTRACT The objective of this program is to develop an interior, fire-retardant submarine paint with special performance requirements not present in currently available paints. A direct consequence of this investigation has been the development of a general method for the introduction of fire retardancy into a combustible coating system without modification of the paints themselves. This is achieved by use of a thin flame-quenching undercoat in combination with the regular coating system. The fire-retardant undercoat contains high proportions of chlorinated paraffin and anti-mony oxide which interact under the influence of the heat to produce the powerful flame-quenching intermediate. By concentrating these fire-retardant additives in an undercoat, they are much more effective than when dispersed throughout the whole coating system. Although these fire-retardant systems will burn under the influence of an extraneous flame or fire, the burning paint film will immediately self-extinguish when this ignition source is eliminated or when that part of the film directly exposed to the fire is consumed. This performance has been obtained even when four or five coats of a combustible paint have been applied over only one fire-retardant undercoat.			

(see over)

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fire-retardant coatings Nuclear submarine habitability Paints Water-base paints Chlorinated compounds Antimony oxide						

However, since these paints will be used only on noncombustible substrates, their burning characteristics have been evaluated only on these types of materials, and their burning characteristics on combustible substrates have not been evaluated.

Although this investigation has been limited to water-based paints to prevent contamination of the submarine's atmosphere with toxic organic solvents, this approach to fire retardancy appears to be applicable to any paint system.