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Performance of Chlorinated-Rubber Traffic Paint

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RESEARCH REPORT 146

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PERFORMANCE OF CHLORINATED-RUBBER TRAFFIC PAINT

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Final Report on Research Project 167-2
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16. Abstract

Based on promising performance in earlier tests, 90,000 gal of chlorinated-rubber (CR) traffic paint were installed by Region 4 (Rochester) striping crews in 1987. This material appeared to offer 12-month durability, unlike the Department's standard modified alkyd (MA) traffic paint. This report documents performance of nearly 300 miles of test lines installed by Regions 1 (Albany) and 4, compared to matching sections of MA traffic paint. The only area of concern during installation was the longer no-track time of CR paint, requiring increased traffic protection measures to protect wet lines from vehicles. It would appear that CR is capable of providing year-round delineation under typical conditions, on most New York roadways currently requiring traffic paint. However, it may require a second restriping of some lines to achieve this goal and continued observation of CR paint performance is necessary to identify those combinations of traffic, roadway, and climatic conditions under which CR is not capable of providing 12-month durability.

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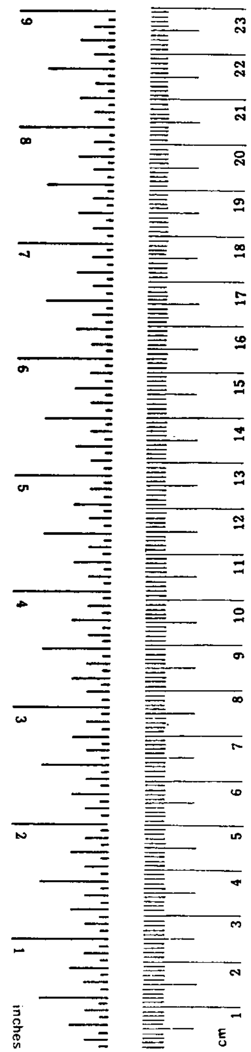
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

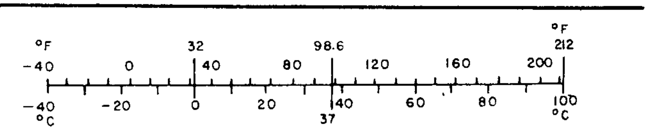


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Table 1. Summary of paint test sections.

Site	Route	County	Paint Type	Date Striped	Width	Pavement Type	Two-Way AADT
PAIRED SECTIONS							
1	354	Wyoming	CR	7/01/87	2-lane	Asphalt	1950
2	354	Erie	MA	7/15/87	2-lane	Asphalt	1875
3	5	Genesse	CR	7/08/87	2-lane	Asphalt	4350
4	5	Erie	MA	7/15/87	2-lane	Asphalt	7850
5	33	Genesse	CR	7/08/87	2-lane	Asphalt	4300
6	33	Erie	MA	7/15/87	2-lane	Asphalt	5250
7	31	Orleans	CR	7/09/87	2-lane	Asphalt	5150
8	31	Niagara	MA	7/16/87	2-lane	Asphalt	6350
9	104	Orleans	CR	7/09/87	2-lane	Asphalt	2750
10	104	Niagara	MA	7/16/87	2-lane	Asphalt	3125
11	23EB	Greene	CR	7/28/87	2-lane	Concrete	8200
12	23WB	Greene	MA	8/06/87	2-lane	Concrete	8200
14	67	Saratoga	CR	7/29/87	2-lane	Asphalt	3900
13	67	Saratoga	MA	8/05/87	2-lane	Asphalt	5400
16	67	Saratoga	CR	7/29/87	2-lane	Asphalt	2750
15	67	Saratoga	MA	8/05/87	2-lane	Asphalt	3900
19	67	Saratoga	CR	7/29/87	2-lane	Asphalt	2950
18	67	Saratoga	MA	8/05/87	2-lane	Asphalt	2950
22	29	Saratoga	CR	7/30/87	2-lane	Mixed	6375
21	29	Saratoga	MA	8/04/87	2-lane	Asphalt	4850
23	29	Saratoga	CR	7/30/87	2-lane	Asphalt	6150
24	29	Saratoga	MA	8/30/87	2-lane	Asphalt	3300
25	29	Saratoga	CR	7/30/87	2-lane	Asphalt	3300
26	29	Saratoga	MA	8/05/87	2-lane	Asphalt	3500
27	19	Wyoming	CR	7/01/87	2-lane	Asphalt	600
28	19	Allegany	MA	-------	2-lane	Asphalt	1550
29	19A	Wyoming	CR	7/07/87	2-lane	Asphalt	1300
30	19A	Allegany	MA	-------	2-lane	Asphalt	1350
UNPAIRED SECTIONS							
17	67	Saratoga	MA	8/05/87	2-lane	Asphalt	2750
20	67	Saratoga	MA	8/05/87	2-lane	Asphalt	2950
31	70	Living.	CR	7/07/87	2-lane	Asphalt	700
32	441	Monroe	CR	6/04/87	4-lane	Mixed	18900
33	5	Genessee	CR	6/08/87	2-lane	Asphalt	4900
34	33	Genessee	CR	6/09/87	2-lane	Asphalt	3450
35	5	Genessee	CR	6/10/87	2-lane	Asphalt	7100
36	I490	Monroe	CR	6/23/87	4-lane	Concrete	47000

I. INTRODUCTION

A. Background

Engineering Research and Development has been working with the Highway Maintenance Division since 1981 to identify a traffic paint that would improve marking durability compared to the Department's standard modified alkyd (MA). Based on earlier installations on accelerated-wear test decks (1) and in pilot projects by maintenance striping crews (2,3), a chlorinated-rubber (CR) paint was identified that provided a substantial improvement in durability, and appeared to meet criteria for installation characteristics, dry-times, and employee safety.

About 90,000 gal of this CR paint were ordered for installation by the two striping crews stationed in Region 4 near Rochester during the 1987 striping season. This permitted changing the entire operation of these crews to the new paint for that season. Researchers documented installation of about 4300 gal of CR paint and 3000 gal of MA paint. That work was described in October 1987 in Client Report 21 (4).

After installation, periodic condition surveys were conducted by research personnel to monitor performance of both paints. The surveys were continued through July 1988 and rated paint performance in terms of reflectivity, line condition, and visual appearance.

This evaluation documents installation and durability of the CR traffic paint. It also discusses important handling characteristics as well as material properties after winter storage.

B. Layout of Test Sites and Sections

Thirteen CR test sections were located near Rochester in Region 4, including 11 rural two-lane highways and two urban expressways (Table 1). Seven MA control sections were located on the same highways as the CR test sections, but on adjacent segments in Regions 3, 5, and 6. Eight additional CR test sections were placed in Region 1 near Albany, and eight MA sections were placed adjacent to them. All the CR sections were installed by the Region 4 striping crews, and MA control sections were placed by striping crews in the respective regions.

Test sections were selected to include highway configurations, traffic volumes, pavement types, and climatic conditions representative of New York State. Every test section included four preselected test sites where all observations and measurements were conducted. All lines -- edge line, centerline, skip line -- present at each site were included in the evaluation.

C. Installation Procedures

Test sections were installed during June, July, and August of 1987 by Department Maintenance crews, using Wald paint stripers. Installation was monitored and recorded by research personnel, including information on paint handling characteristics, application parameters, and subjective comments regarding workability.

1. Application Rates

Paint application rates were based on Department contract requirements and maintenance guidelines -- wet-film thickness of 15 $\pm$ 1 mils is equivalent to 16.5 gal of paint per mile of 4-in. line. Striping crews adjusted paint guns, pressures, and speeds in the maintenance yards, which produced lines of acceptable appearance. Throughout initial months of installation of CR paint, minor adjustments were made that improved application.

Department-approved reflective glass beads were applied at a nominal rate of 6 lb/gal -- 99 lb/mile of 4-in. line -- as required by maintenance guidelines and construction specifications.

During installation, research personnel collected plate samples of both CR and MA traffic paint with and without beads. These samples were used for microscopic examination of bead embedment and a micrometer determined dry bead-paint thickness.

2. Material Temperatures and Climatic Conditions

Material temperatures were recorded during installation from temperature gages located on the paint trucks. Air and pavement temperatures were also measured and recorded periodically. All temperature measurements were taken using a Cole-Parker Instrument Co. Digi-Sense-Digital thermocouple thermometer. All test sections were installed on dry pavement surfaces.

3. Material Dry-Times

The time required for a traffic paint to dry to a track-free condition ("no-track time") is an important operational parameter. It is defined as the time required for a paint to dry to a state where no material is picked-up and redeposited by traffic. This an extremely important property of traffic paints and is the major characteristic controlling the amount of line protection required during striping. An apparatus designed after ASTM D 711-75 ("No-Pick-Up Time of Traffic Paint") was constructed under a previous research project. It consists of a 3-in. diam roller weighing 7-1/4 lb, fitted with a rubber O-ring having a 3/8-in. track width. The ring exerts a surface pressure of about 66 lb/sq in. This device was rolled across the stripe frequently, until no paint pickup was observed. No-track times were recorded for most test sections.

No-track times were also recorded by research personnel based on vehicles in the traffic stream tracking freshly applied paint. This was most common at intersections or areas of high roadside development, and was generally more pronounced when vehicles turned as they crossed a freshly painted line.

4. Initial Reflectivity and Appearance

Initial reflectivity was measured and recorded for each test section using a retroreflectometer. This was done a few days after installation to allow traffic action to wear off any excess beads. Initial appearance was recorded, including subjective visual observations of edge spattering, sharpness, and brightness.

D. Evaluation Procedures

Stripe condition was inspected periodically for reflectivity, condition, and appearance. Surveys began shortly after installation in the summer of 1987 and were repeated in October 1987, and February, April, June, and July 1988.

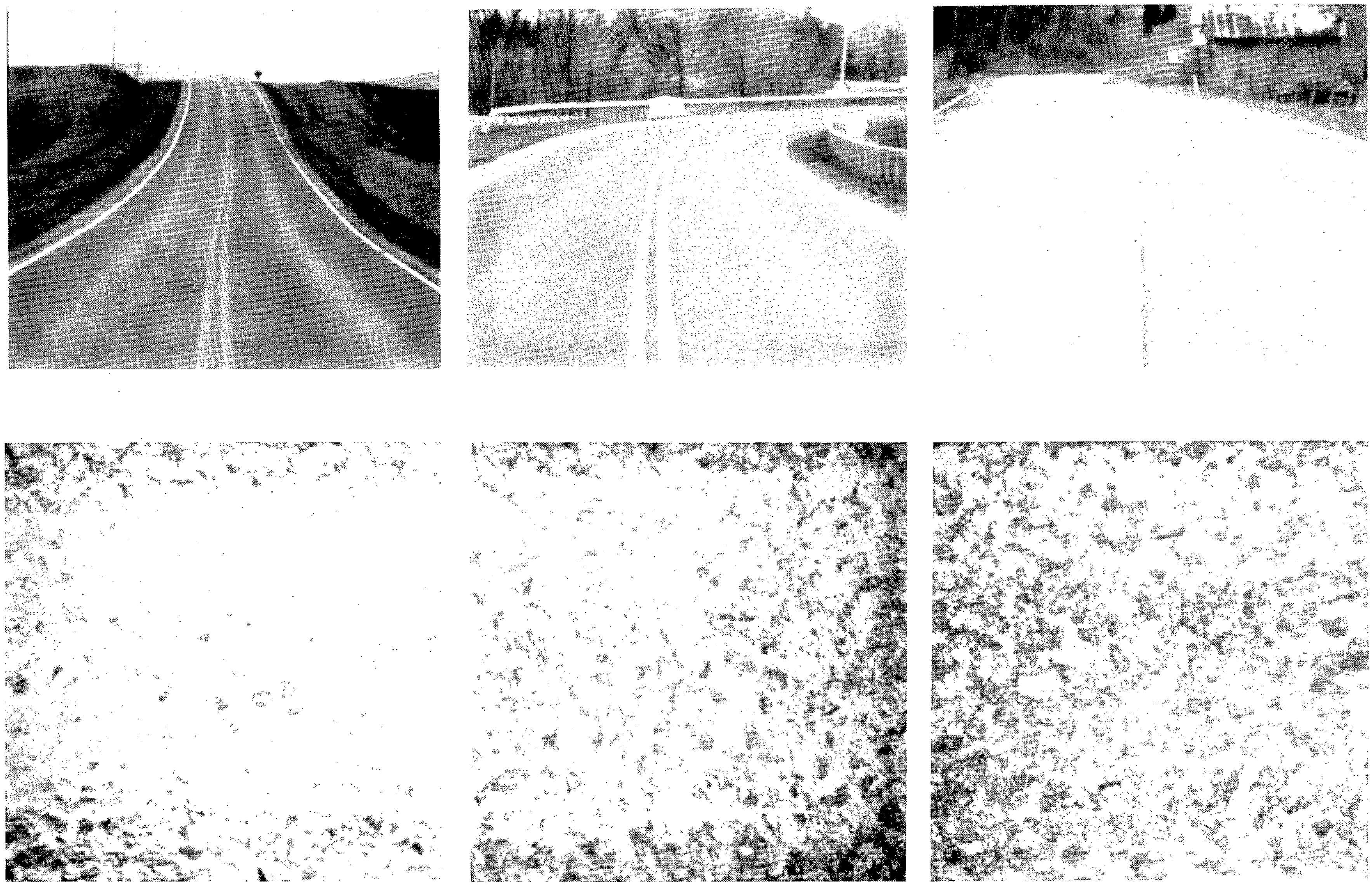
1. Reflectivity

Reflectivity was measured using a retroreflectometer patterned after a device built by the Michigan Department of Transportation (5). This device uses a light source and a photocell to produce a digital readout representing reflectivity of a small area of pavement marking. The device is designed to work using the basic principal of retroreflective theory -- that light striking an object is reflected back to the source along a parallel path.

The Michigan retroreflectometer does not measure in absolute units but does provide a means of judging difference in reflectivity between two markings. The scale relating measured reflectivity to nighttime pavement-marking visibility was based on a subjective visual rating of numerous pavement markings at night and their corresponding unitless reflectivity values. The relationship between measured reflectivity and subjective nighttime visibility developed for this instrument is as follows:

Subjective Rating	Measured Reflectivity White	Measured Reflectivity Yellow
Excellent	>300	>250
Good	≥225	≥175
Fair	≥140	≥110
Failed	<140	<110

Figure 1. Examples of lines in good condition (left, rated 8), fair condition (center, rated 6), and poor condition (right, rated 2).



At each of the four sites within a test section, five reflectivity readings were taken on each line. For skip lines, 10 readings were taken -- two on each of five successive skips. Average reflectivity was calculated for each line in each section.

2. Condition

Condition was rated subjectively to indicate extent of imperfections present in a given marking, including percentage of pavement still covered by paint, discoloration, staining, and other imperfections. A single rating on a scale of 0 to 10 -- 10 is perfect and 0 complete line loss -- was assigned to each line type. Typical examples are shown in Figure 1.

3. Appearance

Appearance is a subjective rating used to represent overall daytime visual effectiveness of markings present at a given site, based on all stripes visible at that location, with all line types and colors grouped together. This rating ranged from 3, representing good markings with only minor imperfections, to 0 representing wornout markings no longer serviceable.

4. Service Life

Based on results of the periodic surveys, service lives were determined for each test section based on the first line to fail in reflectivity or appearance. Although condition is also important in evaluating traffic paint, it was not used as a failure criterion because service life is based on effective delineation. It is possible for the condition rating of a section to fall very low while appearance and reflectivity remain acceptable. Because delineation is primarily associated with daytime visual appearance and nighttime reflectivity, it is appropriate to base service lives on those criteria.

E. Test Materials

The formulation of chlorinated-rubber paint used in this evaluation was based on the New Jersey IV paint, substituting toluene solvent for methyl-ethyl-ketone. The paint has a nominal no-track time of about 90 sec. Because toluene is the same solvent currently used in the Department's standard MA paint, no modifications were necessary to striping equipment before using CR paint. It consists of a vehicle composition of pure drying alkyd, chlorinated rubber, chlorinated paraffin, pigments, stabilizers, and flow control agents. Specifically, the vehicle consists of a short-drying oil, phthalic alkyd resin, chlorinated paraffin, chlorinated rubber, and toluene.

The control paint used was the Department's standard hot-applied MA traffic paint with a nominal no-track time of 60 sec. Past experience had shown that it cannot provide 12-month durability under typical New York conditions. Two yearly applications are made on some highways, but midwinter stripe failures often occur, and these highways thus do not have effective markings for some portion of the year. The Appendix contains detailed specifications for CR traffic paint.

II. RESULTS

A. Loading, Spraying, Handling, and Storage

Research personnel documented paint loading from 55-gal drums to the paint storage tanks on the striping truck. These trucks are equipped with a paint-transfer pump, using a suction hose of about 3-in. diam. The 55-gal drums of CR paint were uniform in consistency and required only minimal stirring before loading. No problems with lumps, settling, or skinning-over were observed, although these problems are frequently encountered with the standard MA paint. Pumping times for the CR paint were about 2 min and little or no residue remained in the drums after pumping. The CR drums could be disposed of immediately because no material remained after pumping.

The MA paint showed considerable separation in the drums when opened. The solvent (toluene) was rising to the tops of the barrels and required stirring before pumping. Pumping times for the MA paint ranging from 2.5 to 4.0 min, and the barrels contained considerable residue after pumping. Residue in the MA barrels had to be collected into another drum and disposed of as a hazardous substance.

Because CR paint includes the same toluene solvent as MA, no additional safety precautions are required in working with this material. Loading was accomplished outdoors, and no buildup of fumes was experienced. For indoor cleaning or repair of striping equipment, suitable respirators and protective clothing are used to prevent inhaling fumes and contact of paint with the skin.

After trucks were initially loaded, adjustments were made to spray equipment to achieve acceptable line quality and the required 15-mil wet-film thickness. The following parameters were determined to produce acceptable line quality and are compared to those for MA traffic paint:

	CR	MA
Tank Pressure, psi	90	80
Atomizing Air Pressure, psi	85-90	60-70
Paint Temperature, F	120-130	110-120
Truck Speed, mph	8-10	8-10
Bead Tank Pressure, psi	20-40	20-40

These settings generally produced good line quality, but some variations were necessary depending on installation conditions -- air temperatures, pavement temperatures, relative humidity, roadside development.

Based on their experience over the first 3 months in use, both Region 4 crews considered CR paint easier to spray than MA paint. There was less clogging and paint buildup at the paint guns, and by midsummer no gun tips had been replaced. They reported that use of the MA paint would normally require tip replacement by midsummer, and often requires complete rebuilding of the paint guns at that time. In addition, there was noticeably less accumulation of material in the in-line filters with CR paint than typically encountered with MA paint.

Another noticeable advantage of CR paint was reduction in overspray during painting. Using MA paint, crews report that there is typically a cloud of paint mist surrounding the rear of the truck, but this is absent when using CR paint.

The specification for the CR paint requires a minimum shelf life of 6 months, but no specific design figure is included in the MA specification. It is normally impossible to control inventory so precisely that all the paint ordered each year is consumed by season's end. Typically, some MA paint is held over winter, representing a storage period of 6 months or longer. The paint reportedly is subject to settling and separation problems during over-winter storage, making it difficult to remix and apply the following spring. In April 1988, Region 4 striping crews began the striping season with white CR paint stored since the previous fall. They reported that the CR had some minor settling and that a short period on the paint shaker quickly remixed it to a uniform consistency. They did notice the paint seemed thicker than the previous summer but required only slightly longer pumping times to load the trucks and it sprayed well.

B. Paint and Bead Application Rates

To obtain a reasonably precise measure of paint and bead application rates, volumes of the bead and paint tanks were calibrated for Region 4 stripers and those used to apply control sections. By measuring depth of the material in the tanks, it was possible to calculate paint consumption in gallons and bead consumption in pounds over a section of line. All stripes had distance counters that recorded the length of line striped, and application rates could then be calculated in gallons of paint and pounds of beads per mile of line. For a 4-in. wide line placed at a wet-film thickness of 15 mils, paint application rate is about 16.5 gal per mile. Beads applied at 6 lb/gal equals a rate of 99 lb/mile of 4-in. line.

None of the stripers observed were equipped with flow meters, and the operators thus had no way of periodically checking application rate. This rate is checked and adjusted each time paint trucks are refilled, based on the quantity consumed and distance painted. However, this calculation applies to a substantial length of line, and application rates for small areas are not available.

Application rates in Table 2 were calculated by measuring paint and bead tanks at the start and end of test sections, and Table 3 summarizes the application rates for CR and MA, in both cases in gallons per mile, bead rates in pounds

Table 2. Summary of paint and bead application rates.

Site	Route	Paint Type	White Paint Mi	White Paint Total Gallons	White Paint Paint Rate, gal/mi	White Paint Thickness, mils	Yellow Paint Mi	Yellow Paint Total Gallons	Yellow Paint Paint Rate, gal/mi	Yellow Paint Thickness, mils	Bead Rate lb/mi
PAIRED SECTIONS											
1	354	CR	7.0	117	16.7	20.3	4.5	81	18.0	21.0	113.5
2	354	MA	5.7	112	19.6	22.1	3.4	35	10.3	18.4	106.0
3	5	CR	6.1	94	15.4	21.8	2.8	43	15.3	19.4	58.8
4	5	MA	8.1	171	21.1	26.3	2.8	31	11.1	17.6	93.1
5	33	CR	6.4	97	15.1	24.1	1.4	20	14.3	22.4	123.5
6	33	MA	2.2	26	11.8	22.3	0.5	7	14.0	N/A	88.0
7	31	CR	7.6	118	15.5	22.8	3.0	48	16.0	21.5	116.3
8	31	MA	8.7	96	11.0	25.7	2.0	24	12.0	NA	92.5
9	104	CR	7.8	112	14.4	26.2	2.3	35	15.2	20.3	96.0
10	104	MA	9.5	95	10.0	22.7	4.7	47	10.0	17.9	65.6
11	23EB	CR	13.5	211	15.6	21.8	11.1	149	13.4	21.8	117.0
12	23WB	MA	12.2	217	17.8	24.9	8.4	127	15.1	24.1	111.0
14	67	MA	8.8	86	9.8	24.1	3.9	53	13.6	21.7	114.0
13	67	CR	1.9	46	24.2	N/A	1.5	31	20.6	N/A	180.0
16	67	MA	9.3	147	15.8	20.9	4.2	54	12.9	20.8	95.6
15	67	CR	2.3	43	18.7	24.0	1.8	31	17.2	25.7	105.0
19	67	CR	5.7	103	18.1	22.2	5.6	81	14.5	21.8	135.0
18	67	MA	2.8	59	21.1	25.4	2.6	47	18.1	19.3	94.0
22	29	MA	4.9	87	17.8	23.6	1.5	20	13.3	23.4	128.0
21	29	CR	9.6	217	22.6	32.0	7.1	123	17.3	25.2	134.0
23	29	CR	11.3	175	15.5	21.9	8.7	117	13.4	20.9	107.0
24	29	MA	8.7	113	13.0	25.1	7.1	123	17.3	25.2	138.0
25	29	CR	6.3	112	17.8	18.5	3.9	59	15.1	21.4	97.0
26	29	MA	6.6	127	19.2	25.1	3.0	65	21.5	26.8	135.0
27	19	CR	4.8	75	15.6	23.1	5.2	78	15.0	21.2	94.1
28	19	MA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
29	19A	CR	8.0	125	15.6	20.7	7.2	115	16.0	21.3	95.0
30	19A	MA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
UNPAIRED SECTIONS											
17	67	CR	2.6	43	16.5	27.1	1.0	22	22.0	29.4	79.0
20	67	MA	2.4	43	17.9	N/A	2.1	31	14.8	N/A	112.0
31	70	CR	7.8	125	16.0	20.6	3.2	50	15.6	21.2	90.0
32	441	CR	2.6	89	34.2	21.5	7.6	101	13.3	N/A	204.0
33	5	CR	0.0	0	N/A	N/A	6.7	113	16.9	20.7	140.0
34	33	CR	0.0	0	N/A	N/A	5.1	73	14.3	20.8	91.0
35	5	CR	1.8	33	18.3	24.1	5.8	98	16.9	N/A	122.0
36	I 490	CR	59.6	947	15.9	N/A	47.2	612	13.0	N/A	107.0

Table 3. Application rate and thickness of dry paint film with beads.

Evaluation Criteria	CR Paint X*	s**	n	MA Paint X*	s**	n
White Application Rate, gal/mile	16.2	4.7	19	15.3	4.2	13
Yellow Application Rate, gal/mile	14.6	2.3	21	14.4	3.3	13
Bead Application Rate, lb/mile	97.4	--	--	105.6	--	--
Thickness (Beads and Paint), mils	21.8	1.6	28	23.8	3.5	20***

*Average rates based on paint total type and color divided by total lane miles.
**Standard deviations are those for individual test sections.
***Statistically significant difference compared to CR, using a student's t-test at the 95-percent confidence level.

per mile, and bead/paint thickness in mils. As seen from these values, actual application rates were variable, and some were not close to the nominal rates. Figure 2 shows paint application rate distributions for both CR and MA paints. A paired t-test at the 95-percent confidence level confirmed that there was no statistical difference between CR and MA application rates. Overall, however, average rates were close to nominal rates.

Measured dry-film thicknesses of the beaded plate samples are summarized in Figure 3. Although the difference is relatively small, the 21.8-mil average thickness of CR lines is significantly less than the 23.8-mil average for MA lines. This difference may depend on actual differences in paint and bead application rates, different bead embedment characteristics for the two paints, or both. Because the difference is small, it is not expected to have a major effect on stripe performance.

C. No-Track Times

A total of 55 no-track-time observations were recorded for CR paint (Table 4). No-track times for CR paint ranged from 50 to 150 sec, averaging 83.6. A Student's t-test determined that no-track times for white and yellow CR paint were not statistically different at the 95-percent confidence level. A total of 10 no-track observations on MA paint averaged 29.3 sec -- significantly less than the average for CR paint. Seventeen of the 55 CR no-track observations were on portland cement concrete pavement (PCCP) and 38 were on asphalt cement pavement (ACP). A Student's t-test indicated no significant difference in no-track times between PCCP and ACP.

During installation no-track times appeared to increase with air temperature, pavement temperature, and paint thickness. Contingency tables were developed in an attempt to identify relationships, but, no statistical evidence exists confirming this based on an X^2 analysis at the 95-percent confidence level.

Subjective observations during striping indicated that crews initially experienced some tracking problems with the CR paint, but almost none with MA. As crews became familiar with the no-track properties associated with CR paint, tracking was reduced when more appropriate line-protection measures

Figure 2. Distribution of paint application rates.

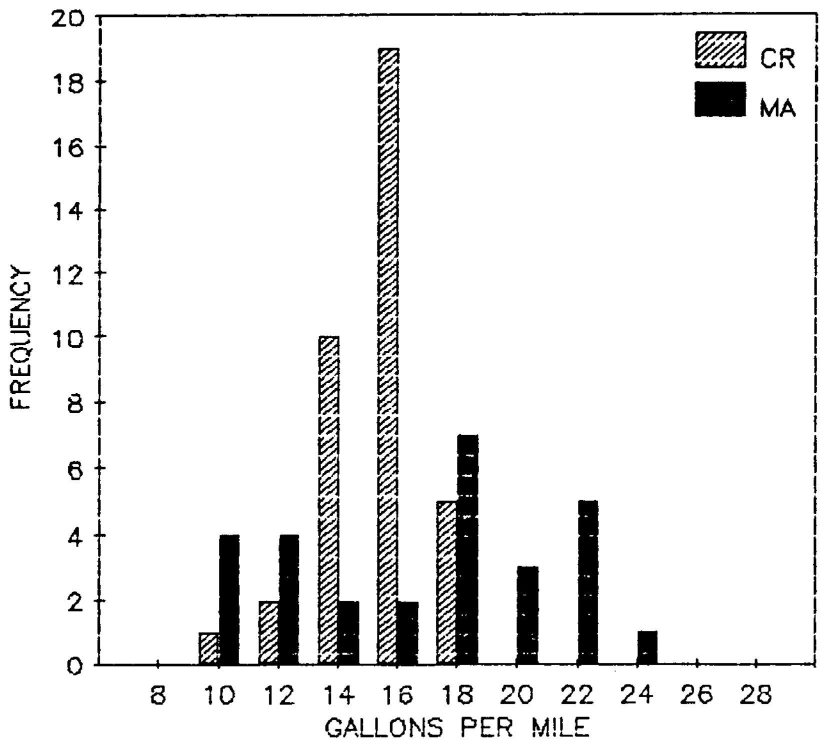


Figure 3. Distribution of thickness of dry paint film with beads.

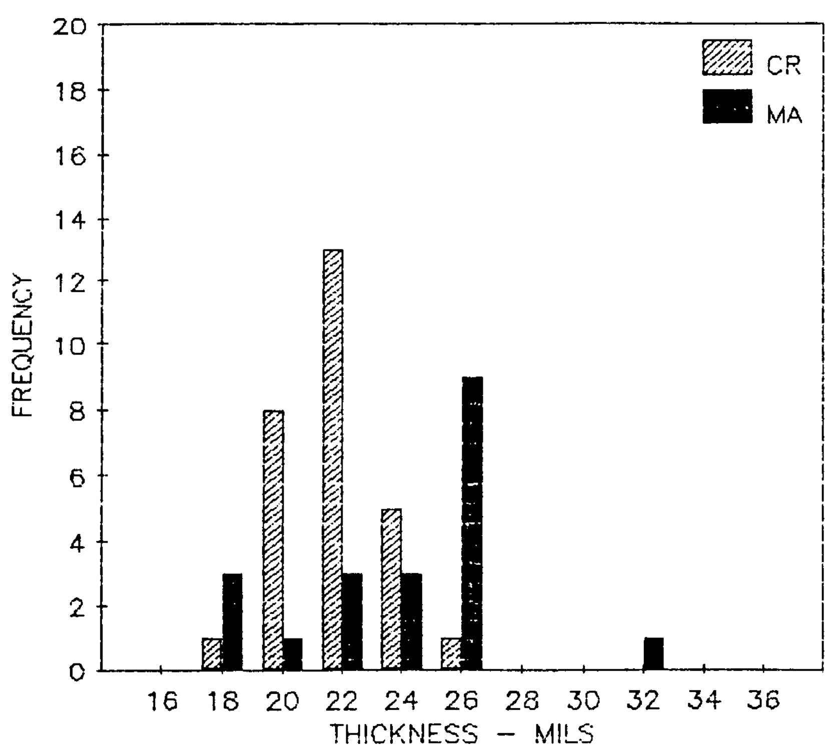


Table 4. Summary of no-track times.

Evaluation Criteria	Seconds X	s	n
White CR	86.8	13.4	25
Yellow CR	85.7	19.2	30
PCP CR	81.4	14.9	17
ACP CR	84.4	17.9	38
Yellow and White CR	83.7	16.9	55
Yellow and White MA	29.3	4.92	10*

*Statistically significant difference compared to CR, using a student's t-test at the 95 percent confidence level.

were implemented. Only urban areas with considerable roadside development continued to require special efforts to minimize tracking.

D. Durability

Detailed condition surveys were conducted within 10 days of installation to document initial condition of CR and MA test sections. Followup surveys were conducted and information obtained as follows:

Survey Date	Performance Criteria Reflectivity	Condition	Appearance
August 1987	x	x	x
October 1987	x	x	x
January 1988	-	x	x
April 1988	x	x	x
June 1988	x	x	x
August 1988	x	x	x

The January 1988 condition survey did not include reflectivity readings because sand and salt deposits from snow-removal operations made reliable measurements impossible. Durability is summarized in Table 5 in terms of number and percent of test sections and lines that were serviceable after a given period. These values are based on data collected in the condition surveys.

Service lives for test sections were based on the first line in the section to fail in reflectivity, appearance, or both. Service lives for test lines were based on the same criteria for each individual line. Any section repainted by maintenance forces was considered to have failed by both criteria, assuming it was repainted because lines were no longer serviceable. In some cases, striping schedules resulted in repainting lines that were worn but had not completely failed. Inclusion of repainted sections in Table 5 as having failed thus results in a conservative estimate of service life.

Table 5. Summary of service lives of test sections and test lines.

Criteria	Months in Service	CR Paint (20 Sections, 42 Lines) Number	Percent	MA Paint (16 Sections, 33 Lines) Number	Percent
SECTIONS					
Reflectivity	<1	20	100	15	94
	3	20	100	15	94
	6	20	100	15	94
	9	20	100	13	81
	12*	16	80	0	0
	13*	11	55	0	0
Appearance	<1	20	100	16	100
	3	20	100	16	100
	6	20	100	9	56
	9	20	100	7	44
	12*	16	80	0	0
	13*	13	65	0	0
Both	<1	20	100	15	94
	3	20	100	15	94
	6	20	100	8	50
	9*	20	100	6	38
	12*	13	65	0	0
	13	4	20	0	0
LINES					
Reflectivity	<1	42	100	32	97
	3	42	100	32	97
	6	42	100	32	97
	9	42	100	30	91
	12*	38	91	0	0
	13*	31	74	0	0
Appearance	<1	42	100	33	100
	3	42	100	33	100
	6	42	100	20	61
	9*	42	100	15	46
	12*	36	86	0	0
	13*	36	62	0	0
Both	<1	42	100	32	97
	3	42	100	32	97
	6	42	100	19	58
	9*	42	100	14	42
	12*	33	79	0	0
	13*	17	41	0	0

*Difference is significant at 95-percent confidence level (X^2 test using 2x2 contingency table).

Table 5 shows that CR paint was considerably more serviceable than MA paint as early as 6 months after installation, considering either individual lines or entire test sections. Performances were examined at 9, 12, and 13 months using a 2x2 contingency table with an X^2 test at the 95-percent confidence level. Results of that analysis are also shown in Table 5. By 9 months -- near the end of the winter -- much of the MA paint had failed, but the CR lines remained completely serviceable. By 12 months, MA paint had failed completely, but most CR paint was still serviceable. However, failures increased substantially from 12 to 13 months for the CR paint.

The two CR expressway sections -- Rte 441 and I 490 -- had both failed by the July 1988 survey. Rte 441 had a service life of 12 months, failing in reflectivity, and I 490 was repainted by maintenance forces after 12 months in service.

Several site variables are generally thought to affect pavement marking durability, including roadway alignment, lane width, and traffic patterns. Interaction among these variables makes it difficult to distinguish which has the greatest influence on marking. For these test sections, contingency tables were developed for CR and MA paint to examine effects of traffic volume (AADTs) on test-section serviceability. However, no differences in performance could be attributed to the ranges of traffic volumes on these sections.

Another variable that can potentially affect pavement-marking durability is weather, specifically annual snow accumulation. Previous research has shown that pavement-marking deterioration accelerates during winter months and is related to snowfall accumulations (1). For this reason, weather records from Rochester and Albany were consulted to determine snowfall accumulations for the evaluation period. Rochester experienced a total accumulation of 69.8 in., somewhat less than the normal 89.3 in. The Albany total accumulation of 76.7 in. was slightly higher than the average of 65.2 in. Because the number of test sections is small, statistical examination of effects of snowfall accumulation on marking durability is not possible. However, these accumulations are typical of most of upstate New York, and thus indicate that CR paint can survive typical New York winters.

Another variable affecting service life of a pavement marking is line type (i.e., edge line, skip line, centerline). Contingency tables were developed to examine durability for both CR and MA paint, and again no differences in service lives could be attributed to line type based on the data collected.

III. DISCUSSION AND FINDINGS

This evaluation has shown that CR paint can be applied using current maintenance practices with minor equipment adjustments. CR paint was shown to be more workable than the MA paint and capable of producing acceptable line quality. The major change associated with CR paint is longer no-track times -- averaging 84 sec and as high as 150 sec -- requiring increased traffic protection during striping. Initially, maintenance crews reported some difficulty protecting wet lines and considerable tracking. This problem was primarily associated with areas of high traffic volumes, complex intersections, or areas with high roadside development. As maintenance crews gained experience and became familiar with no-track properties of CR paint, tracking was considerably reduced. This was accomplished by adding vehicles to striping trains, reducing striping speeds, or bunching the maintenance vehicles to protect wet lines in difficult areas. Although productivity may lessen when any of the line protection schemes just mentioned is used, situations requiring those schemes are not regularly encountered. Current statewide pavement-marking policy generally allocates long-life marking materials to those situations, and it is not expected that CR paint will be used extensively in those problem areas.

Protecting the fresh line from traffic is difficult even under ideal conditions with a fast-drying paint. Striping at 8 mph requires protecting a line of over 700 ft for a 60-sec no-track time, and nearly 1100 ft for a 90-sec no-track time. On low- and moderate-volume roadways with good geometrics, these levels of protection can be provided with little or no problem of tracking. However, under high traffic volumes, especially at intersections and areas with high roadside development, some tracking may occur. Additional traffic-control vehicles and improved signing may effect some improvements. Under the revised pavement-marking policy enacted in 1987, most high-volume highways will be marked using long-life marking materials, reducing the tracking problem at those locations.

CR paint clearly provided a substantial improvement in durability compared to the standard MA paint. At the end of winter, after 9 months in service, 100 percent of the CR test sections were completely serviceable in terms of both reflectivity and appearance, with no failed lines in any section. This compares to 38 percent of the MA sections that were completely serviceable. After 12 months in service, 65 percent of the CR test sections had experienced no failures, with 79 percent of all lines placed still serviceable. At that time, none of the MA sections were completely serviceable, and only 42 percent of the lines survived. Ideally, a traffic paint with a service life of at least 12 months offers a major advantage because adequate pavement markings can be maintained with only one annual restriping. At the opposite extreme, paint that cannot last through the winter fails to meet the most basic requirement of providing continuous year-round delineation, because worn markings cannot be replaced during the winter months. These installations show that MA paint cannot meet the basic requirement of providing continuous year-round delineation, because every test section experienced some failed lines before the end of winter. The new CR paint provided a very substantial improvement. Although not every test section provided 12 months of serviceability, every section was completely serviceable at the end of winter after about 9 months in service. This paint can provide continuous year-round delineation, although some lines may require repainting more than once per year to achieve this goal.

A number of variables were examined to determine their effects on service life of CR paint, including traffic volumes, roadway characteristics, pavement type, and winter severity. Although the excellent durability of CR paint was confirmed, effects of these variables could not be determined due to the limited scope of this experiment. Continued observation of performance of this traffic paint is needed to determine service lives that can be expected under a range of traffic, roadway, and climatic conditions.

Based on the observation of the CR and MA traffic paint installations by the Department maintenance forces in 1987, and observations of marking condition over the following year, the following findings can be stated:

1. It was possible to apply CR traffic paint and to achieve acceptable line quality using standard Department equipment and procedures, with only slight modifications to accommodate the new material. Except for longer no-track time, CR paint workability and handling characteristics were superior to the standard MA paint.

2. CR paint experienced longer no-track times than the standard MA paint, averaging nearly 90 sec and ranging up to 150 sec for the sections observed, compared to an average of about 30 sec for the MA paint. These longer no-track times required increased line protection to minimize tracking of the wet line by traffic, especially in areas of high traffic and complex traffic patterns.

3. CR paint provided much better durability than MA paint. Although nearly two-thirds of the MA test sections experienced some line failures before the end of winter, all CR sections were completely serviceable, and two-thirds of those sections remained completely serviceable after 12 months. All MA sections had experienced some failure by 12 months.

4. CR paint can provide continuous year-round delineation on a large portion of New York's state highway system, but more than one annual repainting will be required for some lines.

5. Continued observation of CR paint performance is needed to determine those combinations of traffic, roadway, and climatic conditions under which the CR paint can provide acceptable year-round service.

ACKNOWLEDGMENTS

The research reported here was performed under the technical supervision of James E. Bryden, Civil Engineer III (Physical Research). Installation documentation was conducted by Peter D. Kelly, Civil Engineer I (Physical Research), and performance surveys were supervised by Ronald A. Lorini and John E. Disbro, Civil Engineers I (Physical Research). Performance surveys were conducted by William D. Nolan and Steven L. Roden, Senior Engineering Technicians. Special thanks are due to striping crews from Regions 1, 4, 5, and 6 for cooperation during test-paint installation.

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2. Bryden, J. E., and Lorini, R. A. Test Installation of Chlorinated-Rubber Traffic Paint. Research Report 125, Engineering Research and Development Bureau, New York State Department of Transportation, August 1985.

3. "Update on Chlorinated-Rubber Traffic Paint." Memorandum from W. C. Burnett to J. H. Shafer, April 30, 1984.

4. Bryden, J. E., and Kelly, P. D. Installation of Chlorinated Rubber Traffic Paint. Client Report 21, Engineering Research and Development Bureau, New York State Department of Transportation, October 1987.

5. Research Notes. Testing and Research Division, Michigan Department of Transportation, No. 7, December 1979.

APPENDIX

Specifications for Chlorinated-Rubber Traffic Paint

DETAILED SPECIFICATIONS

Address inquiries relative to detailed specifications to Edward J. Morgan, Senior Specification Writer, Telephone Number 518-474-4432.

ITEM 1A - TRAFFIC ZONE PAINT, WHITE, CHLORINATED RUBBER BASE RAPID-DRY TYPE FOR HOT APPLICATION

GENERAL:

This specification is intended to cover white fast drying traffic paint which shall be suitable for application by spray equipment owned by or approved by the Department and which will provide an adhesive binder for receiving and holding glass beads when applied by the drop-in method for producing reflectorized traffic markings on hard surface pavements of all types.

The vehicle and pigment shall be so prepared and blended that the resulting paint shall be uniform in composition and of the required consistency. After storage for periods up to 6 months from date of packaging, the pigment shall not settle badly or cake in the container, nor shall the paint skin or thicken in storage sufficiently to cause an undesirable change in consistency. The paint at the time of use shall comply with all the provisions of this specification and shall be capable of being redispersed with a paddle to a smooth uniform condition.

In addition to the methods of tests and inspection set forth in this specification and the applicable portions of the 1961 Standard Specifications, the Department reserves the right to make any and all additional tests it may deem necessary to determine compliance with these specifications and the suitability of the paint for its intended usage. The Department further reserves the right to require the manufacturer of the paint to certify to the use of specific materials and components that are not readily identifiable in the finished paint.

Where reference is made herein to material specifications and methods of test by citation, it shall mean the current edition of such specifications and methods approved and adopted at the date of receipt of bids.

TYPE:

White fast drying traffic paint, as specified herein shall be based on a vehicle composed of pure drying alkyd, chlorinated rubber and chlorinated paraffin, with appropriate pigments, stabilizers and flow control agents.

PREPARATION OF PAINT:

The specified portions of titanium dioxide, magnesium silicate, zinc oxide, and calcium carbonate shall be dispersed in a suitable amount of vehicle. The grinding shall be performed by either a High-R-speed mill, roller mill, pebble mill, or high speed disc disperser similar to those manufactured by Cowles-Morehouse or Hockmeyer. The resultant paste shall have a fineness of not less than 4 as determine on a Hegman grind gage (Federal Standard No. 141A Method 4411). The remainder of the vehicle, additional thinners and stabilizers when required, shall then be added to produce a paint having the specified consistency. The equipment to be used in the preparation and manufacture of the paint shall be subject to inspection and approval of the Engineer.

PHYSICAL PROPERTIES:

A. Consistency

Forty-eight hours after the paint has been prepared and placed in the containers, it shall have a consistency of 80-90 K.U. for use in spray type equipment. Consistency shall be determined according to ASTM Method D-562.

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DETAILED SPECIFICATIONS (Cont'd)

ITEM 1A (Cont'd)

PHYSICAL PROPERTIES (Cont'd)

B. Drying Time

The paint shall dry to no-pick up in not more than 7 minutes without glass beads when tested in accordance with ASTM D-711. The film shall be applied at a wet film thickness of 0.015 inches (15 mils).

C. Flexibility and Adhesion

A film of paint having a wet film thickness of 0.015 inches shall be applied with a doctor blade to a tin panel 3 inches x 5 inches weighing 0.39 to 0.51 lbs./sq. ft., previously cleaned with toluene and lightly buffed with steel wool. After drying in a horizontal position at room temperature (70-80°F.) for 18 hours, the coated panels shall be baked in an oven at 122° ± 4°F. for 2 hours, removed and allowed to cool to room temperature. It shall then be bent rapidly with the painted surface uppermost over a 1/2 inch diameter mandrel and examined without magnification. The paint shall adhere firmly to the panel and any evidence of cracking or flaking of the film shall be cause for rejection of the paint.

D. Water Resistance

A film of paint having a wet film thickness of 0.015 inches shall be applied with a doctor blade to a 4 inch x 8 inch glass plate and allowed to dry in a horizontal position at room temperature (70-80°F.) for 72 hours. Immerse one-half of the painted plate in distilled water at room temperature for 18 hours, allow to air dry for 2 hours and examine. The paint shall adhere firmly to the plate and any evidence of softening or blistering shall be cause for rejection. The glass plate shall be thoroughly cleaned with a suitable solvent and dried before application.

E. Light Resistance

The paint shall show resistance to discoloration or darkening, when tested by the method prescribed by Federal Specification TT-P-115.

PAINT COMPOSITION:

When tested in accordance with the provisions of Federal Test Method Standard No. 141A and applicable methods of test, the finished paint shall consist of:

	Minimum	Maximum
Pigment, % by wt., Method 4021	47.0	49.0
Vehicle, % by difference	51.0	53.0
Wt./gal., lbs., Method 4184	12.5	
Non-Volatile Vehicle, % by weight	40.0	
Total Solids in Paint, % by weight	69.0	

(continued)

DETAILED SPECIFICATIONS (Cont'd)

ITEM 1A (Cont'd)

PIGMENT COMPOSITION:

	Minimum	Maximum
Titanium dioxide	34.0	
Magnesium silicate	29.0	31.0
Calcium carbonate	25.0	27.0
Zinc oxide	8.0	10.0

The titanium dioxide shall be ASTM D476, Type III, 94% minimum TiO_2, maximum oil absorption 20; TiPure R-900 (DuPont), or Unitane OR-600 (American Cyanamid), or equivalent.

The magnesium silicate shall be ASTM D605, maximum mean particle size 6 microns, maximum oil absorption 30; Nytal 300 (Vanderbuilt), or equivalent.

The calcium carbonate shall be ASTM D1199, Type GC, Grade II; Snowflake (Thompson-Weinman) or equivalent.

The zinc oxide shall be ASTM D79 99% minimum ZnO; AZO 33 (Asarco) or XX601 (N.J. Zinc) or equivalent.

STABILIZER COMPOSITION:

Anti-Settling Agent shall be added - 2 lbs. to each 100 gallons of finished paint; Bentone SD-1, or Bentone 38 (NL Industries) or a substitute previously approved by the Materials Bureau. DO NOT USE METHANOL TO WET BENTONE.

Anti-Skinning Agent shall be added - 3 lbs. to each 100 gallons of finished paint; Exkin #1 (Nuodex), or equivalent.

Chlorinated Rubber Stabilizer shall be propylene oxide, styrene oxide (Union Carbide) or a substitute previously approved by the Materials Bureau. This is to be added to the finished paint just before closing and sealing the drum. The proportion shall be 3% of weight of propylene oxide based on the chlorinated rubber.

VEHICLE COMPOSITION:

The vehicle shall consist of short drying oil, phthalic alkyd resin, chlorinated paraffin, chlorinated rubber, and toluene. The vehicle, as separated from the pigment, shall show non-volatile content of at least 40.0%. Formulation of the vehicle, excluding additional solvents, shall be as follows:

42% Alkyd Resin Solution
33% Chlorinated Rubber
25% Chlorinated Paraffin

Alkyd Resin Type - a short, drying oil, phthalic alkyd containing 32 to 34% phthalic anhydride and 38 to 42% fatty acids based on the solid resin (Hercules or equal). The fatty acid shall be of tall oil origin, with a maximum rosin content of 4% and with an iodine value of 115 minimum. The resin shall have an acid number of 6 maximum. No fatty acids, oils or resin other than the above shall be present.

The alkyd resin solution shall be supplied at 60% ± 1% solids in toluene. The alkyd resin solution must tolerate 500% dilution with toluene. A solution containing 100 grams of 20 cps chlorinated rubber, 130 grams of the 60% alkyd solution, and 300 grams of methyl ethyl ketone shall be clear and transparent.

(continued)

DETAILED SPECIFICATIONS (Cont'd)

ITEM 1A (Cont'd)

VEHICLE COMPOSITION: (Cont'd)

The alkyd resin, at 45% solids basis (reduced from 60% solids with toluene) shall have a Gardner color of 5 maximum and a viscosity (Gardner) of A to D. A cast film of the alkyd containing driers, 3 mils thick, shall be clear, and set to touch in not more than 90 minutes.

Phthalic anhydride shall be determined in accordance with Federal Standard No. 141A, Method 7021 or ASTM D1307.

Fatty acids shall be determined in accordance with Federal Standard No. 141A, Method 7031.

Iodine number of fatty acids shall be determined in accordance with Federal Standard No. 141A, Method 5061.

Chlorinated Rubber shall have the following properties:

Fixed Chlorine	65.0% minimum
Color (Gardner), 20% by wt. in toluene	4 maximum
Viscosity, 20% by wt. in toluene	19-25 cps.

Chlorinated Paraffin shall comply with MI-C-429A. The chlorinated paraffins should be Chlorafin 40 (Hercules Incorporated), Chlorowax 40 (Diamond), Cereclor 42 (I.C.I.) or approved equal.

Toluene shall meet the requirements of ASTM designation D362.

Driers shall be 0.08% cobalt (metal) and 0.6% lead (metal) based on alkyd resin solids.

PACKAGING:

The paint shall be packaged in 55 gallon drums.

The 55 gallon drums shall be 17H to comply with the Code of Federal Regulations revised 1-70 and be 18 gauge metal for body and bottom head sheet, and have welded side seams, and be epoxy-phenolic lined. The drums shall be of the open end type and all containers, after being filled, shall be closed with a tight fitting cover that will assure a leak-proof seal. The removable head sheet shall be epoxy-phenolic lined 14 gauge; 16 gauge is authorized provided there are one or more corrugations in the cover near the periphery.

ITEM 1B - TRAFFIC ZONE PAINT, CHLORINATED RUBBER BASE, YELLOW, RAPID-DRY TYPE FOR HOT APPLICATION

Shall be the same as Item 1A (White) except as follows:

COLOR:

The color shall match color Chip No. 33538 of Federal Standard Specification TT-C-595.

(continued)

DETAILED SPECIFICATIONS (Cont'd)

ITEM 1B (Cont'd)

PAINT COMPOSITION:

When tested in accordance with the provisions of Federal Test Method Standard No. 141A and applicable methods of test, the finished paint shall consist of:

	Minimum	Maximum
Pigment, % by wt., Method 4021	50.0	52.0
Vehicle, % by difference	48.0	50.0
Wt./gal., lbs., Method 4184	12.4	
Non-Volatile Vehicle, % by weight	40.5	
Total Solids in Paint, % by weight	71.0	

PIGMENT COMPOSITION

	Minimum	Maximum
Medium Chrome Yellow	34.0	
Magnesium Silicate	11.0	13.0
Calcium Carbonate	53.0	55.0

The medium chrome yellow shall be ASTM D211, Type III; X 3480 Traffic Yellow (Ciba-Giegy), or equivalent.