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Executive Summary

EVALUATION OF PROPERTIES OF VARNISHES EXTERIOR STAINS EXTERIOR PRIMERS

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ABSTRACT

The evaporation of solvents during the application of most paints and coatings is a significant source of reactive organic gas (ROG) emissions. Consequently, the California Air Resources Board (ARB) has established specific limitations in the amount of solvents employed in certain types of architectural coatings. However, because the low solvent technology had not been fully developed, some classes of architectural coatings were exempted.

Among these exempted coatings were clear finishes, wood stains, primers of all types, wood preservatives, fire retardant paints, glaze coatings, waterproofing, maintenance and metallic paints, swimming pool paints, sign paints, mastics and multicolor paints.

The ARB wished to determine whether products, among these exempt classes, were commercially available, which would meet the VOC limitations and be competitive to conventional, solvent-thinned coatings. Therefore ARB sponsored a study in 1979, performed by D/L Laboratories, to test architectural coatings among the exempt classes. The results published in August 1980 demonstrated that only a few of the classes tested were commercially available in competitive low VOC products.

Among the classes which required further study were clear finishes, wood stains and stain-blocking primers. Therefore, this study was undertaken to determine whether competitive low VOC coatings were presently available. Results of the limited laboratory tests conducted on products having VOC's below 450 g/l demonstrate that both interior and exterior gloss varnishes are available which can readily compete with equivalent conventional clear gloss finishes. On the other hand, satin varnishes require some improvement in resistance to liquids and stain blocking primers require improvement in their ability to prevent bleeding when topcoated with a water based enamel.

Work on semi-transparent stains, opaque stains and stain blocking primers were limited by financial considerations. As noted above, the primers need improvement in bleed resistance. The stains are disappointing due to inferior penetration into the wood, a major property of good wood stains.

Overall, although correlation varies considerably, it is evident that reduction of VOC tends to degrade resistance of varnishes to water, stains and blocking, to reduce penetration of stains and to reduce resistance to staining of stain-blocking primers when topcoated with a water based topcoat. On the other hand, weathering of exterior varnishes is improved and weathering of exterior stains is essentially unchanged. Also recoatability of exterior stains is slightly improved.

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SUMMARY AND CONCLUSIONS

This investigation is a continuation of a study, initiated in 1979, to evaluate low solvent varnishes, wood stains and stain-blocking primers presently exempt from the California ARB Model Rule for Architectural Coatings. These products were compared with equivalent conventional solvent-thinned coatings in order to determine whether these low VOC products were competitive with equivalent conventional products, thereby enabling their removal from the exempt list.

Products were solicited from a select group of coating manufacturers and raw material suppliers. A total of 16 companies responded submitting a total of 30 low VOC and 25 conventional coatings representing interior and exterior varnishes, semi-transparent and opaque stains as well as the primers.

The evaluation was carried out using standard laboratory test methods but covering only a limited number of properties as requested by the ARB. The results of the tests were then summarized using a simple rating scheme of 10 to 0 in order to enable the analysis of the data without the necessity of having a background in coatings technology.

The following conclusions may be drawn from the results of the tests conducted:

1. Four interior gloss varnishes are competitive with the equivalent conventional varnishes tested. The best low VOC coatings are equal to the best conventional products. They exhibit no significant differences in properties.

2. Only one interior satin varnish is competitive with the equivalent conventional coating. The others are inferior in resistance to water, especially hot water, and to stains.

3. Two exterior varnishes are competitive with the equivalent conventional varnishes. These are essentially equivalent to the best conventional products, exhibiting slightly superior color retention at some loss in drying speed.

4. None of the semi-transparent stains are competitive. They tend to exhibit less penetration into the wood and are not as durable as desired.

5. None of the opaque stains are competitive primarily because they do not exhibit the penetration desirable in a stain as opposed to a paint.

6. None of the low VOC stain blocking primers tested are competitive to the best conventional product inasmuch as all of the low VOC primers are inferior for resistance to bleeding when topcoated with a water based enamel.

7. Overall, regression analysis of the performance ratings demonstrate some definite trends as VOC is reduced although correlation varies widely, from a high of 95% to a low of 9%:

   a. Resistance of all varnishes to cold water, hot water and blocking is definitely poorer.

   b. Resistance of interior varnishes to staining is slightly poorer.

   c. Penetration of exterior stains is slightly to decidedly poorer.

   d. Resistance of stain blocking primers to staining when recoated is decidedly poorer.

   On the other hand -

   e. Weathering of exterior varnishes is improved and weathering of exterior stains is essentially unchanged.

   f. Recoatability of exterior stains is slightly better.

II RECOMMENDATIONS

It is apparent from the results of this evaluation that low VOC clear gloss finishes, both interior and exterior, are available to compete with equivalent conventional coatings. However, VOC limits are fairly high. The best products vary from 249 to 448 g/l competing with conventional coatings with VOC's as low as 457 g/l. It is a very fine line of demarcation. On the other hand, acceptable clear coatings are available with VOC's varying from 187 to 413 g/l.

Only one low VOC satin varnish is acceptable with a VOC of 441 g/l. More work is needed to improve resistance to water and stains.

The wood stains are disappointing. None of the semi-transparent stains are particularly durable and most of the low VOC stains, especially the opaque stains, should have better penetration to act as stains rather than paints.

Considering both the stains and the stain-blocking primers, financial limitations of the contract prevented a complete evaluation of these products. The latter should be reevaluated in the future for bleed resistance and tested for weatherability when topcoated with typical exterior paints.

III INTRODUCTION

Both Architectural (field applied) and industrial (in-plant applied) coatings are a significant source of VOC emissions inasmuch as half or more of each gallon of most solvent thinned coatings consist of volatile organic compounds (VOC), primarily solvents, which evaporate when the coating is applied and cured.

CARB has taken steps to control these emissions by devloping or adopting various Model Rules for both Architectural and Industrial coatings to reduce the VOC to, e.g., half of the amount used in solvent thinned coatings

However, because the low solvent technology had not been fully developed, fourteen classes of architectural paints were exempted. These included the following:

1. Clear finishes, e.g., varnishes
2. Semi-transparent wood stains
3. Opaque wood stains
4. Primers, sealers and undercoaters
5. Wood preservatives
6. Fire retardant paints
7. Tile-like glaze coatings
8. Waterproofing coatings
9. Maintenance paints
10. Metallic, e.g., aluminum paints
11. Swimming pool paints
12. Graphic art, e.g., sign paints
13. Mastic (thick) coatings
14. Multicolor (speckled) paints

The ARB wished to determine whether products, among these exempt classes, were available on the market which would meet the VOC limitations and be competitive in performance to conventional, solvent-thinned, coatings. Therefore, the ARB sponsored a study in 1979, performed by D/L Laboratories, to test architectural coatings among the exempt classes. A total of 89 low solvent and 57 conventional coatings representing eleven of the fourteen classes were tested. The results were published in 1980.

IV OBJECTIVE

The purpose of this study was to obtain and evaluate specified physical and performance properties of the following commercial available high solids or water borne (low VOC) coatings in order to determine if these products are competitive with equivalent conventional (high solvent) coatings:

Varnishes
- Interior gloss
- Interior satin
- Exterior

Wood stains
- Semi-transparent
- Opaque

Stain blocking primers

V PROCEDURE

Potential suppliers, including twelve companies supplied by the ARB, were contacted. These included raw material suppliers as well as coating manufacturers.

Letters requesting samples and enclosing Data Sheet forms were sent to these companies. See Appendix I. A total of 16 companies supplied a total of 55 products as follows. See Table 1.

Varnishes	Low VOC*	Conventional
Interior Gloss	7 (2)	7 (1)
Interior Satin	6	5
Interior/Exterior	2	2
Exterior	3	2
Wood Stains		
Semi-transparent	3 (1)	3 (1)
Opaque	3 (2)	3 (1)
Stain-Blocking Primers	6 (2)	3
	30	25

( ) Number submitted by raw material suppliers

* Below 450 g/l for varnishes, 365 g/l for stains and 250 g/l for primers.

Tests were limited to the following with the approval of the ARB:

		Varnishes			
		Interior	Exterior	Stains	Primers
1.	Solids Content			X	X
2.	Viscosity a. Initial b. 2 wks at 125°F	X	X		
3.	Storage Stability	X	X		
4.	Drying Time a. 77°F, 50% RH b. 40°F, High RH c. 90°F, Low RH d. 2 wks at 125°F	X X X	X X X	X X X	X X X
5.	Recoat - 24 hrs	X	X		
6.	Penetration			X	

	Varnishes			
	Interior	Exterior	Stains	Primers
7. Self-Sealing				
Unstained wood	X	X		X
Stained wood	X	X	X	
8. Gloss	X	X		
9. Resistance to Staining				X
Solvent Based Topcoat				
Water Based Topcoat				
10. Grain Raising	X	X		
Unstained				
Stained				
11. Water Cleanup (Low VOC)	X			
12. Adhesion				
Wet	X	X		
Dry	X	X		X
13. Time to Sand	X	X		
14. Yellowness Index		X		
a. Initial				
b. Exposed to UV				
15. Resistance To -				
a. Cold water	X	X		
b. Hot water	X	X		
c. Stains	X			
16. Blocking	X			
17. Accelerated Weathering				
a. Unstained wood		X		
b. Stained wood		X	X	
18. Recoat Weathered			X	

VII TEST RESULTS

The test data are presented in the Appendix section of this report. See Section IX "Glossary" for a description of the properties tested, Section X "Code and Abbreviation" for an explanation of the terms used and the Test Procedure (Appendix III) for the test methods used.

Inasmuch as some tests are subjective, the observations made have been scored using the following ASTM Scheme:

Score	Performance	or	Effect
10	Perfect		None
9	Excellent		Trace
8	Very good		Very slight
6	Good		Slight
4	Fair		Moderate
2	Poor		Considerable
1	Very poor		Severe
0	No value		Failed

The use of this numerical scheme avoids the necessity of inserting verbal descriptions in the Test Data tables.

The test results can be compared and analyzed most effectively by rating the data obtained using a scale from 10 to 0. This has been done using the Rating Scheme described in Appendix IV.

The ratings for all coatings are shown in Tables 8 thru 16 which correspond with the data shown in Appendix IIA thru IIJ.

The following properties have been described rather than rated since they do not necessarily have a significant effect on paint performance.

Viscosity
Gloss

The following properties have not been rated for the reasons given.

Set to touch (Drying time) - It is of minor importance.

Recoat (1 hour) - All are excellent exhibiting no defects when recoated.

Grain Raising - All are excellent exhibiting no raising of the wood grain.

Water Cleanup - All waterborne varnishes are excellent exhibiting no difficulty when brushes were washed in water.

Adhesion - All are excellent exhibiting no adhesion failure.

The following properties in which differences were observed were considered to be critical and have been so designated by an X to the left of that property in the tables.

Cold water resistance

Hot water resistance - Interior varnishes

Accelerated weathering - Exterior varnishes, Stains

Recoatability after weathering - Stains

Resistance to staining - Primers

The products can then be compared for relative performance by deciding whether or not they are acceptable based on the following criteria:

Rating of 6 or greater for Critical Properties as above

Rating of 4 or greater for all other properties

The ratings for the acceptable varnishes are shown in Tables 1 thru 3. None of the low VOC stains or primers were found to be acceptable.

Table 1

ACCEPTABLE INTERIOR GLOSS VARNISHES

	I-18* V	I-24 V	I/E-1 V	I/E-2 V	I-2 C	I-7 C	I-13 C	I-14 C	I-16 C	I-20 C	I-21 C	I/E-3 C
Viscosity	LM	LM	L	L	L	L	L	L	L	VL	L	VL
Viscosity Stability	9	9	10	9	9	9	10	10	9	10	9	10
Storage Stability	10	10	10	10	10	10	10	10	10	10	10	10
Drying Time												
Ambient	8	10	6	9	6	8	9	9	9	9	9	8
40°F, high RH	6	10	6	9	4	4	8	8	6	6	6	6
After storage	9	10	8	10	8	8	9	9	9	9	9	9
Self-Sealing	10	10	10	10	10	10	10	10	10	8	10	8
Gloss	H	HM	VH	VH	VH	VH	H	VH	VH	VH	HM	VH
Time to Sand	10	10	10	10	10	10	10	10	10	10	10	10
Resistance To -												
Cold water	10	10	10	10	10	10	10	10	10	10	10	10
Hot water	10	4	9	10	10	10	10	10	9	9	9	10
Stains	8	6	8	9	8	8	8	8	8	8	8	8
Blocking	10	6	10	8	10	10	10	10	10	10	10	10

* Solvent thinned

V - Low VOC

C - Conventional

Table 2

ACCEPTABLE INTERIOR SATIN VARNISHES

	I-19* V	I-3 C	I-15 C	I-17 C	I/E-4 C
Viscosity	L	M	M	L	L
Viscosity Stability	8	9	8	9	9
Storage Stability	9	6	9	10	8
Drying Time					
Ambient	8	6	9	8	9
40°F, high RH	6	4	8	4	6
After storage	9	8	9	8	10
Self-Sealing	10	10	10	10	6
Gloss	M	M	ML	M	ML
Time to Sand	10	10	10	10	10
Resistance To -					
Cold water	8	10	10	10	10
Hot water	9	10	9	10	9
Stains	4	8	8	8	8
Blocking	10	10	10	10	10

* Solvent thinned

V - Low VOC

C - Conventional

Table 3

ACCEPTABLE EXTERIOR VARNISHES

	E-2* V	I/E-1 V	E-3 C	E-4 C	I/E-3 C
Viscosity	L	L	L	L	VL
Viscosity Stability	10	10	9	10	10
Storage Stability	10	10	9	10	10
Drying Time					
Ambient	6	6	8	8	8
40°F, high RH	6	6	6	6	6
After storage	4	8	8	8	9
Self-Sealing	10	10	10	10	8
Gloss	H	VH	ML	VH	VH
Time to Sand	10	10	10	10	10
Yellowness	4	4	4	4	6
Color Retention	9	8	9	8	6
Resistance To -					
Cold water	10	10	10	10	10
Hot water	9	9	8	9	10
Blocking	8	10	10	10	10
Accel. Weathering					
Unstained wood	8	9	6	9	8
Stained wood	8	10	6	10	9

* Solvent thinned

V - Low VOC

C - Conventional

Comparison Of Products

The products can be evaluated most effectively by averaging the results of the best two products, both low VOC and conventional then comparing them directly. This has been done in Table 17 below wherever at least two low VOC coatings are determined to be acceptable based on the tests conducted. The following are not included for the reasons given:

Interior Satin Varnish - Only one Acceptable low VOC coating

Semi-transparent Stains - No acceptable products

Opaque Stains - No Acceptable products

Stain Block Primers - No Acceptable products

This comparison demonstrates the following:

1. The two best low VOC interior gloss varnishes are generally equal in performance to the best conventional varnishes tested.

2. The best low VOC exterior varnishes are generally or slightly superior to the best conventional varnishes except for slightly slower drying, especially after storage.

Table 4

Best Competitive Products

Average Ratings	Interior Varnish		Exterior Varnish	
	Low VOC	Conv.	Low VOC	Conv.
Product Nos.	I-18 I/E-2	I-13 I-14	E-2 I/E-1	E-4 I/E-3
Viscosity Stability	9.5	10	10	10
Storage Stability	10	10	10	10
Drying Time				
Ambient	8.5	9	6	8
40°F, high RH	7.5	8	6	6
After storage	9.5	9	6	8.5
Self-Sealing	10	10	10	9
Time to Sand	10	10	10	10
Yellowness	--	--	4	5
Color Retention	--	--	8.5	7
Resistance To -				
Cold water	10	10	10	10
Hot water	10	10	9	9.5
Stains	8.5	8	--	--
Blocking	9	10	9	10
Accelerated Weathering				
Unstained wood	--	--	8.5	8.5
Stained wood	--	--	9	9.5

Effect Of VOC On Performance

The effect of decreasing solvent content, as VOC is reduced to acceptable ranges has a definite effect on some performance properties. A linear regression analysis of the performance ratings in Summary Tables 8-16 in the report demonstrate the following:

Interior Gloss And Satin Varnishes

Resistance to cold water, hot water and blocking is degraded.

Resistance to staining is slightly poorer

Exterior Varnishes

Resistance to cold water, hot water and blocking is degraded

Weathering is improved

Exterior Semi-transparent Stains

Penetration is slightly poorer

Weathering is about the same

Recoatability is slightly better

Stain-Blocking Primers

Resistance to staining with a water based topcoat is degraded considerably

There was no consistency with regard to the regression analysis data. Some performance parameters showed fairly good correlation with solvent content while other performance parameters could not be correlated in a stastically significant manner with solvent content.

Table 5 summarizes the number of coatings, both Low VOC and Conventional, which either met or failed the performance criteria.

The variation in total solids for most of the coatings tested is considerable as shown in Table 6. All of the low VOC products, with the exception of the semi-transparent stains, exhibit from moderate to extreme variation in solids content between samples as compared with the equivalent conventional samples. The average solids content of the low VOC products (except the exterior varnishes) and especially the primers are lower than that of the equivalent conventional products.

Table 5

SUMMARY OF RESULTS

Product (number tested) Performance Property	LOW-SOLVENT Acceptable	LOW-SOLVENT Not Acceptable	CONVENTIONAL Acceptable	CONVENTIONAL Not Acceptable
INTERIOR GLOSS VARNISHES (17)				
Resistance to Cold Water	6	3	8	0
Resistance to Hot Water	3	6	8	0
Resistance to Stains	9	0	8	0
Resistance to Blocking	9	0	8	0
All Other Properties*	8	1	8	0
INTERIOR SATIN VARNISHES (12)				
Resistance to Cold Water	3	3	6	0
Resistance to Hot Water	1	5	6	0
Resistance to Stains	5	1	5	1
Resistance to Blocking	5	1	6	0
All Other Properties*	6	0	5	1
EXTERIOR VARNISHES (9)				
Resistance to Cold Water	4	1	4	0
Resistance to Hot Water	5	0	4	0
Resistance to Blocking	5	0	4	0
Resistance to Acc. Weathering Unstained Wood	5	0	3	1
Resistance to Acc. Weathering Stained Wood	5	0	3	1
All Other Properties*	4	1	4	0
SEMI-TRANSPARENT STAINS (6)				
Penetration	1	2	3	0
Resistance to Acc. Weathering	2	1	3	0
Recoatability	3	0	2	1
All Other Properties*	0	3	1	2
OPAQUE STAINS (6)				
Penetration	0	3	3	0
Resistance to Acc. Weathering	3	0	2	1
Recoatability	3	0	2	1
All Other Properties*	2	1	0	3
STAIN-BLOCKING PRIMERS (9)				
Resistance to Staining Solvent Based Top Coat	6	0	3	0
Water Based Top Coat	2	4	3	0
All Other Properties*	1	5	2	1

* "All" includes other performance properties tested. See Tables 8-16

Table 6

SOLIDS CONTENT BY WEIGHT

	Low VOC				Conventional			
	No.	Range (%)	Δ (%)	Average (%)	No.	Range (%)	Δ (%)	Average (%)
Interior Gloss Varnish	9	27.0-56.2	29.2	35.5	8	41.2-50.7	9.5	46.5
Interior Satin Varnish	6	24.1-51.9	27.8	34.4	6	38.3-48.1	9.8	42.5
Exterior Varnish	5	33.2-57.6	24.4	49.7	4	45.3-49.2	3.9	47.0
Semi-Transparent Stain	3	21.2-26.8	5.6	23.9	3	22.1-33.1	11.0	27.6
Opaque Stain	3	24.7-58.5	33.8	38.5	3	30.0-55.2	25.2	46.1
Stain-Blocking Primer	6	6.6-53.1	46.5	43.3	3	51.7-70.5	18.8	63.9