STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
OFFICE OF TRANSPORTATION LABORATORY

INVESTIGATE ALTERNATIVES FOR SOLVENT-BORNE TRAFFIC PAINT

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16. ABSTRACT

Restrictions on the amount of volatile organic compounds emitted into the atmosphere during traffic striping operations have been drastically increased by the proposed rulings of the California Air Resources Board. To comply with these regulations, alternative materials for road delineation had to be investigated. These alternatives include water-borne paint and high solids coatings. The high solids coatings include the epoxies, polyester, hot melts and cold preformed plastic.

Work on the water-borne traffic paint was terminated before the final evaluation was made and research efforts were directed toward the high solids coatings. Final evaluation on the high solids coatings and any further work done on water-borne traffic paint will be reported at a later date.

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40	millimetres (mmm)
		.02540	metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2)	.09290	square metres (m^2)
	acres	.4047	hectares (ha)
Volume	gallons (gal)	3.785	litres (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic yards (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph)	.4470	metres per second (m/s)
	feet per second (fps)	.3048	metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G)	9.807	metres per second squared (m/s^2)
Weight Density	pounds per cubic (lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs)	4.448	newtons (N)
	kips (1000 lbs)	4448	newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb)	1.356	joules (J)
	foot-kips (ft-k)	1356	joules (J)
Bending Moment or Torque	inch-pounds (ft-lbs)	.1130	newton-metres (Nm)
	foot-pounds (ft-lbs)	1.356	newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi $\sqrt{in}$)	1.0988	mega pascals $\sqrt{metre}$ (MPa $\sqrt{m}$)
	pounds per square inch square root inch (psi $\sqrt{in}$)	1.0988	kilo pascals $\sqrt{metre}$ (KPa $\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{tF - 32}{1.8} = tC$	degrees celsius (°C)

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Pervo Paint Company, Los Angeles, California
Bauer Paint Company, Los Angeles, California
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Our appreciation also is extended to the late Mr. Tim Broyhill of Headquarters Shop, for the design and fabrication of a water-borne spray unit and subsequent conversion to a polyester spray unit.

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INTRODUCTION

The most common material used for traffic lane delineation is a white or yellow paint that, when applied to the pavement surface, results in a highly visible line with good durability. The paint used for this purpose is formulated to dry rapidly and normally contains a significant quantity of highly volatile solvents.

In July 1977, the California Air Resources Board proposed a model rule to local air quality control districts that would strictly limit the quantity of volatile organic compounds contained in a traffic marking material. The proposed rule was scheduled to become effective September 2, 1982 but in most cases, exemptions have been granted extending this date to September 2, 1984. A copy of the model rule for Architectural Coatings, which covers any coating applied to pavements, is in Appendix A.

As a result of the impending regulations, it is necessary to investigate practical alternatives that will comply with air quality rules. The coatings evaluated are shown in the following list and complete descriptions of the materials given in Appendix B.

1. Water-Borne Paint
2. Hot Melt Extruded Thermoplastic
3. Hot Melt Sprayed Thermoplastic
4. Flame-Sprayed Thermoplastic
5. Polyester Paint
6. Two-Part Epoxy Paint
7. Cold Preformed Plastic
8. Epoxy Thermoplastic

Most of the investigative work done on this part of the project was devoted to water-borne paint with lesser emphasis placed on the other materials. All of the delineation systems described, however, were evaluated by some laboratory tests and full-scale field application. The laboratory tests provide not only a general characterization and comparison of the materials evaluated, but also include the volatile organic compound content of the coatings. The full-scale field work describes actual application characteristics of the various materials and problems associated with their use. The performance of the various marking materials after application to the pavement surfaces is also discussed.

At the present time, the most readily available alternative to solvent-borne traffic paint appears to be water-borne traffic paint. While some restrictions would be required due to weather conditions, the majority of the year in California should be satisfactory for use of water-borne paint. This transition could be made without requiring new equipment. Thermoplastic marking materials also offer a practical alternative and should provide a more durable line. However, additional equipment would have to be purchased in order to apply any significant quantity of thermoplastic material. The remaining materials that were investigated, although having some desirable characteristics, pose application or performance problems that will require further development work.

This report covers all the investigative work done on water-borne traffic paints up to May 1981 when emphasis was shifted to high solids, long service-life coatings. Further work on high solids coatings will be reported at a later date.

CONCLUSIONS

Water-Borne Traffic Paints

- Hot and cold applied water-borne traffic paint is a viable alternative to solvent-borne paints.

- Service life of the water-borne traffic paints is equal to the conventional solvent-borne paints.

- Bead retention of the water-borne paints is excellent and considered superior to the solvent-borne coatings.

- Application of water-borne paints during winter months would be selective and depend on weather conditions.

- No specialized application equipment is necessary

Hydrocarbon Thermoplastic

- Hydrocarbon thermoplastic traffic line coating is a viable alternative to solvent-borne traffic paint.

- Hydrocarbon thermoplastic is not suitable for use in snow areas.

- In nonsnow areas, hydrocarbon thermoplastic has provided excellent service for six years.

- Bead retention in hydrocarbon thermoplastic is excellent

- The white hydrocarbon thermoplastic has good color stability for the service life of the coating.

- The yellow hydrocarbon has poor color stability after two years service.

- Specialized application equipment is required.

Two-Component Epoxy (100% Solids)

- The two-component epoxy coating (H. B. Fuller-Prismo) has shown inconsistent results, especially on portland cement concrete (PCC). One PCC test area, at 4000 foot elevation, failed badly in adhesion after four months of summer service. Another test area on asphalt concrete (AC) at 6000 foot elevation barely survived after one winter of snowplow and chain wear.

- At lower elevations, service life is excellent on PCC and AC.

- The color of the white two-component epoxy shows a pronounced yellowing after 1-1/2 years of service and is not acceptable for daylight delineation on PCC pavement.

- Bead retention is excellent.

- Dirt and road film pickup in the desert areas of Southern California is excessive. In some cases, daytime delineation is nonexistent

- The no-track time varies considerably with ambient and surface temperature. This system is not an instant dry coating.

- Specialized application equipment is necessary.

Two-Component Epoxy (65% Solids) EPO 108

- The two-component epoxy traffic coating (long pot-life) system is not considered a suitable replacement for the solvent-borne traffic paints.

- Service life is about the same as existing solvent-borne paints.

- Very poor adhesion has occurred on crosswalks and legends.

- Bead retention is poor.

Cold Preformed Plastic

- The 3M Stamark cold preformed plastic has shown a service life of five years with surface application on both AC and PCC surfaces and is an alternative to solvent-borne traffic paint where it is cost effective.

- After two years of service, the nighttime retroreflection is significantly decreased due to bead loss.

- Inlaid preformed tape has shown inconsistent service in snow areas.

- The preformed plastic tape has been satisfactory for legends and crosswalks when primer is applied.

IMPLEMENTATION

- The South Coast Air Quality Management District in Los Angeles has enforced the compliance of all air pollution regulations in the Los Angeles basin. To meet these regulations, 70,000 gallons of water-borne traffic paint have been ordered for use during 1983. This paint, and any additional orders, will be used primarily for application in the Los Angeles area. Smaller quantities will be applied in the San Bernardino, San Diego and San Francisco areas.

- As additional application equipment becomes available, thermoplastic will be applied more extensively, especially in the critical air pollution areas.

- Cold preformed plastic will continue to be applied in limited amounts where it is cost effective.

WATER-BORNE TRAFFIC PAINTS

A. Objectives

To develop a water-borne traffic paint suitable for use in the California hot striper and capable of cold application with nonheated application units.

1. Dry time around five minutes or less at the lowest heat of application possible.

2. Paint must be capable of withstanding the high shear of the kinetic heater used in the hot striper.

3. Viscosity as close to regular solvent-borne paint as possible, about 72 KU.

4. Ability to accept and retain post-applied glass beads.

5. Meet or exceed all air pollution regulations.

6. Exhibit storage stability without loss of properties.

B. Laboratory and Application Tests

Three paint companies expressed interest in the development of a rapid dry water-borne traffic paint; Bauer, Baltimore and Pervo. These companies submitted samples of their proprietary paints for laboratory tests and spray tests using our small scale hot striper with a kinetic heater.

After laboratory and spray testing, selected paints were purchased and applied operationally by a California hot striper with the kinetic heater and cold applied with the Wald machine in District 04, Oakland, California.

The series of paints submitted by Baltimore, Pervo and Bauer are summarized in Table 1. The usual paint physical constants are shown along with any tests done with our small scale hot striper using the kinetic heater. In general, the paint was gradually raised in temperature, a 4-inch wide stripe laid down and the no-track time determined at each paint temperature by running over the line with a regular sized passenger car. The line was sampled and dry film thickness and retained lbs beads per gallon of wet paint were determined in the laboratory. In conjunction with the ASTM D711 dry time determination, a dry through time also was determined concurrently by noting the time at which the light pressure of the thumb when rotated 90° while in contact with the film, does not break the film. This test does offer some idea of how the film breathes during the drying process. Sometimes a film will skin over rapidly and lead to a very short ASTM wheel time but the paint under the skin is still wet and has no strength to resist the passage of an automobile.

A laboratory method to screen paints sensitive to heat and shear is also included in the data. This was determined by using high speed shear in a Waring Blender to heat a pint sample of the paint to about 180°F, usually taking about 10 to 15 minutes to attain temperature. The top was sealed to prevent solvent loss. After shearing, the paint was placed in a pint can, sealed and allowed to set overnight and examined at 77°F. Gel formation or excessive viscosity

TABLE 1

Baltimore Paint and Chemical Company

Lab No. S	Vendor I.D.	Color	Vis KU	Solids %	(ARB) VOC GRS/L	ASTM Dry Min.	Dry Thru Min.	Heat-Shear Waring Blender	No-Track Time — Minutes Air °F	Heater °F	RH %	Dry Film Inches	Lbs Beads Gal	No Track
1177	232-292	W	100	70	130	30	40	To 135°F OK	57	-	54	.006	2.3	15
									57	-	54	.012	8.5	15
									64	-	54	.005	13.1	3
									70	115	50	.005	13.4	3
									70	120	50	Gelled		
1178	232-291	Y	102	69.8	130	40	45							
1196	232-310	W	70	71.6		35	40		75	-	45		None	6
									82	-	45		None	6
									86	-	45		Hvy	3
									86	112	45	Gelled		
1222	232-332	W	70	73.6		23	30		68	-	45	.005	13.4	5
									69	-	45	.009	7.5	6
									83	-	45	.005	None	4
									83	-	45	.007	17.9	2
									83	-	45	.008	4.6	3
									83	-	45	.007	6.9	3
1223	232-333	W	71	73.7		23	30		69	-	45	.007	15.3	5
									69	-	45	.008	14.7	5
									75	-	45	.010	None	8
									75	-	45	.008	21.0	3
									72	-	45	.007	10.6	3
									72	-	45	.006	11.2	3

TABLE 1 (Continued)

Baltimore Paint and Chemical Company

Lab No. S	Vendor I.D.	Color	Vis KU	Solids %	(ARB) VOC GRS/L	ASTM Dry Min.	Dry Thru Min.	Heat-Shear Waring Blender	No-Track Time — Minutes Air °F	Heater °F	RH %	Dry Film Inches	Lbs Beads Gal	No Track
1267	232-390	W	112	79.4				—Viscosity Too High—						
1269	232-389	W	92	75.7		18		To 160°F OK	49	143	74	.008	8.2	15
								To 190°F	49	163	74	.008	7.3	5
								Gelled O'nite	49	191	74	.008	4.7	2
									49	197	74	.007	None	3
									48	190	61	.007	9.2	1
									48	190	61	.008	7.1	1
1270	232-391	W	77	73.6		23			70	-	57	.006	None	10
									70	-	57	.006	9.0	6
1300	232-448	W	96	76.0		14	22	To 190°F OK Gelled O'nite	52	135	69	.004	10	10
									52	135	69	.005	13	10
									52	170	69	.005	10	6
									52	180	69	.005	8	4
									52	190	69	.005	8	1
1301	232-449	Y	95	75.7		12	23	To 190°F OK Gelled O'nite	57	185	60	.008	7.4	1
									57	200	60	.007	7.8	0.5
1303	232-475	W	104	75.3		27	32		47	200	74	.005	16.5	2
									47	192	74	.006	15.5	1
									47	199	74	.005	18	1
									47	197	74	.005	17.1	1
									47	175	74	.006	3.3	6

TABLE 1 (Continued)

Pervo Paint Company

Lab No. S	Vendor I.D.	Color	Vis KU	Solids %	(ARB) VOC GRS/L	ASTM Dry Min.	Dry Thru Min.	Heat-Shear Waring Blender	No-Track Time — Minutes Air °F	Heater °F	RH %	Dry Film Inches	Lbs Beads Gal	No Track
1338	-	W	91	67.7	217	23		To 155°F OK	68	169	60	.005	7.5	15
									68	197	60	.006	8.0	8
									68	213	60	.006	6.2	6
1380	3100	W	80	70	217	2.5	17	To 180°F OK	64	-	60	.005	7.0	7
									64	140	60	.005	6.2	2
									64	155	60	.005	6.0	2
									64	172	60	.006	7.1	1.5
									64	212	60	.005	7.5	0.5
1441	3101	Y	86	67.5	164	3	15	To 200°F OK Gelled	61	135	54	.005	8.0	3.5
									61	175	54	.006	7.0	2
									61	200	54	.005	7.3	1
1526	3210	W	73	71.5	193	9	28							
1542	3220	W	80	72.0		6	22	To 180°F OK O'nite 86 KU						
1543	3221	Y	72	71.3		6	22	To 180°F OK O'nite 95 KU						
1549	3221A	Y	93	69.2		6	18	To 180°F OK O'nite 94 KU						
1610	3220A	W	95	70.5	242	6	20	To 180°F OK O'nite 100 KU						

TABLE 1 (Continued)

J. E. Bauer Company

Lab No. S	Vendor I.D.	Color	Vis KU	Solids %	(ARB) VOC GRS/L	ASTM Dry Min.	Dry Thru Min.	Heat-Shear Waring Blender	No-Track Time — Minutes Air °F	Heater °F	RH %	Dry Film Inches	Lbs Beads Gal	No Track
1143	1030A9	W	87	57.2		90	Dry Time Too Slow							
1144	1056A9	Y	88	57.2		90	Dry Time Too Slow							
1432	1954A9	W	78	64.5	125	2	24	To 190°F OK O'nite 73 KU	61 61 61	- 145 177	52 52 52	Splatters Too Thin		
1433	1959A9	W	82			60	Dry Time Too Slow							
1434	1952A9	W	Paint Gelled in Can After 1/2 Hour on Roller — No Heat											
1435	1950A9	W	Paint Full of Bubbles											
1436	1955A9	Y	72	61.6	200	2.5	30	To 190°F OK O'nite 71 KU						
1453	1960A9	W	86			9		To 190°F Gelled	Contains Ballotini Spheres					
1454	1961A9	Y	86			7			Contains Ballotini Spheres					
1465	1979A9	Y	93	69.1	209	6.5	24	To 180°F Gelled						
1466	1980A9	W	90	70.0		10	27	To 190°F OK O'nite 130 KU	59 59 59	85 147 175	50 50 50	 Gelled		6 4

TABLE 1 (Continued)

J. E. Bauer Company

Lab No. S	Vendor I.D.	Color	Vis KU	Solids %	(ARB) VOC GRS/L	ASTM Dry Min.	Dry Thru Min.	Heat-Shear Waring Blender	No-Track Time — Minutes Air °F	Heater °F	RH %	Dry Film Inches	Lbs Beads Gal	No Track
1478	1998A9	W	82	69.4		11	23	To 185°F OK O'nite 89 KU		Excessive Settling				
1479	1999A9	Y	86	70.5		19	33	To 185°F OK O'nite 102 KU						
1492	2006A9	W	94	72.7	156	4.5	16	To 185°F OK O'nite 84 KU		Some Hard Dry Settle				
1493	2007A9	Y	90	73.6	160	3	16	To 185°F OK O'nite 84 KU		Some Hard Dry Settle				
1519	JS1	W	82			13	24	To 185°F OK O'nite 84 KU	62	-	54	.005	7.2	16
									62	135	54	.005	7.5	11
									62	180	54	.005	8.0	5
1520	JS2	W	72			17								

increase indicated poor stability. When viscosity measurements were taken, the percent solids was also determined and if more than 0.5 percent solvent loss had occurred, water was added back to bring solids up to original solids content before measuring viscosity.

Summary of Laboratory and Application Tests

Baltimore Paint and Chemical Company was the first to express interest in the water-borne emulsion paints. Initial laboratory and application tests showed surprisingly fast dry times for water-borne paint. Initial bead retention was excellent as shown by the high levels of beads retained in the film. Heat stability appeared to be a problem, especially at the higher temperatures (190°F). Of course, these initial tests were performed on small batches (5 gallon) rather than full-scale production batches of 1000+ gallons. In spite of the apparent heat sensitivity, the Baltimore white 232-448 and yellow 232-449 were selected for field trials. It was imperative to get field experience as soon as possible due to long procurement delays between date of order and actual delivery.

The Pervo Company series produced very satisfactory dry times and initial bead retention. Although the question of heat stability is still present, it manifested itself in the form of increased viscosity rather than a solid gel formation.

J. E. Bauer Company had their share of problems as indicated in Table 1; again the necessity of getting paint into a field application as soon as possible did not provide much time for extended laboratory investigation. The 2006A9 and 2007A9 were selected for field trials.

C. Operational Field Applications

The total quantity of water-borne traffic paint applied in District 04 (Oakland) is as follows:

Baltimore Paint and Chemical	TM211E (232-449)	-	Yellow	500 Gals.
Baltimore Paint and Chemical	TM212V (232-448)	-	White	1000 Gals.
Pervo Paint Company	3100	-	White	1000 Gals.
Pervo Paint Company	3101	-	Yellow	1000 Gals.
Pervo Paint Company	3220	-	White	1000 Gals.
Pervo Paint Company	3221	-	Yellow	1000 Gals.
Pervo Paint Company	3210	-	White	220 Gals.
Pervo Paint Company	3210	-	White**	2000 Gals.
Pervo Paint Company	3211	-	Yellow**	2000 Gals.
J. E. Bauer Company	2006A9	-	White*	1000 Gals.
J. E. Bauer Company	2007A9	-	Yellow	1000 Gals.
		Total		11720 Gals.

*Batch returned to Bauer due to poor condition of paint which had completely settled to dry hard state and could not be redispersed.

**In storage, Oakland Yard for 8 months before application.

Baltimore Paint and Chemical Company

The physical constants of the applied paint were as follows:

	White TM 212V	Yellow TM 211E
Viscosity, KU	95	87
Solids, % weight	73.3	74.9
ASTM dry time, minutes	18	13
Weight, lbs/gal	13.4	13.6
Type Resin	Vinyl Acrylic	Vinyl Acrylic

Application Data - Baltimore TM212V and TM211E
Applied by hot striper unit 438

		Line Type	°F Air	°F Surface	°F Paint	RH %	Dry Thick Ins	Lbs Beads Gal	No Track Min
11-27-78	John A. Nejedly Bridge Deck, coarse texture PCC	6 inch White Bicycle Lane	63	61	190	60	-	-	10
		Yellow	63	61	203	60	Paint started to gel		
		Edgeline	63	61	190	60	.008	8.0	3
11-28-78	SR84-Vallecitos Road PM 19/PM 20 New AC Blanket	Yellow Center Line	63	72	140	48	.006	-	4
		White Edgeline	63	72	140	48	.009	5.0	4
11-29-78	SR82, San Mateo to Belmont, AC	Yellow Median	65	70	190	68	.009	8.3	2
		White Edgeline	65	70	180	68	.005	8.3	3

Summary

No cones or traffic control were used in these applications. The application on the Nejedly Bridge at a paint temperature of 200°F+ showed the start of gel formation. The next day when operations began, the paint had completely gelled up in all the paint lines. The main tank, not being heated, was not gelled. The paint extruded through the guns like spaghetti. After removing the gun tips and pumping out the gelled material, operation was satisfactory. Subsequent applictaions were made at 140°F to prevent further gelation. At 140°F, the operation was satisfactory and the paint sprayed normally.

On SR82, the yellow median line was applied satisfactorily under heavy traffic. Due to heavy fog during the night, the paint did not thoroughly dry and remained soft. Heavy traffic, especially at intersections where left turns were made over the line, smeared the paint so that some areas looked like a barrel of paint had been spilled. This unexpected fog and mist showed the inability of the water-borne system to cure under adverse conditions. Where traffic had not passed over the "softened" lines and subsequent warm weather allowed the film to cure, the line was very good and capable of withstanding wet weather. This was observed on the edge line application in Belmont which had the same wet fog condition but no traffic to smear the line.

The application on SR84, Vallecitos Road, being inland, was most satisfactory with dry times of four minutes at 140°F and good bead retention. This area was not affected by the fog as was the San Mateo-Belmont installation.

Although this first attempt with water-borne traffic paint did not come up to the standards we have been accustomed to with solvent-borne paints, it brought out some of the limitations of this material under adverse weather conditions.

Pervo Company - 3100 and 3101

The physical constants of the applied paint were as follows:

	White 3100	Yellow 3101
Viscosity, KU	95	95
ASTM Dry, minutes	2	2
Dry Thru, minutes	15	14
Solids, % weight	70.9	69.4
Lbs/Gal	13.1	12.7
Grind	5	3
% Pigment	54.8	50.4
Grs. VOC/Liter-H2O (CARB)	243	223
Reflectance, green filter	94.2	65.0
Dry Opacity	0.96	0.75
Yellowness Index	0.04	-
Resin Type	Acrylic	Acrylic
Heat-Shear to 190°F	OK	Gelled at 175°F

Condition of Paint After 4-1/2 Months Storage

Due to scheduling difficulties, the paint was held in the 55 gallon drums for 4-1/2 months before use. During this period, the white (3100) had increased in viscosity from 95 to 130+ KU making transfer of the paint very difficult. It was necessary to add about 5 gallons of water to each drum to pump the material into the striper tank. Viscosity of the yellow actually decreased from 95 to 79 KU.

Summary - Pervo 3100 and 3101

To prevent gelling, this batch was run at a paint temperature of 130°F and no problems were encountered with gel formation. When paint temperature lowered to 100°F, the line width dropped from four inches to three inches so temperature was kept at 130°F. In general, application was satisfactory with no-track times averaging four minutes at

Application Data Pervo 3100 and 3101

Applied by Hot Striper Unit 438

Date	Location	Line Type	Air	°F Surface	Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
9-12-79 to 9-18-79	SR4, Hercules to Martinez, 4 lane divided, new AC blanket, east & west, 3-1/2 miles	White Edge Line	106	140	130	10	.007	4.1	4
			95	130	130	15	.006	3.8	4.5
			95	130	130	15	.006	11.0	3.0
			100	148	130	5	.008	5.1	4.0
		Yellow Median	85	118	130	34	.008	3.0	4.0
			85	118	130	34	.006	3.4	3.0
			85	118	130	34	.008	3.1	4.0
			75	128	130	40	.006	3.0	3.0
			75	128	130	40	.005	1.9	3.0
			75	128	130	40	.005	2.6	3.0
			75	128	130	40	.005	1.6	3.0
		White Broken Line	73	95	130	54	.006	2.8	3.0
		White Edge Line	73	95	130	54	.008	4.0	3.0
			73	95	130	54	.010	3.6	7.0
			73	95	130	54	.007	4.2	4.0
9-19-79	US 101, Rhonert Park O/C. New AC blanket all ramps & bridge deck	Yellow Median	79	90	130	52	.008	4.5	4.0
		White Edge	79	90	130	52	.007	4.6	4.0
9-20-79	US 101, Storey Road Realignment	Yellow Median	82	93	130	49	.009	3.3	8.0
		White Edge	82	93	130	49	.008	3.7	5.0

0.006 to 0.008 inch dry thickness. Some bead delivery problems were encountered on SR4 where bead levels were low but beads were well embedded into the film. Excessive viscosity increase of the 3100 with storage, and, conversely, a viscosity decrease of the 3101 indicates stability problems with these water-borne systems.

Pervo 3220 and 3221

The physical constants of the applied paint were as follows:

	White 3220	Yellow 3221
Viscosity, KU	81	87
ASTM Dry, minutes	7	8
Dry Thru, minutes	22	24
Solids, % weight	70.9	67.9
Lbs/Gal	13.1	12.8
Grind	4	3.5
Pigment, % weight	54.0	51.6
Grs. VOC/Liter-H20 (CARB)	220	250
Reflectance, green filter	96	67
Dry Opacity	0.90	0.90
Yellowness Index	0.04	-
Resin Type	Acrylic	Acrylic
Heat-Shear to 180°F	OK,Vis 84 KU	OK,Vis 107 KU

After two months storage, there was no problem with pumping either white or yellow paints into the striper. Pumping took about three minutes per 55 gallon drum. Suspension was excellent and no settling occurred.

Application Data Pervo 3220 and 3221

Applied by Hot Striper Unit 203

Date	Location	Line Type	Air	°F Surface	Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
7-21-80	SR17, Nimitz Freeway, north and southbound from Mowrey Ave.	White Edge	76	90	120	64	.004	3.1	2
			76	90	120	64	.006	3.7	2
			76	90	120	64	.008	3.3	5
7-23-80	to Xn of SR237 PCC. Total 7 miles north and 7 miles south	Yellow Median	75	98	130	67	.007	3.7	3
			75	98	130	67	.007	3.0	3
			84	115	130	56	.008	2.7	3
7-25-80	SR1, Gualala, 2 lane, new AC blanket-3 miles	Yellow Center Line	57	90	130	70	.007	2.0	5
			57	90	130	70	.008	2.0	5
7-28-80	SR680 from 680 CC9[97] to CC0[00]	Yellow Median	100	120	125	28	.008	3.0	3.5
			102	122	125	29	.007	2.9	4
7-29-80	10 miles north & 10 miles south PCC		102	122	125	29	.005	3.2	3
			102	122	125	29	.004	4.4	2
7-30-80	SR116, Sebastopol Keating and N. Main St., AC	Double Yellow Median	84	118	125	42	.010	3	9
		white 8" Turn	84	118	125	42	.010	None	7

Application Data Pervo 3220 and 3221

Applied by Hot Striper Unit 203

Date	Location	Line Type	Air	°F Surface	Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
7-29-80	SR29 from Trancas	White 8" Turn Lane	85	130	125	50	.015	-	30
7-31-80	to Salvador St.	White Edge Line	105	130	125	28	.007	2.0	2
8-12-80	New AC blanket		80	118	120	45	.004	3.0	2
8-14-80	northbound 2 lanes		80	118	120	45	.005	3.4	2
8-14-80		Yellow Median	71	105	120	66	.006	4.9	5
8-5-80	SR680 from Jn	White Edge Line	85	110	130	40	.004	3.0	2
	580-680 to Alcosta		85	110	130	40	.004	3.0	2
	eastbound, PCC								
8-5-80	SR580 Diamond	White Edge Line	85	110	160	40	.003	3.4	1
	Commute Lane		85	110	180	40	.004	3.4	1
	grooved PCC		85	110	180	40	.004	4.6	1
			85	110	120	40	.004	4.3	1
8-28-80	SR121, South	White Edge Line	77	97	125	50	.006	3.0	3
	Jefferson, NAPA		77	97	None		.008	3.7	4
			77	97	None		.009	2.1	4

Summary - Pervo 3220 and 3221

Application properties of both paints were excellent and showed considerable improvement over the 3100 and 3101. Paint suspension in the 55 gallon drums was excellent and pumping rates from the drums were about 20 gpm.

Bead retention and nighttime visibility were very good on both white and yellow. Increasing the paint temperature on the white up to 180°F did not affect the flow properties of the paint or the line width. Increasing the paint temperature of the yellow to 180°F did cause flow problems as seen by decreasing line width from 4 inches at 130°F to 2-1/2 inches at 180°F. When temperature was returned to 130°F, line width promptly increased back to 4 inches. In both the white and yellow paints, increasing the paint temperature did not significantly decrease the dry time. About 120°F to 130°F was found to produce good paint flow and spray pattern.

Application on fresh AC surfaces did not result in any bleed-through or adhesion problems.

Pervo Co. - Cold Applied Code 3210, white

The physical constants of the applied paint were as follows:

Viscosity, KU	72
ASTM Dry, minutes	14
Dry Thru, minutes	30
Solids, % weight	69.5
Lbs/Gal	12.7
Grind	6
Pigment, % weight	51.5
Grs. VOC/Liter-H2O (CARB)	244
Reflectance, green filter	90
Dry Opacity	0.92
Yellowness Index	0.03
Resin Type	Acrylic

Suspension in the 55 gallon drums was excellent. Paint pumped easily into the striper in about two minutes per barrel.

Application was made with the Wald striper, no heat, using air atomized Binks 33 paint guns.

Summary - Pervo 3210 Cold Applied

The 220 gallons applied through the Wald striper, although a small quantity, showed the difference in spray characteristics of the water-borne paint. The paint splattered considerably and was not sufficiently atomized to produce a smooth splatter-free line. Since no atomizing air control is available on the Wald, the paint flow was gradually reduced until paint flow matched the available atomizing air. This combination produced a very smooth splatter-free line. With some plumbing changes to increase the amount of atomizing air at full paint flow, good operation could be realized.

Application Data Pervo 3210, Cold Applied

Applied by Wald Striper

Date	Location	Line Type	Air	°F Surface	Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
12-8-80	SR152 from J^n	White Edge Line	55	70	-	44	.006	6.0	10
	SR156 east to		55	70	-	44	.005	4.3	11
	Merced County		55	70	-	44	.005	4.7	11
	Line, 2 lane AC		55	70	-	44	.005	5.1	10
12-9-80	SR84 Livermore	White Edge Line	51	74	-	53	.003	9.9	7
	from J^n SR580 to		51	74	-	53	.010	9.1	
	J^n SR680		51	74	-	53	.006	5.1	7
	2 lane AC		51	74	-	53	.005	4.5	8
			51	74	-	53	.007	3.9	10
			51	74	-	53	.007	1.0	10
12-10-80		White Edge Line	48	70	-	59	.004	5.2	8
			48	70	-	59	.003	5.9	8
			55	73	-	53	.004	12.2	7
			55	73	-	53	.006	7.4	8
			55	73	-	53	.003	16.5	6

Application temperatures were not ideal for water-borne paint, ranging from 48 to 58°F. In spite of the splatter, the lines provided good delineation and excellent bead retention. Dry times varied from 7 to 10 minutes and were considered very good for a cold-applied paint.

J. E. Bauer Company - Yellow Code 2007A9

The physical constants of the applied paint were as follows:

Viscosity, KU	78
ASTM Dry, minutes	5
Dry Thru, minutes	16
Solids, % weight	72.1
Lbs/Gal	13.3
Grind	2.5
Pigment, % weight	50.0
Grs. VOC/Liter-H20 (CARB)	160
Reflectance, green filter	58
Dry Opacity	0.93
Resin Type	Not Known

The white paint (2006A9), in 55 gallon drums, was in such poor condition due to excessive hard dry settlement, that it could not be redispersed with a power mixer. The 1000 gallons of white was returned to Bauer and only the yellow was applied. The yellow did show settlement but not as severe as the white and could be redispersed satisfactorily.

Summary - J. E. Bauer Company, Yellow 2007A9

The Bauer yellow showed satisfactory application properties. Again, it was found that a paint application temperature of 180°F did not result in significantly faster

Application Data J. E. Bauer 2007A9 Yellow

Applied by Hot Striper Unit 203

Date	Location	Line Type	Air	°F Surface	Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
8-28-80	SR1 from PM 0^{00}	Yellow Broken	72	92	140	60	.005	1.3	3
	to PM 15^{84}	Center Line	66	98	140	65	.009	1.0	5
8/21/80	2 lane AC		56	75	130	80	.009	4.2	6
			57	75	130	73	.005	4.8	5
8-27-80			60	74	180	78	.010	1.4	3
			60	74	180	78	.008	1.2	5
			60	74	130	75	.007	1.7	2
8-26-80	SR13 from J^{n}	D. Yellow	52	68	150	92	.010	1.7	5
	SR24 north to	Median and	52	68	150	92	.005	2.0	2
	Claremont	Center Line	56	77	150	85	.007	1.0	5
		Broken							
8-28-80	SR29 and SR121	D. Yellow	60	85	125	78	.009	1.2	4
	J^{n} new AC blanket	Center Line	60	85	125	78	.008	2.2	2
8-29-80	SR29 from South		70	102	-	60	.006	4.0	4
	Jefferson to								
	SR121, 4 lane AC								
9-3-80	SR680 Benicia-	Yellow Median	74	110	130	60	.008	2	6
	Martinez Bridge		85	110	120	50	.007	2.7	3
9-4-80	SR4 Martinez	Yellow Median	75	108	120	63	.008	2.4	4.5
	from PM 5^{00} to		75	108	120	63	.007	2.5	3
	PM 18^{83} east &		70	94	120	62	.009	1.5	5
	west, 4 lane		70	94	120	62	.009	1.8	5
	PCC		70	94	120	62	.005	1.5	3
			70	94	120	62	.009	2.1	5

dry times. Also, the application with no heat resulted in narrow lines, and about 130°F gave the best spray application. The Bauer yellow did not show the increased viscosity reaction at 180°F. Based on these tests with Pervo and Bauer, we have revised our requirements for water-borne paints to be able to withstand 180°F shear test. Application at this temperature does not yield any significant decrease in drying time and would only serve to hasten the wear on the heater seals. It would appear that temperatures in the 120 to 130°F range should yield good spray patterns and dry time for the water-borne systems.

D. Inspections of Water-Borne Traffic Paint Test Areas

Baltimore Paint and Chemical
Applied 11-27/29-78
Inspected 9-21-79

All original double yellow islands have been replaced with permanent raised curbs so much of the original yellow has been covered by construction. Toward Belmont, some of the original yellow median lines are still visible. Lines are very dirty but beads are quite visible along with traces of the original paint that was smeared due to the heavy fog. The edge line at Belmont is still intact and with good bead retention but is very dirty. Service life in this area of heavy traffic is estimated at 10 months for the water-borne paint.

SR84, Vallecitos Road, has been freshly restriped. The original water-borne paint was well worn on the center line of this busy two-lane road. Traces of beads are visible where the old paint shows. The estimated service life for this area is about 10 months.

Pervo Hot Applied 3100 and 3101

SR4 Hercules to Martinez
Applied 9-12/18-79
Inspected 10-10-79

There is a full complement of ceramic and retroreflective markers on the white broken line. Both the white broken lines and yellow median lines are in excellent condition with good bead retention.

Inspected 3-20-80

It is difficult to evaluate white broken lines with ceramic markers installed, but observation of paint between buttons looked very good with good bead retention. Yellow median stripes are in good condition with good bead retention.

U.S. 101 Rhonert Park
Applied 9-19-79
Inspected 3-20-80

All yellow median and white edge lines are in good condition in spite of very heavy traffic volume over this overcrossing to Rhonert Park Expressway. Some intersections are showing signs of wear at locations of turning and crossing. Bead retention is good. In general, service wear is considered very good for one coat of paint over a new AC blanket.

Pervo Hot Applied 3220 and 3221

SR17 Nimitz Freeway
Applied 7-21/23-80
Inspected 1-31-81

All white edge lines are in excellent condition with good color and bead retention. The yellow median is also satisfactory with good color and bead retention. Edge lines on various ramps are also in good condition.

Inspected 1-27-82

Area was restriped early in January 1982 due more to dirt pickup than wear. Service life is estimated at about 1-1/2 years for this area of extremely heavy traffic volume (100,000 ADT).

SR1 Gualala
Applied 7-25-80
Inspected 8-1-80

Section had been restriped with thermoplastic and could not be evaluated.

SR680 from 680CC 9^{97} to 680CC 0^{00}
Applied 7-28/29-80
Insepcted 1-12-81

Yellow median was in excellent condition with good color and bead retention.

Inspected 1-27-82

Line was recently restriped before inspection, so service life is about 1-1/2 years.

SR29 Trancas to Salvador Street
Applied 7-29-80 to 8-14-80
Inspected 4-8-81

Although the white broken line had been installed with a full complement of raised markers, the lines were in excellent condition. The white edge lines and yellow median were also in good condition showing good color and bead retention.

SR680 from Junction 580-680 to Alcosta
Applied 8-5-80
Insepcted 1-12-81

White edge line is in excellent condition. Color and beads are very good.

Inspected 1-27-82

Area was freshly painted after 1-1/2 years.

SR580 Diamond Commute Lane
Applied 8-5-80
Inspected 1-12-81

Condition was excellent with good color and beads.

Inspected 1-27-82

Paint was in very good condition and beads and color were still good.

Pervo Cold Applied 3210

SR152 from Junction SR156 to Merced County Line
Applied 12-8-80
Inspected 1-25-82

White edge lines have a worn look (probably due to splatter during application) where thin spots are showing through. Condition good in spite of the uneven coverage during application. The beads were still visible. This area is due for repainting. Truck traffic is heavy in this area.

SR84 Livermore from Junction SR580 to Junction SR680
Applied 12-9/10-80
Inspected 1-26-82

White edge line in this area is in very good condition with good color and bead retention.

J. E. Bauer Company Hot Applied 2007A9

SR1 from PM 0.00 to PM 15.84
Applied 8-20/27-80
Inspected 1-15-81

The yellow center line was in excellent condition all through this test section of two-lane narrow AC road with many sharp turns and steep grades. The beads and color were also very good.

Inspected 1-28-82

Unfortunately, excessive rainfall in this area had caused many mud slides and slipouts necessitating restriping. In some areas where remains of the original stripe could be found, the line was in remarkably good condition and still contained beads.

SR13 from Junction SR24 to Claremont
Applied 8-26-80
Inspected 1-13-81

Double yellow median shows good color and beads and no wear. The two-lane section with yellow centerline shows well in spite of heavy traffic on this narrow, winding road (ADT 30,000).

Inspected 1-27-82

The double yellow median was very dirty and the color was faded. Considerable dirt and debris had collected in this median due to the raised concrete bars for dividers; this needs restriping. The two-lane section with yellow centerline was also worn and needs restriping.

E. Laboratory Testing Water-Borne Traffic Paints

Taber Abrasion

Taber abrasion tests were run per Federal Test Standard 141B, Method 6192 with CS17 wheels and 1000 gram weights.

$$\text{Wear Index} = \frac{(A-B)\ 1000}{C}$$

Where A = Weight in milligrams before abrasion
B = Weight in milligrams after abrasion
C = Number of cycles of abrasion recorded

Samples were drawn down to a 0.015 inch wet film thickness and cured 18 hours at 77°F plus 24 hours at 120°F. Results are listed in Table 3.

TABLE 3

Taber Abrasion Resistance of Water-Borne and Solvent-Borne Paints

Paint	Type	Wear Index
Pervo 3220 White	Water-Borne	165
Pervo 3210 White	Water-Borne	160
Bauer 2007A9 Yellow	Water-Borne	160
Fast Dry White	Solvent-Borne	270
Rapid Dry White	Solvent-Borne	230

These tests indicate the water-borne paints to be about 1-1/2 times more abrasion resistant than the present solvent-borne paint. Service life on the road test sections indicates wearability to be at least equivalent to the solvent-borne paints.

Scrub Resistance

Scrub resistance tests run per ASTM D2486 using the 0.010 inch shim, nylon brush and Leneta scrub medium abrasive type, Item SC-2. All paints drawn down with a 0.010 inch

gap doctor blade on black Leneta scrub test panels, 6-1/2 in. x 17 in., form P-121-10N. The film was cured one week at 77°F before the test and the dry film thickness was measured with a micrometer. Results are shown in Table 4 as an average of three runs.

TABLE 4

Scrub Resistance of Water-Borne and Solvent-Borne Paints

Paint	Type	Dry Film Thickness Inches	No. Cycles at Failure
Pervo 3210	Water	0.003	669 (650,696,660)
Pervo 3220	Water	0.003	577 (550,600,580)
Bauer 2007A9	Water	0.005	1825 (1981,1760,1735)
Rapid Dry	Solvent	0.003	482 (495,460,490)
Fast Dry	Solvent	0.003	552 (500,590,566)

As in the Taber abrasion tests, the water-borne paint shows more scrub resistance than the solvent-borne paint by a factor of about 1.2. The Bauer paint, even considering the higher film thickness, seems to be very scrub resistant. Road service tests showed the Bauer to have excellent properties, but not on the same scale as indicated by the scrub tests.

It is interesting to note here that Federal Specification TT-P-1952b, Acrylic Emulsion Paint for Traffic and Airfield Marking, requires a minimum of 300 cycles for scrub resistance requirements.

Heat Stability

The water-borne paints were tested for heat stability in a one-pint closed can for a week at various temperatures as shown in Tables 5, 6 and 7.

TABLE 5

Viscosity Stability for One Week at Various Temperatures

Paint	Initial Vis KU	Viscosity 120°F	KU After One Week at: 130°F	140°F
Pervo 3210	74	93	99	107
Pervo 3220	90	107	109	116
Pervo 3221	96	141	141+	Gel

TABLE 6

Viscosity Stability After 26 Days at 120°F

Paint	Initial Viscosity KU	Viscosity After 26 Days at 120°F, KU
Pervo 3210	74	101
Pervo 3220	90	109
Pervo 3221	96	Gel

TABLE 7

Viscosity Stability at 70°F-75°F

Paint	Initial Vis KU	Time of Storage Months	Final Vis KU
Pervo 3210	72	3.5	74
Pervo 3220	81	8.5	90
Pervo 3221	87	8.5	96

Examination of data in Tables 5, 6 and 7 indicates storage of these water-borne paints could present a problem in the hotter areas of California where summer temperatures reach 100+°F. This viscosity increase should not affect stripers with heat capability but for cold application, these high viscosities would lead to application problems, especially with air atomized guns.

Freeze-Thaw Tests

Freeze-thaw tests were run per ASTM D2243. Samples in a closed one-pint can were kept at 15°F for one week, allowed to return to 77°F, and the viscosity measured as shown in Table 8.

TABLE 8

Freeze-Thaw Tests, Water-Borne Paints

Paint	Initial Vis KU	After One Week at 15°F KU
Pervo 3210 (white)	74	74
Pervo 3220 (white)	90	89
Pervo 3220 (yellow)	96	102

The yellow paint (3221) appears to be more sensitive than the white, but the data indicate that freeze-thaw would not present a potential problem as serious as the heat stability.

Spray Application Tests, Cold-Applied Water-Borne Paint

Spray tests were conducted with a small air-atomized paint striper to determine the basic differences between water-borne and solvent-borne paints when applied with an air-atomizing pressure-fed system. The unit has a Binks 61 gun with full control over both atomizing and pot pressure air. Paint flows were determined at various pot pressures at 48°F. Then at various pot pressures, the atomizing air was adjusted to produce a smooth splatter-free line. Tests were run at 48°F to try and correlate with the field application of the Pervo 3210 which was applied in cold weather.

Results are tabulated in Table 9.

TABLE 9

Spray Characteristics of Water- and Solvent-Borne Paint

Pot Pressure psi	Paint Flow, gpm		Minimum Atomizing Air, psi	
	Pervo 3210	Solvent Type	Pervo 3210	Solvent Type
45	0.05	0.07	75	60
60	0.07	0.08	75	60
75	0.08	0.09	90	60
90	0.10	0.11	90	60

As seen by Table 9, the atomizing air requirement for the water-borne paint is higher than for the solvent-borne. This is in agreement with field observations during the cold application of Pervo 3210 through the Wald machine which uses air-atomizing guns.

To determine the optimum viscosity for air-atomized application, Pervo 3220, with a viscosity of 81 KU, was run through our air-atomized lab unit. Excessive splatter and very poor spray pattern resulted. Water was added in small increments to reduce the viscosity and the spray pattern again was checked. It was found that a satisfactory smooth, splatter-free line was produced at a maximum viscosity of 74 KU.

F. Compositional Water-Borne Formulas

Some preliminary work has been done on laboratory compositional formulas for water-borne traffic paints. The following commercial resin emulsions were examined:

Resin	Manufacturer	% Solids	Type
MV9	Rhom & Haas	45.5	Acrylic
AC64	" "	60.0	"
AC507	" "	46.5	"
AC707	" "	65.0	"
98-980	Reichhold	65.0	Vinyl-Acrylic
40-140	"	65.0	" "
92-100	"	75.0	Water-Reducible Alkyd
98-967	"	75.0	" " "
SF7823-19	"	75.0	" " "

The purpose was to develop a system with the lowest viscosity and fastest dry time in addition to good stability and flow properties. The water-borne phase of this project was de-emphasized before any formulas were selected for further testing. Thus, the work done is described briefly and the indicated formulas are possibilities that might provide an acceptable water-borne traffic paint.

The composition of representative formulas for each emulsion is shown in Table 11.

All paints were made on a Cowles dissolver at low speed. All the pigment, soya lecithin, ethylene glycol and Texanol, along with half the emulsion, antifoam and water, initially were charged and dispersed to a 3 grind. The Texanol and the remainder of the emulsion, water and IPA were then added and sheared. Then 28 percent NH_4OH was added to adjust pH to 9.0.

The constants of PT 1161 and PT 1164 are shown in Table 10.

TABLE 10

Constants of Laboratory Formulated Water-Borne Paint

Paint Type PT No.	%Solids	$\%H_2O$	VOC'S Grs/L-H_2O	PVC	Vehicle Solids%	Heat Stability 120°F - 1 Week Starting KU Final KU
1161 Cold Applied	71.6	23.1	106	51.8	40.5	72/72
1164 Hot Applied	74.3	20.6	103	54.6	42.6	95/93

Summary Compositional Formulas

The water reducible alkyds, Beckosol 92-100, 98-967, and SF 7823-19, all produced slow drying paints of over 30 minutes and were not pursued further.

TABLE 11

Composition of Water-Borne Traffic Paints

*Pounds Per 100 Gallons

PT No.	MV9	AC64	AC507	AC707	98-980	40-140	Tamol 731	Texanol	$CaCO_3$ 25-11	MicroCel T-70	H_2O	IPA	Vis KU	ASTM Dry Min.	Dry Thru Min.
1088	500						17	28	680				77	24	29
1114		400					35	17	445	40	98	60	82	10	15
1130			400				30	20	450	40	38	100	98	5	18
1143			400				30	20	450	40	61	80	83	6	20
1144			400				30	20	495		61	80	76	8	45
1150			400				30	20	472	20	61	80	78	8	35
1152			500				30	20	500	40	48		96	16	19
1135				286			30	20	450	40	150	100	73	12	18
1160				350			30	20	520	40	190		72	22	22
1161				350			30	20	560	40	175		72	19	22
1164					359		30	20	627	40	150		95	10	15
1107						500	35	17	445	40	76	17	96	10	15

*All Formulas Contain 10 lbs Soya Lecithin
5 lbs Foamaster O
75 lbs TiO_2 (Rutile)
25 lbs Ethylene Glycol + about 2 lbs NH_4OH to adjust pH to about 9.0

Examination of Table 10 shows that rapid drying water-borne traffic paints with low viscosity can be made with the use of isopropyl alcohol (IPA) as indicated in PT 1114, 1143 and 1135. However, the alcohol gels up the paint in a few days in varying degrees from solid gel to heavy paste. The function of the Micro Cel T-70 is shown in PT 1143 with a loading of 40 lbs and ASTM dry time of 6 minutes with dry-through time of 20 minutes. When T-70 is removed, as in PT 1144, the dry time goes up only to 8 minutes but the dry-through time is 45 minutes. In PT 1150 with only 20 lbs of Micro Cel T-70, the dry-through time drops to 35 minutes, indicating the 40 lb level is probably the best level to allow escape of volatiles and provide earlier hardening of the film.

Without the isopropyl alcohol (IPA), PT 1161, with a low viscosity of 72 KU and an ASTM dry time of 19 minutes and dry-through time of 22 minutes, offers a possibility for cold application, although the dry time could be better. If we compare PT 1161 with Pervo 3210, cold applied with a viscosity of 72 KU, an ASTM dry time of 14 minutes, and a dry-through time of 30 minutes, the PT 1161 appears to be just as fast in dry-through which is more important as far as field application goes.

With a higher viscosity and faster dry time, again with no isopropyl alcohol (IPA), the PT 1164 offers promise with an ASTM dry time of 10 minutes and dry-through time of 15 minutes. Comparing this with Pervo hot-applied 3220 with an ASTM dry time of 7 minutes, but a dry-through time of 22 minutes, it would appear that PT 1164 would make a suitable hot-applied coating.

Table 11 reflects the excellent heat stability of these two paints as well as being well below the CARB requirement of 250 grams of VOC's (Volatile Organic Compounds) per liter of paint excluding water. If we ignore the requirement of "excluding water", the VOC's would calculate to 81 grams VOC/Liter. Hence the "penalty" for having water in the formula!

These formulas are far from being finalized but represent a base from which a workable system could be built. These formulas do not contain bactericide or antifungal agents which should be incorporated into any water-borne paint to prevent spoilage during storage. Antisettle agents, other coalescents, dispersants, surfactants and other miscellaneous additives which might improve the performance of the paint were not investigated. Of course, other water-borne emulsions might be available with faster film forming properties.

DURABLE PAVEMENT MARKINGS

A. Hot Melt Hydrocarbon Thermoplastic

An extensive thermoplastic test application was undertaken in December 1975 by contract with Cataphote Company of Jackson, Mississippi as part of a federally financed delineation study. About 23 tons of hot spray thermoplastic were applied in seven California locations. The work on this test installation is reported in FHWA Report No. CA-DOT-TR-1134 dated December 1976. A summary of the test locations and data is shown in Table 12. A five-year inspection summary is included. The I-80 Davis section was repainted with traffic paint after six years service although there was some question as to the need for restriping. With regard to the yellow, if color was the sole criterion, it is estimated that about a three-year restriping schedule would be necessary due to excessive fading.

Extensive testing of thermoplastic hot-melt materials is planned for this project and will be reported at a later date.

Five-Year Inspection

SR75 Coronado

Typical weathering cracks were observed but daytime lane delineation was very good. Color was satisfactory with no yellowing. Bond to old paint lines was very good with no sign of spalling or chipping. Bead retention was excellent.

TABLE 12

Hydrocarbon Thermoplastic Test Areas

TEST LOCATION	DISTANCE (MILES) COLOR PAINT	HOT SPRAY THERMOPLASTIC SAMPLES				PAINT THICKNESS INCHES	AIR F°	NO TRACK TIME SECONDS
		SAMPLE NO.	DATE	LOCATION				
SR 75, Orange Avenue, Coronado; 4-lane divided A/C; from 3rd & Orange south for 2 miles and back 2 miles to 3rd	4 White	1	12-9-75	333 Orange SB		.075	60	
		2	"	6th & Orange SB		.060	60	10
		3	"	Coronado Hotel SB		.050	60	10
				POST MILE	LANE			
I-5, Gorman-Lebec 8-lane divided PCC; 5-Ker-3.48 south to 5-L.A-84.0 and north to 5-Ker-3.48	14.3 White	4	12-10-75	3.0	SB	.075	53	10
		5	"	2.0	SB	.063	53	
		6	12-11-75	1.0	SB	.085	57	15
		7	"	86.5	SB	.080	57	
		8	"	86.5	NB	.062	53	10
I-80, Davis; 6-lane divided PCC; 80-Yol-9.0 to 80-Yol-00. All lanes east and west.	36 White	9	12-16-75	7.2	1WB	.085	45	
		10	"	5.0	1WB	.080	53	
		11	"	4.0	1WB	.068	53	10
		12	"	1.5	1WB	.062	61	
		13	"	1.0	2EB	.060	61	10
		14	"	2.0	2EB	.052	61	
		15	12-17-75	3.0	2EB	.080	50	
		16	"	4.0	2EB	.070	51	
		17	"	5.0	2EB	.061		
		18	"	6.5	2WB	.063	56	10
		19	"	5.0	2WB	.040		
		20	"	4.5	2WB	.052	56	
		21	"	3.4	2WB	.061		
		22	"	2.0	2WB	.088	66	
		23	12-18-75	1.0	2WB	.062	45	
		24	"	3.0	1EB	.065		
		25	"	4.0	1EB	.065	47	10
		26	"	5.0	1EB	.065		
		27	"	7.2	1EB	.061		
I-5, north of Redding; 4-lane divided PCC; from 5-Sha-37.0 north to 5-Sha-44.5 then south to 5-Sha-32.5	19.2 White	28	12-19-75	30.0	NB	.097	49	
		29	"	39.0	NB	.100		
		30	"	0.0	NB	.070	49	10
		31	"	41.0	NB	.065		
		32	"	42.0	NB	.062		
		33	"	44.2	NB	.060	60	10
		34	"	44.2	SB	.090		
		35	"	42.0	SB	.067		
		36	"	39.0	SB	.060	61	
		37	"	33.0	SB	.075		
SR 78, Glamis; 2-lane A/C new blanket 3 months old thin coat existing yellow traffic paint 78-Imp-41.0 to 78-Imp-35.0	6.0 Yellow	38	1-19-76	37.0		.090	69	
		39	"	36.0		.090		30
		40	"	35.0		.090		
SR 115, Brawley; 2-lane A/C new blanket 3 months old 1 coat of existing yellow traffic paint; 115-Imp-21.0 to 115-Imp-13.5	7.5 Yellow	41	1-20-76	21.0		.090	.58	
		42	"	19.0		.075		30
		43	"	17.0		.058	72	
		44	"	16.0		.071		
		45	"	15.0		.070		30
SR 98, Calexico; new blanket one month old; thin existing coat yellow traffic; 98-Imp-42.4 to 98-Imp-34.8	7.6 Yellow	46	1-20-76	38.1		.065	68	
		47	"	36.0		.062	70	

Night observation showed good retroreflectivity providing satisfactory lane delineation.

Excessive wear was observed only on intersections that experienced heavy turning and crossing traffic. On the straight stretches, practically no wear was observed except for weathering effects.

Gorman-Lebec, I-5

This area failed the first year after application due to snowplow activity and abrasives used to control skidding. The plastic line is not suitable for the higher mountain areas on a PCC pavement.

Sacramento-Davis, I-80

This area has provided good day and night lane delineation over the five-year period. However, chipping and spalling of the plastic has been observed during the last two years. These lines were applied over old paint stripes on PCC pavement. Even with the loss of adhesion in some areas, the general lane delineation is still very good and provides adequate lane guidance for the driver.

Redding, I-5

This area failed early due to snowplow and chain activity.

SR-78, Glamis

Delineation is still good in spite of severe abrasion from drifting sand. Bond and bead retention on both bare AC and over old paint are good and the lines still provide satisfactory day and night delineation. The yellow color has faded considerably.

SR-115, Brawley

Delineation is satisfactory both day and night. There is no excessive wear; bond and bead retention are good. Weathering cracks were observed. The yellow color has faded considerably.

SR-98, Calexico

Delineation is satisfactory both day and night. There is no excessive wear except for the usual weathering cracks. There is no spalling or chipping. The yellow color has faded considerably.

Summary

1. This thermoplastic shows excellent service both over bare AC and over painted traffic stripes.

2. The plastic system shows excellent bead retention for a five-year period providing good night visibility.

3. The plastic system provides good service both night and day over painted PCC, even with some loss of bond as evidenced by chipping and spalling.

4. The white plastic shows good color stability.

5. The yellow plastic shows a pronounced fading after two years of service.

6. The plastic system, when surface applied, is not suitable for high elevations subject to chain and snowplow traffic.

B. Two-Component Epoxy (100% Solids - H. B. Fuller)

The complete system consists of two coating types; a regular or slow set and a fast set. Each type is available in white and yellow. The same curing agent is used in both types and is designated as HS502 Part B. The other types to be used with HS502 are listed below:

HS501	Part A Fast Set White
HS506	Part A Fast Set Yellow
HS504	Part A Slow Set White
HS508	Part A Slow Set Yellow

Mixing ratio for all types is two volumes of A to one volume of B (HS502). The fast set yellow was not used on this job.

Epoxy samples of the white slow and fast systems were taken from 55 gallon drums and gave the following analysis:

	HS504	HS501	HS502
Lbs/Gal	10.94	11.27	8.29
% Solids	89.5	96.3	70.9

Brookfield Viscosity, Poise at 77°F	HS504	HS501	HS502
No. 4 Spindle, 1.0 rpm	1750		
No. 4 Spindle, 0.5 rpm	2870		
No. 4 Spindle, 5 rpm		281	176
No. 4 Spindle, 1.5 rpm		284	
No. 4 Spindle, 10 rpm			174

Glass Spheres

Sieve Number	% Weight Passing
30	92
60	12
80	1
100	0
140	0

Index of Refraction = 1.51
True Spheres % by count = 82
Spheres are "moisture proof"

The HS504 is highly viscous and thixotropic, whereas the 501 and 502 are far less viscous and show Newtonian flow characteristics.

Physical Properties of the Mixed Epoxy

On a 1/8 inch cast sheet, cured 18 hours at 77°F + 5 hours at 158°F.

	Tensile Strength psi	Elongation %	Hardness Shore D
Slow Set White			
(504-502)	3723	11.0	
	3894	15.0	
	3843	12.0	
Average	3820	13.0	80
Fast Set White			
(501-502)	7819	3	
	6993	2	
	7782	3	
Average	7531	3	85

ASTM D-711 Dry Time (No Beads, 0.015 inch)

Slow Set White	80 minutes
Fast Set White	35 minutes

Pot Life (6 ounce mass)

Slow Set White	17 minutes
Fast Set White	12 minutes

Density, lbs/gal of Mixed Epoxy

Slow Set White	9.82
Fast Set White	10.0

CARB Compliance HS504-HS502
The samples contained 188.1 grams volatiles/liter of coating, assuming the volatiles are nonreactive. If volatiles are reactive, then this figure would be less. The CARB rule limits volatiles to 250 grams per liter.

Contract Application by Century Fence Company

Application Unit

The striper unit was built by Idaho Norland for Century Fence Company. The chassis is a 2-axle, diesel powered, Ford truck with a diesel power plant to operate the equipment. All pumps and heaters are hydraulic. Since the epoxy is a two-component system, dual pumps and heaters are required up to the point of final mixing and spraying. Components A and B are pumped directly out of 55 gallon drums by separate GrayCo 250 hydraulic piston pumps. Each component is pumped to a separate kinetic heater where the material is heated to the required temperature and fed to GrayCo Viscount II metering pumps. The metering pumps proportion the A and B components in a volume ratio of 2A:1B. The proportioned materials, still separate, are pumped to gun carriages on the right or left side of the chassis and here they are mixed in a convoluted tube about two feet long and 1/2 inch in diameter. From the mixing tube, the mixed epoxy goes directly to the airless spray guns. A solvent pumping system using methylene chloride (nonflammable) is connected to the mixing tube and must be flushed through the tube if spraying is stopped for more than two minutes with the slow set material and 40 seconds with the fast set material. The flushings are directed to a waste tank on the truck.

This unit has separate systems for white and yellow coating only, no black.

The application spray guns are mounted on hydraulically operated outriggers, one on each side of the truck. There are no provisions for sulky operation. The outriggers are capable of moving horizontally up to four feet. Each outrigger carries a complete package of spray guns, bead guns, air guns and hot water guns. The unit is capable of spraying line widths up to eight inches, double yellow (no black) and any cycle of broken line.

For road cleaning purposes, a hot water gun is positioned at the front of the gun package. The water is heated by a separate kinetic heater and pump system. Behind the hot water gun is a high pressure air gun which blows excess water from the road surface. The epoxy is designed to tolerate damp road surface conditions. Behind the air cleaning gun are the epoxy and bead guns.

A television guidance system is used to provide alignment. The TV camera is portable and is mounted behind the outrigger facing the direction of travel. A monitor in the driver's cab allows the driver to keep in alignment. The outrigger has a steering mechanism controlled by another operator at the rear of the truck. A minimum of two men are required to operate the unit; one driver and one operator to steer the outrigger and monitor the working equipment.

A ground level bead loading, hydraulically-operated auger feeds two bead storage tanks. This equipment is an excellent labor saving device and loads beads as fast as the operator can open bags and feed them into the auger.

The maximum striping speed to apply a .015 inch thick traffic line is about eight miles per hour with the present epoxy system and pumps. The post-applied glass beads are "moisture proof" and comply with New York State specifications. Beads are manufactured by Potters Industries, Inc.

Application data are shown in Table 13. The application unit was new and suffered from a series of mechanical breakdowns and malfunctions from truck transmission to metering pumps and flat tires. However, the test areas were completed as scheduled. Due to erratic behavior of the bead dispensing system, bead delivery to the line ranged from 2 lbs to 17.5 lbs per gallon.

Inspection - H. B. Fuller Epoxy

SR-18 - PM 40.4 to PM 44.3
Applied 7-28-78
Inspected 5-2-79

Lines in this area, a four-lane AC winding mountain road at 6000 foot elevation subject to snowplow and chain traffic plus sanding operations, managed to survive the winter without additional painting. Some areas, especially around the curves, showed high wear and some loss of adhesion. In general, performance was very satisfactory considering the winter conditions in this area. Lines after 10 months service are ready for restriping.

TABLE 13

H. B. Fuller Epoxy, Contract Applied by Century Fence

Date	Location	Line Type Epoxy Type	°F Air	°F Surface	°F Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
7-13-78	I-15 at Jurupa O/C	Edge-Slow	80	140	120	20	.016	15.7	19
7-14-78	Edge & gores around off & on ramps	Gore-Slow	83	120	120	20			38
7-19-78	SR-66 from I-15 O/C west to Haven Avenue	Yellow Median Slow Set	63	100	120	15	.011	3.8	35
			63	100	120	15	.010	2.0	35
7-20-78	New AC blanket 4-lane divided road	White-Broken Fast Set	78	124	120	15	.031	6.8	8
7-21-78	I-15 northbound from 15 SBD 4.41 to 15 SBD 7.00, PCC coarse texture	White-Broken Fast Set	75	116	120	25	.014	17.5	8
7-24/26-78	I-15 northbound from 15 SBD 7.00 to Cajon Summit, 15 SBD 29.77 then southbound to 15 SBD 4.41	White-Broken Fast Set	Not Observed						
7-28-78	SR-18, PM 40.4 to 44.3, 4-lane AC	White-Broken Fast Set	Not Observed Mountain Area - Winter Snow						

Other Test Areas
Applied 7-13/26-78
Inspected 5-29-80

All areas are in excellent condition showing no wear and good bead retention and color. The I-15 location, northbound from PM 4.41 which was applied to light colored concrete, began to show a definite yellowing. The yellow was pronounced enough to cause concern and the maintenance district had to repaint with white traffic paint. This yellowing after about 1-1/2 years was not noticeable on other areas, especially on the darker AC pavements where the color contrast against the dark background does not emphasize the yellowing.

Two-Component Epoxy (100% Solids - Prismo)

This system appears to be the same as H. B. Fuller epoxy traffic line coating.

The white epoxy resin is designated as HS501 and the yellow as HS506. The hardener, or B component, for each is designated as HS502. Mixing ratio is 2A:1B volume.

Viscosity

A (white) = 140 poise
A (yellow) = 180 poise
B (hardener) = 120 poise

These viscosities are very high for normal spray operation, hence the need for heating the components.

Tensile and Elongation

Tensile Strength = 7000 psi for white and yellow
Elongation = 3% for white and yellow
Shore D Hardness = 83 for white and yellow

Pot Life - 6 ounce mass

White = 10 minutes
Yellow = 12 minutes

ASTM D-711 dry time, no beads at 77°F

White = 33 minutes
Yellow = 33 minutes

Accelerated Ultraviolet Exposure - QUV, ASTM G53

White (unbeaded)
Original yellowness index = 0.05
After 26 hours QUV yellowness index = 0.32
After 162 hours yellowness index = 0.48

(The higher the index, the more yellow the material.)

White (beaded 20# beads/gal)
Original yellowness index = 0.06
After 72 hours QUV yellowness index = 0.32

These results indicate considerable yellowing easily detected by the eye.

Yellow

Original reflectance (green filter) = 65.5
After 120 hours QUV reflectance
(green filter) = 54.0
ΔL(ASTM D211) after 120 hours = 6.45

A ΔL of 6.0 is considered a maximum after 168 hours of UV exposure. This yellow has shown considerable darkening only after five days exposure. Laboratory testing indicates both the white and yellow epoxy coatings are not color stable under ultraviolet exposure.

Taber Abrasion

Federal Test Method 141B, Method 6192, CS17 wheels, 1000 gram weights, 4000 cycles, wear index = 32
For comparison, regular traffic paint has a wear index = 200

(The lower the index, the better the abrasion resistance.)

Contract Application by HUG Concrete Company

Test sections in Southern California were applied under contract by HUG Concrete Paving Company, Norwalk, Ohio. The State of California purchased the epoxy (495 gallons at $65/gallon), furnished the glass beads, provided traffic control and a stencil truck, in addition to the contract price for the application which included two operators. The HUG application unit is an older striper and probably was one of the first units to apply two-component epoxy. The A and B components are each heated in their original 55 gallon drums by circulation through heat exchangers heated by electrical heaters powered by a 25 KW generator. Both

drums had to be heated to 120-140°F before the striping operation could begin. The heated components are pumped from the 55 gallon drums by GrayCo proportioning pumps at a 2A:1B ratio by volume through a static mixing head and then to the airless application guns. Beads are applied behind the epoxy gun by a bead hopper under gravity flow. The hopper opening is synchronized with the epoxy guns to flood the line with glass beads. For road cleaning, a hot water gun is positioned in front of the bead hopper and epoxy guns. For stencil work, a hand-held airless gun is connected to the output of the mixing head with 20 feet of hose. The application data for the various test sites are shown in Table 14.

Application of the Prismo two-component epoxy, in general, was satisfactory, but as observed with the Century Fence application in 1978, this system always seems to have more than enough application problems. This system is supposed to apply a cured epoxy film of 0.015 inch. Based on line samples taken during application, the film thickness ranged from 0.011 to 0.022 inch thick and bead content varied from 5.7 to 17.8 lbs beads/gallon. The unit's striping speed at 4.3 miles per hour is about one-half the speed of a normal paint striper operation. Another time consuming operation is the need to heat the whole barrel of each component to 120-140°F before application. This is not the case with the Idaho-Norland which heats about two gallons at one time on a continuous basis just prior to application.

The no-track condition of the applied epoxy varied considerably with temperature. At 70°F, no-track time was 25 minutes and at 100°F+ with very hot AC pavement temperature (140°F), the no-track time was 5 minutes. Only the broken line operation on SR-111 northbound from SR-98 could be

TABLE 14

Prismo Contract Applied by HUG Concrete Company

Date	Location	Line Type	°F Air	°F Surface	°F Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
5-31-81	I-10, Santa Monica Freeway eastbound LA-10-R8.24 to R6.74 PCC	White-Broken	65	70	120	50	.011	5.7	25
5-31-81	I-10 eastbound at National Blvd O/C PCC	8-inch Truck Lane, White	65	70	120	50	.015	6	25
5-31-81	Manning St O/C to eastbound I-10, PCC	Legends for Diamond Lanes	65	70	120	50	Applied by hand gun		20
6-1-81	I-5, Gorman, LA-85.00 to LA-88.00 north and southbound slow lanes, PCC	White-Broken	80 80	103 103	120 120	50 50	.012 .015	14.4 15.0	15 15
6-2-81	I-8, Descanso east-bound, PM 36.5 to 40.2, westbound PM 39.0 to 37.7 PCC	White-Broken				No samples			
6-3-81	SR-115, Holtville from RR Crossing to Grape St Old AC northbound & southbound AC	RR Xing Legend	100	123	120	10			5
		White-Broken	105	130	120	10	.015	13.5	5
		All Legends & Crosswalks	105	130	120	10			5

TABLE 14

Prismo Contract Applied by HUG Concrete Company

Date	Location	Line Type	Air	°F Surface	Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
5-31-81	I-10, Santa Monica Freeway eastbound LA-10-R8.24 to R6.74 PCC	White-Broken	65	70	120	50	.011	5.7	25
5-31-81	I-10 eastbound at National Blvd O/C PCC	8-inch Truck Lane, White	65	70	120	50	.015	6	25
5-31-81	Manning St O/C to eastbound I-10, PCC	Legends for Diamond Lanes	65	70	120	50	Applied by hand gun		20
6-1-81	I-5, Gorman, LA-85.00 to LA-88.00 north and southbound slow lanes, PCC	White-Broken	80 80	103 103	120 120	50 50	.012 .015	14.4 15.0	15 15
6-2-81	I-8, Descanso east-bound, PM 36.5 to 40.2, westbound PM 39.0 to 37.7 PCC	White-Broken				No samples			
6-3-81	SR-115, Holtville from RR Crossing to Grape St Old AC northbound & southbound AC	RR Xing Legend	100	123	120	10			5
		White-Broken	105	130	120	10	.015	13.5	5
		All Legends & Crosswalks	105	130	120	10			5

TABLE 14 (Cont'd)

Prismo Contract Applied by HUG Concrete Company

Date	Location	Line Type	°F Air	°F Surface	°F Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
6-3-81	SR-98 Calexico	White-Broken	103	128	120	10	.014	13.8	6
6-4-81	from 4-lane section west to Ollie Ave AC	White-Broken	91	105	120	20			11
	8-inch turn pockets at SR-111 (Imperial Ave) and Grant St,		110	130	120	10			5
	4th St, 2nd St, 8th St, Birch St		110	150	120	10			5
6-5-81	RR Legends and 24-inch bars at SR-111 & 2nd St, AC		90	125	120				16
6-5-81	SR-111, Calexico north & southbound from X^n SR-98 to 111-Imp-8.00 (Ross Rd), AC	White-Broken	110	142	120	10	.016	11.7	5
6-6-81	SR-98, from 4-lane to Ollie Ave, AC	Yellow Median	100	125	120	25	.022	11.0	6
	SR-115, Holtville from RR Xing to Grape St, AC	Yellow Median				Not sampled			

conducted without traffic control (cones). All the other areas required lane closure due to the long no-track time.

Preliminary field reports indicate considerable "blackening" of the white crosswalk areas in Calexico and a definite change in color of the yellow strips to an orange shade. Laboratory observations of accelerated weather tests also confirm this. Also, considerable discoloration of some crosswalk areas was noticed 24 hours after application.

Inspections of Prismo System

I-10 Santa Monica Section
Applied 5-31-81
Inspected 10-6-81

All striping in this area was satisfactory. Some slight yellowing of the white broken line was noted but adhesion and bead retention were satisfactory.

I-8 Descanso
Applied 6-2-81
Inspected 10-7-81

Lines were in good condition except for definite yellowing of the white broken line. There was no loss of adhesion or beads.

SR-115 Holtville
Applied 6-3/6-81
Inspected 10-7-81

The white broken lines and crosswalks in this area are all very dirty making daytime delineation poor. Nighttime delineation is excellent due to high bead loading and good retention. The yellow median lines are also dirty and have an orange tint. No excessive wear or loss of adhesion was observed.

SR-98 and SR-111 Calexico
Applied 6-3/4/5/6-81
Inspected 10-8-81

All crosswalks, legends, and turn pockets were very dirty. Some of the legends and speed zone markings were so dirty that they could not be seen in the daytime. The railway crossing symbol on SR-111 at 2nd Street was so dirty that it completely disguised the lettering. One railroad crossing symbol and 24-inch bar (old traffic paint) which were not coated with epoxy were still visible and clean even though worn considerably. White broken lines on SR-98, away from the downtown area of Calexico, are discolored but not as bad as the lines and other markings in the downtown area. The yellow median on SR-98 shows some dirt pickup and also an orange tinge to the yellow color.

SR-111, Calexico - Junction SR-98 to 111 Imp 8.00
Applied 6-5-81
Inspected 10-8-81

This area, away from the business section of Calexico, did not show the extreme dirt pickup observed in the other areas. Some yellow tinge was noticed in the white broken line. No loss of adhesion or wear was observed. Nighttime delineation was excellent.

I-5 Gorman
Applied 6-1-81
Inspected 10-6-81

All white broken lines in this area failed completely. The lines show from 50 to 90 percent loss of adhesion. Remains of the lines can be easily lifted off with a pocket knife. No explanation is offered for this failure. Traffic paint applied in this area wears out but does not fail due to adhesion to the PCC surface. This area is at an elevation of 4000 feet and carries very heavy truck traffic.

C. Two-Component Epoxy, Long Pot Life, 65% Solids, EPO 108

This is a two-component epoxy system containing about 65 percent solids and 35 percent volatile matter. This material has been applied in New Mexico with FHWA funding, and from reports, has shown service life of at least 14 months. This system, when mixed, has a claimed usable pot life of about 10 days and would not require the sophisticated application machinery of the Fuller or Prismo systems since the two-components are mixed and then pumped into the application unit. The application unit is a regular paint

striper, preferably with heating capability. Although this system does not comply with the CARB rule, the fact that a long wearing epoxy traffic line can be applied using conventional equipment is good reason for further testing. It is reasoned that the total volatile emissions would be far less for an epoxy line with a service life of two to four years than for a regular solvent-borne traffic paint with an average service life of one year.

The EPO 108 is manufactured by Bradco Plastics and distributed by J and J Plastics in New Mexico.

Laboratory Testing EPO-108

Sample of White EPO-108, Our Lab Number S1695

Mix Ratio 3B:1A by volume
Viscosity A (hardener) = 12 cP clear unfilled
Viscosity B (resin) = 128 poise, white pigmented
Wt/Gal A = 7.08 lbs
Wt/Gal B = 12.82 lbs
Wt/Gal mixed 3B:1A vol = 11.44 lbs
Initial viscosity, mixed 3B:1A vol = 80 KU
After 8 days in closed container, mixed vis = 127 KU
ASTM D711, dry time = 6 minutes

For cold application, a starting viscosity of 80 KU would be too high for satisfactory spray application. Manufacturers instructions indicate that MEK may be added to reduce viscosity for cold spray. Another batch was mixed and MEK added at 8 gallons MEK/100 gallons of mix. Initial viscosity was 72 KU which is ideal for cold application but the viscosity increased very rapidly to 80 KU in three hours and 86 KU after one day. This rapid viscosity increase indicates that cold application of this system would not be practical.

Another sample, S1705 yellow, had an initial mixed viscosity of 68 KU and increased to 72 KU in four hours and remained under 75 KU for three days. This could be sprayed cold even with air-atomizing guns. Two more samples were obtained, S1715 white and S1716 yellow. These two samples had initial viscosities of 86 and 90 KU which certainly could not be cold applied. Due to considerable variation in initial viscosity of the mixed material, we must conclude that the EPO-108 system has to be applied with a heated striper.

Color Stability, ASTM D211

Sample S1705, EPO-108 Yellow

Original photovolt reflectance (green filter) = 58.5
After 24 hours total time QUV, ASTM G53 = 55.0
$*\Delta L = 2.32$
After 25 days in QUV, ASTM G53
$\Delta L = 4.0$
This shows very good light stability.

$$*\Delta L = K\ (Y_2^{1/2} - Y_1^{1/2})$$

Where $K = 10$
Y_2 = Reflectance after exposure
Y_1 = Reflectance before exposure

Sample S1695, EPO-108 White

Original yellowness index = 0.03
After one week in QUV, ASTM G53 = 0.18
The EPO system has better color stability than the Prismo two-component epoxy system.

The Prismo system had a ΔL of 7.8 after 380 hours in the QUV for the yellow. The white had an original yellowness index of 0.05 and after 162 hours in the QUV the yellowness index increased to 0.48.

Abrasion Resistance

Abrasion resistance was run on EPO-108 white per Federal Test Standard 141B, Method 6192 using CS17 wheels and 1000 gram weights. Wear Index calculated as follows:

$$W.I. = \frac{(A-B)\ 1000}{\text{Cycles}}$$

Where A-B is weight loss in milligrams at indicated number of cycles tested.

The abrasion results are tabulated in Table 15 with other coatings shown for comparison.

TABLE 15

Taber Abrasion

Coating	Wear Index
Regular Alkyd Solvent-Borne Traffic Paint	206
Water-Borne Traffic Paint	150
EPO-108 White	48
Prismo HS501-502	32

The EPO-108 compares favorably with the Prismo system and would indicate good wearability. The EPO-108 contains an abrasive filler which might contribute to its low wear index. The abrasive filler could also be hard on pumps and spray nozzles in operational applications.

Field Application Northern California

Since the EPO-108 has a mixing ratio of 3B (resin) to 1A (hardener) by volume, the material was ordered with 30 gallons of B in a 55-gallon drum + 10 gallons of A in two 5-gallon pails. Two 5-gallon pails of A were then added to the 30 gallons of B and mixed with a power mixer for about 10 minutes, then pumped into striper truck.

A total of seven units of white (280 gallons) and seven units of yellow (280 gallons) were purchased for field testing. Price per gallon was about $18.50.

Application data are shown in Table 16.

Inspections EPO-108, Northern California

After One Month Road Service

SR-193

Yellow color and beads satisfactory. No evidence of premature wear. No snow in this area.

TABLE 16

EPO-108 Application Northern California
Applied by Hot Striper Unit 434

Date	Location	Line Type	°F Air	°F Surface	°F Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
9-21-81	SR-20, Marysville 17th-20th St, AC	White-8 inch Turn Pockets	65	80	130	40			2.5
				Yellow Heater Seal Leaking - Repaired					
9-22-81	SR-174, Colfax Pla-1.81 to 2.88 Nev-0.00 to 1.00 AC	Yellow-Broken & Solid	66	85	150	31	.004	2.9	4
9-22-81	I-80 East,Pla-41.00 to 42.00	White-Broken	72	95	130	24	.004	2.0	3
	I-80 East,Pla-42.00 to 43.00	White-Broken			Regular Traffic Paint Control				
	I-80 East,Pla-43.00 to 44.00	White-Broken	72	95	130	24	.004	2.0	3
	I-80 West,Pla-41.00 to 42.00	White-Broken	72	95	130	24			3
	I-80 West,Pla-42.00 to 43.00	White-Broken			Regular Traffic Paint Control				
	I-80 West,Pla-43.00 to 44.00	White-Broken	72	95	130	24			3
9-22-81	Baxter Off Ramp from I-80 West, 80-Pla-47.00	White-Stop Ahead Legend	71	96	130	30			
				White Heater Seal Leaking - Repaired					

TABLE 16 (Cont'd)

EPO-108 Application Northern California
Applied by Hot Striper Unit 434

Date	Location	Line Type	°F Air	°F Surface	°F Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
9-23-81	I-80 East, Yuba Gap, PCC	White-8 inch Auxiliary Line	62	88	130	28			3 hrs+
					3 coats - poor dry				
9-24-81	I-80 East, Nev-59.00 to 60.00	White-Broken	60	75	no heat	31	.003	2.6	4
	I-80 West, Nev-59.00 to 60.00				White Heater Seal Leaking				
	I-80, SR-20 J^n,PCC	White - Ramps & Gores	46	60	no heat	80	Rain-snow sprinkles		
9-25-81	SR-193, Colfax Pla-9.76 to 7.00 AC	Yellow-Broken & Solid	65 65	80 80	130 130	73 73	.005 .004	6.0 3.0	10 5
9-28-81	Unit to Shop			Repair White Heater Seal					
9-29-81	US-50, East, ED 38.20 to 39.18 US-50, West, ED 38.20 to 39.18 US-50, Ice House Rd.	White-Broken and Yellow Median	65	90	130	43	.004 .004 .003	0.7 0.2 4.6	3 3 3
				White Heater Seal Leaking					
9-30-81	US-50, Echo Summit to Meyers, New AC	Yellow-Broken and Solid	50	70	150	45	.004	3.1	5
	US-50, Echo Summit to Twin Bridges	White-Broken Pass Lanes	50	70	no heat				

TABLE 16 (Cont'd)

EPO-108 Application Northern California
Applied by Hot Striper Unit 434

Date	Location	Line Type	Air	°F Surface	Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
10-1-81	SR-89 & US-50 Jn South Lake Tahoe	White-8 inch Turn Pockets	46	62	no heat	52	.003	4	5
		Solid Yellow	46	62	150	52			5
	SR-89, ED 14.84 to 16.54, New AC	Yellow-Broken & Solid	46	62	150	52			5
10-1-81	Tahoe City, Jn SR-28 & SR-89, AC	White Left Turn Pockets	65	109	no heat	27	.004	2.8	4
		& Yellow Solid	65	109	150	27	.004	3.0	4
10-2-81	SR-28, Tahoe Vista North & South to Brockway, AC	White Broken	47	55	no heat	72	.005	3.0	7
			47	50	no heat	72	.005	1.4	3
	SR-89, Alpine Meadows Road, AC	White-8 inch Turn Pocket	47	50	no heat	72			5
10-2-81	SR-89, Squaw Valley Road, AC	White-8 inch Turn Pockets Broken & Edge Lines	47	50	no heat	72			5
10-2-81	SR-89, Deerfield Dr to Jn I-80 North & South, AC	White-8 inch Turns & Broken Line	58	82	no heat	51			5

TABLE 16 (Cont'd)

EPO-108 Application Northern California
Applied by Hot Striper Unit 434

Date	Location	Line Type	°F Air	°F Surface	°F Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
10-2-81	I-80, West, Nev 14.51 to Nev 10.00	White Broken	58	82	no heat	51	.004	1.5	4
			58	82	no heat	51	.004	2.0	4
10-5-81	I-80 West, Donner Pass, Nev 7.30 to Nev 8.70, New AC Blanket	White-Broken Slow Lane 3M Stamark Inlay Fast Lane	Not observed - Applied with 2 coats EPO						
10-6-81	I-80 East, Donner Pass, Nev 3.00 to Nev 13.60, 1 mile EPO starting at 3.00 + 1 mile traffic paint alternating	White-Broken	Not observed						

SR-174

Moderate logging truck traffic. Shows premature wear, especially on the curves. Beads poor. On straight portions of road, wear is satisfactory and beads fair. No snow in this area.

I-80, PM 41.00 - 44.00

Very poor bead retention. Shows solvent bubble pockets. Wear okay. Control lines of regular traffic paint show good bead retention and wear. One snow storm in this area with snowplowing and chain control. Date of snow, 10-11-81.

I-80, Stop Ahead Legend, Baxter Off Ramp West

Beads completely gone on this legend. No excessive wear observed. Date of snowstorm, 10-11-81.

I-80, Yuba Gap

The 8-inch auxiliary lane completely worn off. Old traffic paint in gore separation still intact. White skip line PM 49.00-60.00 completely worn off. Date of snowstorm 10-11-81.

SR-89, Squaw Valley Road

All lines in this area okay. Beads satisfactory including 8-inch turn pockets, white broken lines and edge line. Date of snowstorm 10-11-81.

SR-89 and Deerfield Drive to Junction I-80 at Truckee

White broken lines and 8-inch turn pockets; wear satisfactory but beads fair to poor. Date of snowstorm 10-11-81.

I-80 Westbound at 80 Nev. R11.00 - Donner Summit

Wear satisfactory but beads poor. More beads observed in the old traffic paint line. Date of snowstorm 10-11-81.

I-80 Westbound - New AC Blanket PM 7.30 to 8.70

Fast lane with rolled-in 3M Stamark Tape in excellent condition; no sign of wear or loss of beads. The EPO in the slow lane, which was applied with two coats, was in very poor condition, almost worn completely away and showing no beads. Date of snowstorm 10-11-81.

US-50, ED 38.20 to 39.18 - Ice House Road

White broken line okay, beads poor. Double yellow at Ice House Road wear satisfactory and beads fair. No snow in this area.

US-50 - Echo Summit to Meyers

Yellow broken and double yellow, new AC blanket. Beads poor and showing excessive wear. Date of snowstorm 10-11-81.

SR-89 from Junction 50 to Tahoe City

On new AC patches, yellow broken and double yellow show excessive wear especially on curves; beads very poor. Date of snowstorm 10-11-81.

SR-28 - Tahoe City

Yellow two-way turn lanes showing excessive wear and poor beads. White 8-inch turn pockets wear satisfactory but poor beads. Date of snowstorm 10-11-81.

SR-28 - Tahoe Vista at Brockway

Beads very poor, wear acceptable on straightaway sections but shows excessive wear at intersections where traffic cuts across line. Date of snowstorm 10-11-81.

I-80 Eastbound from 80 Nev. 3.00 to 13.60

This section has EPO white broken line with one-mile alternate sections of regular cold-applied traffic paint. Both coatings are still intact with the regular traffic paint as good as, or better than, the EPO sections. The regular traffic paint shows much better bead retention than the EPO sections.

Summary

Application of the EPO-108 was satisfactory in regard to sprayability; no problems were encountered with flow of material, either hot or cold. When cold-applied, the line widths decreased from 4 inches to 2-1/2 to 3 inches. Pot life of the material was as claimed, remaining usable from

September 21, 1981 to October 6, 1981. As evidenced by the low dry film thickness, the application speed should have been slower to yield a dry film thickness of at least 0.005 inch. This low coverage is probably due, in part, to the lower solids content of this system (60-65%). Premature wear after only one month of service life in a nonsnow area is of prime concern. An epoxy system would be expected to provide better wear resistance than regular traffic paint. The no-track time of this system is most sensitive to the application thickness. In thin applications (.004 to .005 inch thick), the dry time is satisfactory but when wet film thicknesses of 0.15 to .020 inch are applied, the dry time increases rapidly. For example, the 8-inch auxiliary line applied on I-80 at Yuba Gap had three coats and took over three hours to dry to a no-track condition. Even then the coating was in a soft plastic condition. The traffic passing over this line smeared the paint badly. After the first snowfall the line was almost completely removed due to sand, chains, and snowplow action.

Bead retention on the average was very poor in all test areas. The hot striper, due to restrictions in the feed line, does not deliver more than about four pounds of beads per gallon of paint retained on the line with ordinary traffic paint. The EPO-108 test areas averaged about one-half of this amount which gave very poor night visibility.

As a result of subsequent heavy snowfalls in the mountain areas, chain and snowplow traffic completely removed all traces of the EPO lines and regular traffic paint lines. The only delineation remaining in these areas is the 3M Stamark tape which was rolled in (inlaid) on westbound I-80 at Donner Summit.

A seven-month inspection was made on the only remaining test sites, SR-174 and SR-193. On SR-174, the paint was almost worn completely off, especially on curved areas, and no beads were in evidence. On SR-193, curved areas of the road were badly worn, but straight portions showed satisfactory wear and fair bead retention. It would appear that the EPO is no better than traffic paint in these test areas.

The rupture of the kinetic heater seals is of concern. The seals were replaced in the white heater three times and in the yellow, once. Either the seals were improperly installed or the abrasive material in the EPO-108 caused premature failure.

Field Application Southern California

The remaining 80 gallons of white EPO-108 and 80 gallons of yellow were shipped to Los Angeles for further testing. Both the white and yellow resin components (B side, pigmented) showed hard, dry settlement and could not be properly mixed. It was necessary to scrape up the hard dry settlement to properly incorporate the catalyst to a homogeneous consistency. The yellow resin, besides showing a hard dry settlement, also had a considerable amount of gel lumps varying from soft to hard on the surface of the container. This was skimmed off before the catalyst was added as it was feared that these lumps would clog screens and the paint spray guns. After loading, the striper traveled to San Diego and Indio for application.

Application data are shown in Table 17.

TABLE 17

EPO-108 Application Southern California
Applied by Hot Striper Unit 439

Date	Location	Line Type	°F Air	°F Surface	°F Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
11-18-81	SR-75, Coronado from Toll Booth to Pomona & Orange, AC	White-8 inch	63	87	130	60	.004	4.3	7
		White-Broken	63	87	130	60	.005	2.7	10
		Crosswalks & Legends	63	87	130	60			10
11-18-81	SR-75, Imperial Beach, from SD 11.00 to J^n I-5, then north to 9th Ave., AC	White-Broken	68	98	150	50	.003	NIL	3
		White-Broken					.005	3.2	8
		White Broken					.005	2.9	8
			Crosswalk at 9th Ave., peeled up under traffic						
11-18-81	I-8 East, Descanso SD 37.7 to 41.3, PCC	White-Broken	72	92	150	50	.005	3.5	6
11-19-81	SR-86, Indio, Van Buren to J^n SR-111, north and south	White-Broken	82	106	150	40	.005	2.7	6
			82	106	150	40	.005	2.8	6
11-19-81	Indio Center Road from J^n SR-111 to Jn I-10	White-Edge	82	106	150	40			10
		Yellow Median	82	106	150	40			12
		Crosswalks	At X^n Peeled up under traffic						
11-20-81	J^n Indio Center Road & Ave. 45	White Crosswalks & Legends	72	88	150	40			10

Summary

SR-75 - Coronado

Experience in District 03 with the EPO-108 application showed that at a normal striper speed of nine miles per hour with one paint gun, film thickness averaged 0.004 inch. For this application and subsequent sections, the truck speed was reduced to about six miles per hour. To insure an adequate bead flow, two bead guns were used. This provided a dry film thickness of 0.005 inch except at SD-75-11.00 where the striper speed was too fast and gave 0.003 inch film thickness. At this location, bead retention was nil and no-track time was 3 minutes. With 0.005 inch dry film thickness, the no-track time averaged 7 to 10 minutes. Initial bead content averaged about three lbs beads/gal wet paint. The EPO-108 again showed a very sensitive relationship between film thickness and no-track time. This is due to the formation of a skin over the paint which traps solvent underneath. The thicker the film, the more solvent that is trapped. This leads to very long dry times.

The crosswalk installation at SR-75 and 9th in Imperial Beach was opened to traffic after one hour and a section of the line peeled up almost immediately under traffic. The substrate was old traffic paint.

Cones were used in all applications.

Eastbound I-8 - Descanso

White broken line was applied satisfactorily with 0.005 inch dry film thickness and 3.5 lbs beads per gallon. No-track time was six minutes. Cones were used in this section. Truck speed was six miles per hour with one paint gun and two bead guns.

Indio Area

On SR-86, from Van Buren to Junction of SR-111, two paint guns and two bead guns were used with a truck speed of nine miles per hour. This produced 0.005 inch dry film thickness with about 2.5 lbs beads per gallon. It should be noted here that regular traffic paint, even unheated, with one gun at nine miles per hour, can produce a dry film thickness from 0.005 to 0.006 inch.

The crosswalk at Junction of SR-86 and SR-111 peeled off when traffic opened after one hour of dry time. The substrate was old traffic paint.

The yellow double and single solid section were applied satisfactorily. No-track time was 12 minutes at a dry film thickness of 0.005 inch with 6.4 lbs of beads per gallon. The initial bead retention was much better than that of the white for some unexplained reason. Truck speed was nine miles per hour with two paint guns and two bead guns.

In general, the yellow seems to have better initial bead retention than the white. This was also observed in the District 03 application. The beads in the white film appear to be all on top of the film surface and can be readily dislodged by traffic. The yellow has more beads

submerged in the paint film than the white and should show better bead retention under traffic.

The average dry film thickness in the District 11 application was 0.005 inch which calculates to 0.016 inch wet. The District 03 application averaged 0.004 inch dry which calculates to 0.013 inch wet. The manufacturer recommends 0.015 inch wet film thickness with six to eight lbs of beads per gallon.

There were no problems with the heater seals during this operation.

Field Application Southern California - 2nd Batch

Due to unsatisfactory performance of the EPO-108 in Districts 03 and 11 in September and October 1981, the manufacturer offered to replace about 100 gallons of the EPO-108 and provide a contractor to apply the material. The original applications in Districts 03 and 11 were applied with the California hot striper and showed poor bead retention, premature wear and inability to set hard due to solvent entrapment, especially at a wet thickness of 0.015 inch or more. The white and yellow also showed considerable dry hard settlement in the 55 gallon drums. Loss of adhesion at two separate crosswalk locations (Imperial Beach and Indio) make EPO-108 questionable for this use.

Lab Tests - 2nd Batch EPO-108

White and yellow resin side (B component) and catalyst (A component) were sampled from the five-gallon pails during mixing operations.

The following physical characteristics were noted:

	White	Yellow	Catalyst
Brookfield Viscosity	150 poise (#3/4rpm)	666 poise (#4/2.5)	11 cP (#1/100)
Pounds per Gallon	12.87	12.93	7.07
% Solids	74.8	74.9	9.7

Mixed 3B (White or Yellow) + 1A (Catalyst) by Volume

	White	Yellow
Pounds per Gallon	11.68	11.76
% Solids	65.5	65.0
ASTM D711 dry time	8 min.(.014"wet)	8 min.(.014"wet)
Reflection, green filter, (.010" gap)	82.8	59.5
Yellowness Index (.010" gap)	0.04	--
Dry Opacity (.010" gap)	0.97	0.92

Viscosity, KU @ 77°F

Initial	86	95
After 2 hours	92	101
After 4 hours	93	102
After 8 hours	95	102
After 24 hours	98	102
After 48 hours	99	102
After 72 hours	100	102

The application data for the 2nd batch of EPO-108 are shown in Table 18.

TABLE 18

EPO-108 Contract Applied Southern California Batch 2

Date	Location	Line Type	Air	°F Surface	Paint	% RH	Dry Thickness Inches	Lbs Beads Gal	No-Track Minutes
2-27-82	SR-126, Newhall from 13th St to X^n of SR-14, AC eastbound	White-Broken	65	90	no heat		.005	5.8	4
		White-Broken	65	90	"		.005	4.5	5
		Yellow-Broken	67	98	"		.006	3.0	7
		Yellow-Broken	67	98	"		.007	3.0	7
2-27-82	Rapid Dry Traffic Paint, westbound	White-Broken	67	98	180		.006	3.5	1
2-28-82	SR-1, Laguna Beach Bluebird Canyon Dr to Viejo St, southbound, grooved AC & PCC	White-Broken	54	68	no heat		.007	5.7	10
		White-Broken	54	68	"		.007	4.0	10
		Yellow-2 Way	54	68	"				10
2-28-82	Rapid Dry Traffic Paint, northbound grooved AC & PCC	White-Broken	54	68	190		.006	3.4	1
2-28-82	Crosswalks, SR-1 at Mountain Ave	Laguna Beach Southbound Only							
		North Side of X^n	Regular Traffic Paint South Crosswalk						
			EPO-108 North Crosswalk						
	At Cress St	North Side of X^n	Regular Traffic Paint South Crosswalk						
			EPO-108 North Crosswalk						
	At Laguna Ave	South Side of X^n	Regular Traffic Paint South Crosswalk						
			EPO-108 North Crosswalk						

The contractor for the Los Angeles operation was Consley and Montigny, El Monte, California. Equipment used was a self-propelled small striping unit with an air driven positive displacement pump (5:1) to pump the mixed epoxy from the holding tank to an air-atomized Binks 33 paint gun. No heat was used and state specification glass beads were post-applied at about five lbs per gallon of epoxy. Some equipment problems were encountered with the application unit but these were electrical and not related to the epoxy.

Initial bead retention was very good and the epoxy appeared to dry through the whole film. The material flowed well through the positive displacement pumps and the Binks 33 guns, giving satisfactory film thicknesses averaging about 0.006 inch dry or about 0.013 inch wet. No-track time averaged 5 to 10 minutes for white and yellow. No excessive settlement was observed in the white or yellow five-gallon pails.

Control lines of State Specification 8010-12F-02, Rapid Dry White Traffic Paint, were placed adjacent to all EPO test lines and also on crosswalk areas. The regular traffic paint was applied at 0.006 inch thick dry and gave a no-track condition in one minute.

D. Epoxy Thermoplastic - ETP

Southwest Research Institute of San Antonio, Texas, developed an epoxy thermoplastic coating for highway striping. This work was done under FHWA funding and reported in Report No. FHWA-RD-75-70, July 1975. A subsequent report on application equipment, also by Southwest Research Institute, was published under Report No. FHWA-RD-79-130,

April 1980. A later report on specifications and testing of epoxy thermoplastic is published under Report No. FHWA-RD-80/069, December 1980.

The ETP system consists of a blend of uncatalyzed solid and liquid epoxy resin with prime color pigments, filler and fine mesh glass beads. The ratio of solid to liquid epoxy resin may be varied for desired flexibility. Formulas with more liquid resin give more flexibility. The most common formula, which appears to have good balance between flexibility, dirt pickup and satisfactory wear, has a liquid to solid ratio of 60/40.

The proposed advantage of this system is the simplicity of a one-component epoxy system that makes the application comparatively simple as compared to the two-component epoxy system. In addition, it would provide excellent wear and adhesion properties that are sometimes lacking in regular hot melt hydrocarbon thermoplastic.

The ETP 50/50 and 60/40 formulas are shown in Table 19.

TABLE 19

ETP Composition

	60/40		50/50	
	Lbs.	Gals.	Lbs.	Gals.
Aradite 7097 (Solid)	90	9	50	5
Aradite 6010 (Liquid)	60	6.2	50	5
TiO_2 or Chrome Yellow	30	0.9	30	0.9
Calcium Carbonate	30	1.3	30	1.3
Beads	42	2.1	32	1.6
	252	19.5	192	13.8

Southwest Research Demonstration Unit and Test Areas

To demonstrate the makeup and application of the ETP, Southwest Research Institute used their small applicator and crew to apply test sites in three California locations.

The equipment is mounted on a steel bed approximately 5 feet wide and 10 feet long. The unit is driven by an electric motor powered by a gasoline engine generator. Another gasoline engine generator supplies power for tank agitators, road cleaning wire brush, hot oil circulating pump and heating element for the spray tip.

A compressor supplies air for pressurizing the hot melt and bead tanks and to operate the paint guns. The resin melt tanks, one for white and one for yellow, with separate guns and lines, are heated by propane. The propane also heats the oil circulating system that keeps the hot feed lines to the application guns from cooling. A Binks 1425 airless spray tip is used to spray the hot melt at 450°F. An electric heating element is wrapped around the spray gun tip to keep the melt hot. The insulated hot melt tanks are agitated during heating and application. Melt is sprayed at 30 psi with no air atomization.

The unit is equipped with a skip device timed by a fifth wheel located behind the back wheels. In front of the spray guns, a stout wire brush driven by an electric motor cleans the pavement before the stripes are applied. The wire brush lifts up after each line segment.

The unit is transported on a flatbed trailer pulled by a two-ton truck which also carries material and equipment.

Glass beads (Texas specification) are dropped on. Premix beads at two lbs per gallon are also added to the melt during makeup.

Makeup Procedure

Starting from cold, the liquid resin (6010) is added to the melt tank along with the coloring pigment, titanium dioxide (TiO_2) for white and chrome yellow for yellow. The mix is stirred thoroughly and propane burners started. At 200°F, the solid resin (7097) is added as heating and agitation continue. At 300°F, the filler material ($CaCO_3$) is added. At 350°F, the premix beads are added. When heated to 450°F, the melt is ready to apply. This procedure apparently is necessary to disperse the TiO_2 or chrome yellow with their present mixing equipment. If more powerful mixers were used, the dry materials would probably be dry blended and added to the liquid resin and heated. But again, this unit is simply a demonstration unit, not a full-scale operational machine.

Catalyzed System

Some experimentation has been done in catalyzing the epoxy resin melt. This may be done by melting solid P.A. (phthalic anhydride) and spraying over the epoxy line in a thin mist. The unit demonstrated here was not equipped for this procedure. Accordingly, a 20 percent solution of P.A. in acetone was rolled over the applied stripe in a few sections of each test area. The addition of catalyst to the applied epoxy line surface was an attempt to provide a harder surface. This might result in increased wear resistance and decreased dirt retention.

The first application in California was done by SRI using their own demonstration machine in the following areas:

1. SR-1, Pacific Coast Highway from SR-91 to Garnet Street, both northbound and southbound on 10-3-78. Broken line only, one-half on old worn paint stripe and one-half on bare PCC or AC. Application thickness 0.018 inch with 6.3 lbs/gallon of drop on beads. Formula 60/40.

2. Traver-Kingsburg on SR-99, northbound from Tul-99-46.50 to 52.50. Broken line placed in the gap between raised markers both on PCC and AC. Date of application 10-5-78. Application thickness 0.017 inch with five lbs/gallon drop on beads. Formula 60/40.

3. Blue Canyon-Whitmore, I-80 westbound from Pla-80-53.13 to 50.82. Broken line one-half on old paint stripe and one-half on bare PCC. Date of application 10-11-78. Application thickness 0.022 inch with 6.5 lbs/gallon of drop on beads. Dry time - instant, no problem with tracking. Formula 50/50.

Service Life

The Blue Canyon test site was about 50 percent removed after the first snowstorm one month after application. The Traver-Kingsburg area was not the best of test sites; the line being hard to evaluate between the marker gap, especially at night. No chipping or excessive wear was observed in a three-year period. A slight yellowing was observed.

The SR-1 site, between Redondo and Hermosa Beach, has shown excellent service life, bead retention and night visibility for a three-year period. A slight yellowing was observed after two years. Some intersections in this test area are showing excessive wear and service life is considered to be three years.

No advantage or difference could be seen in catalyzed sections and the use of post-catalyst has been dropped.

After the successful initial test sites, both in California and other states, the FHWA arranged for a large amount of Epoflex to be made in a premelted form for further testing. The Epoflex was made by Bonded Products, Inc., West Chester, Pennsylvania, cast in 25 pound boxes ready for melting and spray applications. California received five tons of white 60 percent liquid to 40 percent solid formula for application in District 04.

Application of ETP in Premelted Block Form

Application Unit

A Prismo Universal small self-propelled applicator, consisting of a propane heated application tank of about 20 gallon capacity, was used. Application guns are air-atomizing and hot melt is fed to guns with about 30 psi air pressure. The unit has a mechanical skip device and bead guns. The operator rides the vehicle. All hot melt lines are heated by a hot oil circulating pump. The premelt tank has a capacity of 120 gallons, heated with a thermostatically controlled propane burner, and vertically mounted hydraulic paddle type agitator. A premelt tank is mounted

on a separate truck and hot plastic transferred to the application unit by gravity flow through a 1/8" screen to catch any coarse particles.

The ETP was shipped in corrugated boxes approximately 6"x6"x12" weighing about 25 pounds each. Boxes were treated with release agent to permit easy removal of plastic. The five tons consisted of material from Lots A1 through A4, FHWA Contract DTFH61-C00041.

Test Areas

No. 1, SR-17 - Nimitz Freeway - PCC, southbound from Ala-17-20.73, (Washington Street) for four miles to Jackson Street. Northbound from Jackson Street to Winter Street, about 2-1/4 miles. Existing complement of ceramic markers and retroreflective markers was removed and the line swept by a power sweeper.

Southbound Section

Date of Application	- August 9, 1981
Ambient Temperature	- 56°F
Surface Temperature (PCC)	- 68°F
Relative Humidity	- 86%

1st Mile Southbound from Ala-17-20.73

Prismo regular thermoplastic was applied in a 12/48 skip cycle, essentially on bare PCC. No primer was used.

Considerable plugging of the air-atomizing gun was due to numerous coarse particles, later traced to residue built up on sides of premelt tank. Air-atomizing gun applies with considerable splatter about two inches on each side of line. Average thickness of coating was 0.090 inch with an uneven coating of post-applied state specification beads due to improper operation of the bead gun. No ceramic markers were used in the pattern; only new Ray-O-Lite retroreflective markers at 48 foot centers.

2nd Mile Southbound

A control section was applied with the regular complement of raised ceramic and retroreflective markers on a 12/48 cycle.

3rd Mile Southbound

Extruded thermoplastic (Pavemark) was applied on a 12/48 cycle with Ray-O-Lite retroreflective markers on 48 foot centers. This section was applied with a small, hand pushed applicator, not sprayed. Average thickness of coating was 0.110 inch with good bead application.

4th Mile Southbound

3M Stamark tape was applied by hand on a 12/48 cycle with no primer. Ray-O-Lite retroreflective markers were applied on 48 foot centers. No problems in installation of this section. Thickness of tape was 0.060 inch.

Northbound Section

Date of Application - August 16, 1981
Ambient Temperature - 58°F
Surface Temperature - 70°F
Relative Humidity - 75%

1st Mile Northbound from Jackson Street

Epoflex spray was applied with a Prismo applicator. Premelt temperature was 420°F and application temperature was 375°F. Operation was good but bead application was spotty due to an erratic bead gun. Average thickness of line was 0.065 inch. The Epoflex flows very readily through the air-atomizing gun but still shows considerable splattering as did the regular thermoplastic. The pattern applied was a 12/48 cycle on mostly bare PCC with new Ray-O-Lite retroreflective markers at 48 foot centers. The Epoflex blocks melted readily in the premelter in about one-half the time required for regular thermoplastic. No smoke or obnoxious fumes were observed.

2nd Mile Northbound

A control section of regular ceramic and retroreflective markers was placed in a 12/48 cycle.

No. 2 Test Section SR-4 - Concord

SR-4 at Willow Pass Road eastbound for 1.5 miles then westbound for 1.5 miles. All PCC pavement with well worn existing 9/24 cycle traffic paint. No raised ceramics in this section; only paint and retroreflective markers at 24 foot centers. Existing retroreflective markers removed and

replaced with new Ray-O-Lite retros on 48 foot centers. Epoflex was applied on a 12/48 cycle so some of the Epoflex was on the existing old paint line and some on bare PCC.

Date of Application	- August 23, 1981
Ambient Temperature	- 60°F
Surface Temperature (PCC)	- 80°F
Relative Humidity	- 77%
Premelt Temperature	- 450°F

The application was satisfactory but there was considerable buildup in the gun shield due to a tendency of the melt to form a stringy mass. This may be due to "self-polymerization" of the Epoflex. Bead application was erratic, not covering the full width of lines. Night performance of this test area was satisfactory but shows erratic bead distribution.

Average film thickness eastbound was 0.075 inch.
Average film thickness westbound was 0.085 inch.

No. 3 Test Area I-680 - Pleasanton

Edge line over old traffic paint, northbound I-680 from Ala-680-15.62 to Ala-680-16.14. Also 8-inch gores, Bernal Avenue off ramp, north and southbound lanes. Average film thickness on the edge line was 0.060 inch and on the gores, 0.070 inch. At Bernal Avenue, the gore northbound line was beaded by hand. Beads retained very well with good submersion.

Ambient Temperature - 86°F
Surface Temperature - 112°F
Gusty Winds
Premelt Temperature - 450°F

The operation was satisfactory although gusty winds kept blowing out the applicator unit burner.

No. 4 Test Area - Palo Alto SR-82

SR-82, north and southbound, 8-inch turn pockets at El Camino Real and Page Hill Road, Grant Avenue and Olive Avenue. Temperature of premelter 420°F, operation satisfactory; no strings or buildup in air-atomizing gun shields.

Date of Application	- August 27, 1981
Ambient Temperature	- 90°F
Surface Temperature (AC)	- 120°F
Relative Humidity	- 51%
Bead Application	- OK

Average thickness about 0.060 inch.

Operation is very good at 400°F. The spray pattern is best at this temperature; still some splatter with air-atomizing gun but much improved. Bead retention good with about 50 percent of bead diameter immersed in coating. Average plastic thickness is 0.065 inch.

Adjustments of Prismo Applicator

Efforts were made to try and minimize splatter and to try an airless tip. These adjustments were made in the Castro Valley Maintenance Yard. The premelter was loaded with 475 pounds plastic, heated to 450°F and held about four hours and then allowed to cool. The next day, without further addition of fresh plastic, the premelter was reheated to 450°F and held about four hours. Batch transferred to application unit. The resultant spray was very poor with

lumps of gelled material and a definite yellow coloration. The material was stringy and hung up in the spray shields. The material was discarded and a fresh batch made up with 275 pounds of Epoflex. This batch was heated to 467°F. On application, the spray was very poor with many "strings" and lumps. Very poor spray characteristics were found with both air-atomizing and airless tip. This batch was discarded and another batch made up in the premelter at 425°F. When transferred to the application unit, the temperature was 410°F. Spray application at this temperature was much improved with no buildup around the gun shields and no strings. When the air-atomizing line was blocked off and the airless tip (Binks M14-25) installed, the plastic flowed through the tip but the spray pattern was only about two inches wide instead of the four-inch width obtained with the air-atomizing gun. Apparently not enough pressure was available in the Prismo unit for airless application. Maximum pressure available was 30 psi and at least 60 psi is required for proper operation of the airless tip. No splatter was observed with the airless tip. To minimize splatter with the air-atomizing gun, it was found that rotating the slit at the tip in a direction parallel to the direction of travel tended to lessen the splatter and improve the appearance of the line.

These experiments indicated that Epoflex is sensitive to overheating and holding too long at 450°F without the addition of fresh plastic to the premelt tank. For best spray application, the ETP should be heated to a maximum of 425°F with the application temperature maintained about 375 to 400°F. Remelt of previously melted material should always be accompanied with the addition of fresh plastic. Application by the Prismo unit was not entirely satisfactory due to splatter and excessive film thickness. To apply

thickness of 0.020 inch, more work will have to be done on application methods for the ETP.

Inspections - Premelted ETP

Test Section No. 1 - Nimitz Freeway After 6 Months

1st Mile Southbound

Prismo thermoplastic section satisfactory; no appreciable wear or spalling; night visibility satisfactory.

2nd Mile Southbound

Control section (raised markers section) satisfactory both day and night markers. About two or three ceramics missing, otherwise satisfactory.

3rd Mile Southbound

Pavemark extruded thermoplastic section satisfactory; some feathering on edges but delineation satisfactory day and night.

4th Mile Southbound

Stamark 3M tape section satisfactory; no loss of adhesion; day and night delineation satisfactory.

Northbound Section After 6 months

1st Mile Northbound

ETP white section satisfactory; day and night delineation; no spalling or loss of adhesion.

2nd Mile Northbound

Control section (raised markers section) satisfactory; good day and night delineation. No markers missing.

The 8-inch gore separation from SR-17 northbound to Cal State University, Hayward, showed transverse cracks through the ETP coating although no loss of adhesion was observed. This may indicate the ETP at 0.060 inch thick is excessive. These cracks will be observed for any further activity.

Test Section No. 2 - SR-4, Concord After 6 Months

Eastbound Section

Delineation satisfactory night and day; beads fair but good where a small section near end of test area was hand beaded.

Westbound Section

Delineation and color good; beads fair. No signs of spalling or adhesive failure.

Test Section No. 3 - I-680 After 6 Months

Delineation satisfactory; beads fair. Beads very good on section of gore line at Bernal Avenue where beads were hand sprinkled.

Test Section No. 4 - SR-82 After 6 Months

All turn pockets in this area show good color and no wear. Beads appear in clumps but satisfactory. Transverse cracks through the ETP coating were observed as in the SR-17 area. No spalling or loss of adhesion was observed.

Test Section No. 5 - SR-238, Fremont After 6 Months

The edge lines in this area are in good condition; beads satisfactory but show transverse cracks as in the other sections.

Future ETP Testing

With the delivery of a new Mini Mac 1000 medium sized hot melt applicator and premelt tank, we intend to pursue the application of more ETP, both white and yellow. Hopefully, this machine will provide improved thickness control and produce the nonsplatter lines with adequate beads necessary for proper evaluation of this material.

Districts 03 and 04 have a combined order for ETP amounting to five tons of white and seven tons of yellow from Pavemark Company. This work will be reported at a later date.

E. Preformed Plastic Tape

The preformed plastic traffic line is a complete package, containing binder, pigment and glass beads. When applied as traffic delineation, it produces an immediate traffic line without the usual problems connected with other forms of delineation. These include requiring heavy trucks,

tanks, pumps, application guns, etc., plus proper application of beads and cure time for the resins to develop strength to withstand traffic. It would appear that preformed delineation presents a solution to all the inherent problems associated with the conventional striping materials.

Some failures on crosswalks and legends due to bond failure in high shear areas have shown up in test sections, especially during the California hot summers. Also, some tapes have shown deformation under traffic, especially on crosswalks and legends on AC during the hot summer weather. Mainline installations have shown some excellent service over PCC and AC. On new AC surfaces where the tape can be inlaid by heavy rollers, service has been most impressive. Inlaid tape in snowplow areas has not been entirely satisfactory. Usual service life has been about one winter. Installation cost for surface applied 4-inch wide, 60 mil tape is about $1.25/linear foot. The rate of application for a broken line is about three miles per hour with an automatic tape applicator which continuously cuts the tape to proper length, applies and rolls the tape on the pavement. Production rates are rather slow as compared to average striper trucks which can apply broken lines from 10 to 25 miles per hour depending on the number of guns and the guidance system used.

Technology on tape application machinery could improve and might eventually be competitive with conventional stripers. Most of the work in this field of application has been done by 3M Company.

Field Application 3M and Prismo

Test sites and application data for the surface-applied tape (not inlaid) are shown in table 20 and the inlaid sections are shown in Table 21.

Inspections of Preformed Tape

SR-37, Sol 7.0 to Sol 10.0 - 5 Years Service

Stamark - The only significant failure of Stamark lane line material observed was between post miles Sol-37-6.96 to Sol-37-7.21. At this location, white Stamark, with adhesive backing, was placed on centerline over fresh unprimed AC. The first failure was observed after five months when a total of six consecutive eight-foot lane lines were either completely missing or badly torn with only small pieces remaining on the road. Failure of material in this area was apparently due to excessive bleeding of the fresh AC. After five years of exposure to traffic, the remaining Stamark lane line material between post mile Sol-37-6.96 and Sol-37-8.45 has been performing very satisfactorily during the daytime. Nighttime delineation has only been satisfactory for the first two years of service life.

Eight-inch wide Stamark was used for turn pocket delineation at the intersection of Rogers Street and Highway 37. After 16 months service, two one-foot sections of the stripe had failed in bond to the AC and were missing. The failure was in the wheel track of autos turning from the far lanes. The material used for turn pockets had no self-adhesive and was applied using only contact cement. It now is in need of repair or replacement.

TABLE 20

Surface-Applied Preformed Tape

Date	Location	Line Type	Tape Type	Tape Lineal Feet	ADT
July 1977	SR-37, Sol 7.0 to Sol 10.0, AC pavement	White Broken	4-inch Stamark	5,390	20,000
		Yellow Median	8-inch Stamark	750	
		White 8 inch	4-inch Scotchlane	9,311	
		White 12 inch	12" Stop Bars	90	
July 1977	I-80, Sol 38.4 to Sol 40.1 East	White Broken No. 1-2 Lane	4 inch Scotchlane	2,244	60,000
		White Broken No. 2-3 Lane	4 inch Stamark	2,244	
	I-80, Sol 38.7 to Sol 40.4 West	White Broken No. 1-2 Lane	4 inch Scotchlane	2,244	
		White Broken No. 2-3 Lane	4 inch Stamark	2,244	
July 1977	SR-113, Sol 8.2 to Sol 18.3	Yellow Centerline	4 inch Stamark	12,276	5,000
		Yellow Centerline	4 inch & 8 inch Scotchlane	5,280	

TABLE 21

Inlaid Preformed Tape

Date	Location	Line Type	Tape Type	ADT/Elev.
August 14-22/80	SR-4, Cal 46.5 to Cal 58.0, New AC. Roller applied twice at 150°F.	Yellow Centerline Legends and Crosswalks	4-inch Stamark	1650/6000
July 7, 1980	US-50, ED 53.36 to ED 53.73	Yellow Centerline	4-inch Stamark, 60 mil	13000/6000
	ED 65.00 to 65.41	Yellow Centerline	4-inch Stamark, 60 mil	
	ED 55.07 to 55.18	Yellow Centerline	4-inch Prismo, 60 mil	
	ED 63.50 to 63.60	Yellow Centerline	4-inch Prismo, 90 mil	

All other Stamark material applied with contact cement and used for turn pockets and legends on Highway 37 has been performing very satisfactorily.

Scotch-Lane Foil - Within two months of being installed, Scotch-lane foil located at the intersection of Sacramento Street and Highway 37 failed. This failure was entirely in adhesion to the road surface and was not unexpected because of the temporary nature of the foil and the extremely high traffic density.

Highway 37 between Enterprise and Sacramento Streets was resurfaced and the Scotch-lane foil subsequently destroyed in this area.

I-80, Sol 38.4 to Sol 40.1 East, Sol 38.7 to Sol. 40.4 West - 5 Years

Stamark - All 3.4 miles of Stamark lane line material has been performing very satisfactorily since it was installed on I-80 over new AC five years ago. Not one lane line in this test area failed in adhesion and no movement of the material has been observed. The material at this location appears to remain clean and all lines are white with no apparent yellowing.

Nighttime observations indicate the Stamark lane lines retain satisfactory reflective properties for two years of service life. Reflective pavement markers were placed on 48 foot centers throughout this installation after one year to facilitate nighttime delineation during wet weather.

Scotch-Lane Foil - Throughout the 3.4 lane miles of foil, only 16 individual lines were badly damaged or missing after two years of service. This accounts for less than three percent of the entire installation. The remaining lines appear in excellent condition and remain adequate for day and night delineation.

All foil lines have remained clean throughout the two years of service.

SR-113, Sol 8.2 to Sol 18.3 - 5 Years

Highway 113 between Dixon city limits and 10 miles south is a two-lane asphalt road with several intersections and agricultural access roads. The entire 10 miles of road had been resurfaced with AC just prior to the installation of the yellow Stamark and Scotch-Lane foil.

After nearly five years of service, almost 100 percent of all Stamark and foil lane lines, including solid intersections, are intact. The intersection of Midway and Highway 113 is the only area with any significant damage. At this location, 30-40 percent of the solid line foil is torn and missing. Some parts of Highway 113, especially the northern half, are very dirty and certainly due, in part, to resurfacing operations within the last year. During the last resurfacing, the centerline was not covered and some asphalt was carried to the centerline by traffic. In general, the test section on Highway 113 has performed satisfactorily during the daytime for the past five years.

At night, both the Stamark and Scotch-Lane foil on Highway 113 retained sufficient retroreflective properties to provide adequate delineation for only the first two years of service life.

SR-4, Cal 46.5 to Cal 58.0 - After 1 Year Service

The centerline inlaid stripe is showing the effects of snowplow activity. About 40 percent of the centerline has been damaged to the point that adequate delineation is not provided and this section is considered a failure after one year's service. A crosswalk at PM 48 also showed accelerated wear.

US-50, El Dorado County - After 1 Year Service

Observations of Stamark at PM 53.36 to 53.73 - Snowplow and chain damage has occurred on many of the stripes. Twenty-seven of 82 line segments had some damage. The damage consisted of a serrated removal of part of the stripe on the ends and sides of the stripe. The Stamark material conforms to each hole or crack in the pavement as traffic depresses the tape into each void in the pavement. Gravel spread during snow conditions is also depressed into the tape surface. The stripes are generally above the existing pavement. It appears the inlaying was only partially successful.

Observations of Prismo 60 mil at 55.07 to 55.18 - This tape shows chipping along the edges of the stripe. It is above the surrounding pavement. The tape does not fill each hole or crack in the pavement. It has a mastic back which conforms to the pavement surface imperfections rather than the tape. It does not show the same serrated damage that the Stamark tape has incurred. However, the tape appears to be brittle, thus, chipping rather than suffering serrated damage. If a snowplow catches the tape, it removes large pieces; one-half of one tape was missing, 11 of 23 line segments were chipped and damaged.

Observations of Prismo 90 mil at PM 63.50 to 63.60 - Stripes were chipped along the edge. Almost all the stripes show some chipping. Nine of the 21 stripes were considered damaged (large chips were visible). The 90 mil generally looks better than the 60 mil material.

Observations of Stamark 60 mil at PM 65.00 to 65.41 - The stripes were well depressed into the pavement. There was little snowplow damage as evidenced by the usual serrated removal of part of the stripes. There was some gravel pressed into the top of the tape. The tape looks dull and well worn.

General Observations - Comparing the preformed tape at these four locations with the recently painted centerline, the tape after one year of use has a daytime delineation equal to, or slightly less than, new paint. The tape does not have any beads visible; therefore, nighttime visibility is probably less than desirable. Only the Stamark between 65.00 and 65.41 appears to have been inlaid to any degree. All the other installations have the stripe on top of the pavment.

F. Polyester Traffic Line

Many delays due to equipment adjustment and one of the wettest winters on record have prevented the actual test application of the polyester traffic coating with our small air-atomizing applicator. We have purchased a Binks catalyst gun, hand operated, for stencil and crosswalk application. We propose to do considerable legend work with the polyester.

Work on this phase will be reported at a later date.

APPENDIX A

State of California

AIR RESOURCES BOARD

Date: July 7, 1977

Model Rule For Architectural Coatings

1. Definitions

a. Architectural Coatings

For the purpose of this rule, an architectural coating is defined as any coating applied to stationary structures and their appurtenances, to mobile homes, to pavements, or to curbs.

b. Bituminous Coatings Materials

Black or brownish materials, soluble in carbon disulfide, consisting mainly of hydrocarbons and which are obtained from natural deposits, or as residues from the distillation of crude petroleum oils, or of low grades of coal.

c. Fire Retardant Coatings

Architectural coatings which are designed to retard fires and which will significantly: (a) reduce the rate of flame spread on the surface of a material to which such a coating has been applied, or (b) resist ignition when exposed to high temperatures, or (c) insulate a substrate to which such a coating has been applied and prolong the time required to reach ignition temperature.

d. Graphic Arts Coatings

Coatings which are marketed solely for application to indoor and outdoor signs and include lettering enamels, poster colors and bulletin colors.

e. Industrial Maintenance Finishes

High performance coatings which are formulated for the purpose of heavy abrasion, water immersion, chemical, corrosion, temperature, electrical or solvent resistance.

f. Metallic Pigmented Paints

Non-bituminous coatings which are formulated with metallic pigment.

g. Opaque Stains

All stains that are not classified as semitransparent stains.

h. Primers

Coatings which are intended to be applied to a surface to provide a firm bond between the substrate and subsequent coats.

i. Sealers

Coatings which are intended for use on porous substrates to protect the substrate, to prevent subsequent coatings from being absorbed by the substrate, or to prevent harm to subsequent coatings by materials in the substrate.

j. Semitransparent Stains

Coatings which are formulated to change the color of a surface but not conceal the surface.

k. Tile-like Glaze Coatings

Coatings which are formulated to provide a tough, extra-durable coating system, which are applied as a continuous (seamless) high-build film and which cure to a hard glaze finish.

l. Undercoaters

Coatings which are designed to provide a smooth surface for subsequent coats.

m. Varnishes, Lacquers, and Shellacs

Coatings which contain resins and binders but not opaque pigments and which are specifically formulated to form a transparent or translucent solid protective film.

n. Waterproofing Coating

Coatings which are formulated for the sole purpose of preventing penetration of the substrate by water. These coatings include, but are not limited to. bituminous roof and resilient type coatings.

o. Wood Preservatives

Coatings which are formulated for the purpose of protecting exposed wood from decay and insect attack. These coatings perform their function by penetrating into the wood.

2. No person shall sell, offer for sale, or apply any architectural coating manufactured after (one year from date of adoption) which:

a. contains more than 250 grams of volatile organic material per liter of coating as applied, excluding water, except as provided in subsection b of this section.

b. contains more than 350 grams of volatile organic material per liter of coating as applied, excluding water, and is recommended solely for use on interior surfaces. Interior coatings manufactured after (three years from date of adoption) may not contain more than 250 grams of volatile organic material per liter of coating as applied, excluding water.

c. is recommended for use as a bituminous pavement sealer unless it is an emulsion type coating.

3. The provisions of Section 2 of this rule shall not apply to architectural coatings sold in this district for shipment outside of this district or for shipment to other manufacturers for repackaging.

4. The provisions of Section 2 of this rule shall not apply to coatings manufactured prior to (two years from date of adoption) by a Small Business.

a. A "Small Business" for the purposes of this rule means any business which in 1976 sold less than 200,000 gallons of paints and coatings.

(i) A business shall not qualify for this exemption if it would not be considered a Small Business, as defined in Subsection (1) of Section 1896 of Title 2 of the California Administrative Code.

(ii) A business shall not qualify for this exemption if its total annual sales volume of paints and coatings which would otherwise be subject to this rule exceeds by more than 10 percent the business's total sales volume of such coatings in calendar year 1976.

b. To qualify for a Small Business exemption, a company requesting such exemption shall file a request in writing with the Air Pollution Control Officer. The company shall provide the Air Pollution Control Officer any necessary information including, but not limited to: (i) total volume (in gallons) of paints and coatings sold in 1976; (ii) the number of persons employed by the company; (iii) the gross sales receipts (in dollars) for 1976; and (iv) total annual sales volume of paints and coatings in 1976 and any subsequent year which would otherwise be subject to this rule. Other information necessary to document that the business is not an affiliate of another business concern which would not be considered a Small Business for the purposes of this rule shall also be provided to the Air Pollution Control Officer.

The Air Pollution Control Officer after considering information submitted by the business concern shall determine whether such concern qualifies as a Small Business as defined in Subsection a. of this section and shall inform the business concern of this determination in writing.

5. The provisions of this rule shall not apply to the following coatings manufactured prior to (five years from date of adoption):

   a. architectural coatings supplied in containers having capacities of one liter or less;

   b. traffic coatings applied to public streets and highways; however, this exemption shall not extend to traffic coatings applied to other surfaces, including, but not limited to curbs, berms, driveways and parking lots.

   c. architectural coatings recommended by the manufacturer for use solely as a:

      1) varnish, lacquer, or shellac
      2) semitransparent stain
      3) opaque stain on bare redwood, cedar, mahogany, and douglas fir
      4) primer, sealer, or undercoater
      5) wood preservative
      6) fire retardant coating
      7) tile-like glaze coating
      8) waterproofing coating, except bituminous pavement sealers
      9) industrial maintenance finish
      10) metallic pigmented coatings
      11) swimming pool coating
      12) graphic arts coatings

6. Identification of Coatings

   Containers for all coatings subject to Section 2 shall display the date of manufacture of the contents or a code indicating the dates of manufacture. The manufacturers of such coatings shall file with the Air Pollution Control Officer and the Executive Officer of the California Air Resources Board prior to (one year from date of adoption) an explanation of each code.

7. Labeling of Coatings

   a. If anywhere on the coating container, on any sticker or label affixed thereto, or in any sales or advertising literature, any indication is given that the coating may be used or is suitable for use for any purpose other than those specifically provided for in Section 5 of this rule, then the exemption provided for in said Section 5 shall not apply to that coating.

   b. In any instance where more than one of the standards set forth in Section 2 of this rule may be applicable, the most restrictive standard shall apply.

APPENDIX B

Water-Borne Paint:

Water-borne traffic paint is a one-component system, similar to solvent-borne paint, but the solvent is mostly water. The organic co-solvent which is necessary to achieve proper application properties is restricted to a low level. Glass beads are normally post-applied.

Hot Melt Extruded Thermoplastic:

This is a 100% solids system consisting of a mixture of various resins, pigments and glass beads, which, when heated to about 425°F, can be extruded to form lines and/or legends. It is applied at 150 to 190 mils. Additional glass beads are post-applied.

Hot Melt Sprayed Thermoplastic:

This is essentially the same as above except that the viscosity of the resin binder may be somewhat lower to permit spray application. It is applied at 60 to 90 mils.

Flame-Sprayed Thermoplastic:

This is a mixture of a special thermoplastic resin which will not darken in a propane flame, pigments and glass beads. It is applied at about 15 mils thickness. No post-applied beads are used.

Polyester Paint:

This is a two-component system consisting of resins, pigments, and a curing agent which is spray applied at 15 mils. The curing agent is somewhat hazardous; however, it has been used in tremendous volume in the fabrication of fiberglass boats and other similar items.

Two-Part Epoxy Paint:

Two-component epoxy traffic paint is a high solids system. It consists of a liquid epoxy resin and a liquid hardener together with proper pigments. The two are proportioned in a definite ratio and then mixed and sprayed to form a traffic stripe of about 15 mils. The subsequent cured material is thermosetting. Glass beads are post-applied.

Cold Preformed Plastic:

This is a 100% solid preformed material consisting of resins, pigments and glass beads. It is furnished cut to proper size, ready to be bonded to the highway surface as a traffic stripe or as legends or crosswalks. The thickness is usually 60 to 90 mils.

This material usually has an adhesive backing. A primer or other treatment is often used under high shear conditions such as crosswalks.

Epoxy Thermoplastic:

This material is a 100% solids system consisting of a mixture of a liquid and a solid epoxy resin of known composition, pigments and glass beads. The mixture is heated from 425°F to 450°F and spray applied about 15 mils thick. No curing agent is used so the material remains thermoplastic. Additional glass beads are post-applied.