EVALUATION OF A POLYCARBONATE VEHICULAR TRAFFIC SIGNAL

TSD-233-74

TRAFFIC and SAFETY DIVISION

DEPARTMENT OF STATE HIGHWAYS
STATE OF MICHIGAN

EVALUATION OF A POLYCARBONATE VEHICULAR TRAFFIC SIGNAL

TSD-233-74

By

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INTRODUCTION

The cast aluminum vehicular traffic signal housing using glass lenses has been the standard for many years. The unit meets all specifications, but is heavy, requires periodic painting, is usually damaged beyond repair in a vehicular knockdown, and the glass lens breaks easily. Acrylic lenses were marketed to compete with the glass lenses, but were rejected by the Department due to the materials' inability to withstand high lamp heat and the color deterioration due to exposure to sunlight. Polycarbonate resin now provides a new vehicular traffic signal housing and lens to compete with the aluminum housing and glass lens. This study details the testing and evaluation of the polycarbonate (tradename Lexan) vehicle traffic signal.

Twelve inch vehicular traffic signals, lenses and mounting hardware are now available in polycarbonate, but were not evaluated for this report.

CONCLUSIONS AND RECOMMENDATIONS

The polycarbonate vehicular traffic signal provides an acceptable alternate to the cast aluminum signal. The Department Vehicular Traffic Signal Specifications should be modified to allow the polycarbonate signal as an alternate on a price competitive basis.

The polycarbonate lenses provide an acceptable alternate to the glass lens. The Department specifications should be modified to allow the polycarbonate lenses as an alternate. (Vehicular Traffic Signal Supplemental Specifications were modified during the writing of this report to allow for the polycarbonate lenses).

The above recommendations apply to both the eight inch and twelve inch vehicular traffic signals and lenses, although the twelve inch signal was not available at the time of this evaluation.

Polycarbonate mounting hardware is also available but was not evaluated.

PRODUCT DESCRIPTION

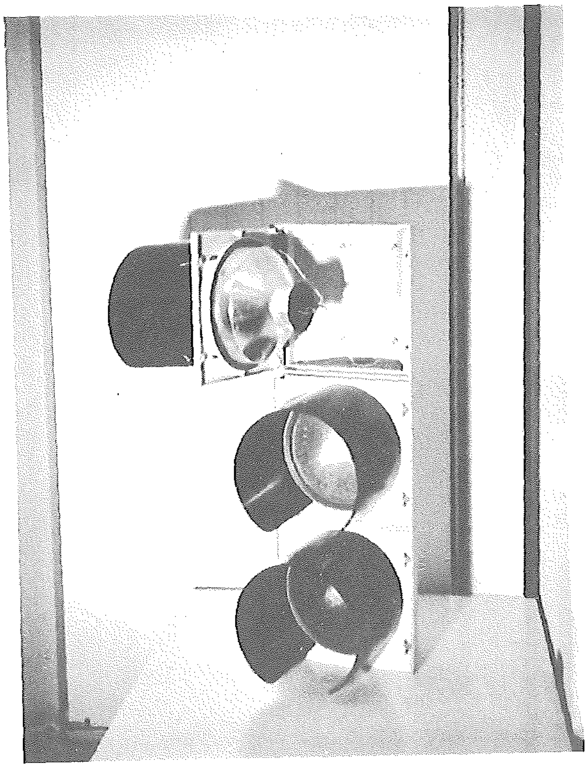
The vehicular traffic signal lens and housing are manufactured from injection molded polycarbonate resin. Polycarbonate plastic is highly resistant to impact, light weight and very durable.

The eight inch signal housing evaluated is molded in one piece, .090" thick with ribbed construction for added strength. The one piece molded door is attached to the housing by two stainless steel pins. The polycarbonate visor attaches at four points by tabs. The lamp, reflector and lens are adequately protected from the weather by a neoprene gasket seal.

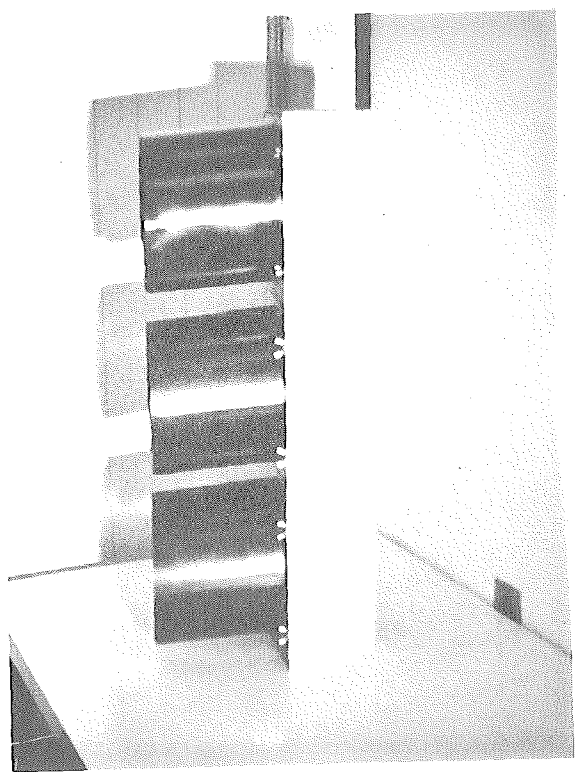
The lenses have a high thermal deflection temperature and the eight inch lenses are not affected by continuous illumination from a 116 watt traffic signal lamp.

The colors are permanently molded into the lenses, doors, visors and housing.

The complete polycarbonate signal assembly, when subjected to tests by independent testing laboratories, was not affected by extreme high temperature changes, humidity, rain, dust and salt environments as detailed in the appendix. No laboratory tests were performed subjecting the Polycarbonate Signal to sub-zero temperature. However the signal operated at the test site for eighteen months, showing no adverse effects due to low temperatures.



Photograph #1 - 3 Level
Polycarbonate Signal



Photograph #2 - Side View of
Polycarbonate Signal

METHOD OF EVALUATION

Laboratory Testing

Laboratory test measurements were performed by the Testing and Research Division's Research Laboratory. Candlepower distribution, color and light transmission tests were performed before and after the eighteen month test installation. The tests were made in accordance with the Institute of Traffic Engineers Technical Report #1, Revised 1966, for Adjustable Face Vehicular Traffic Control Signal Head Standard.

1. Values of relative luminous transmittance were determined by an integrating sphere method as follows:

	Sept. 1971	July 1973	Typical	I.T.E.
	Polycarbonate			
Color	Before	After	Glass	Standard
Red	.166	.166	.163	.095
Yellow	.661	.697	.700	.440
Green	.217	.201	.154	.190

2. The polycarbonate lenses were tested and found to meet chromaticity requirements established by limit glasses for each signal color.

3. Light distribution and candlepower intensity from the combination of lamp, reflector and lens were measured using a 60 watt traffic signal lamp corrected to 665 lumens output. The values are shown by candlepower distribution charts one through twelve in the appendix.

The red, green and yellow polycarbonate lenses meet and/or exceed the Institute of Traffic Engineers standards in all tests performed, both before and after field installation. The red and green lenses show a small decrease in candlepower intensity output and distribution and the yellow lens a slight increase after the eighteen month test installation. These changes are insignificant and not perceptible to the naked eye.

4. Candlepower distribution and intensity readings were taken using the polycarbonate lenses in the aluminum housing and the glass lenses in the polycarbonate housing. The differences in test results were insignificant, indicating that the glass and polycarbonate lenses may be interchanged for field operations.

Field Evaluation

The polycarbonate signals were field tested as follows:

1. One four-way, three level polycarbonate signal housing and lenses installed adjacent to a new four-way, three level aluminum signal housing with glass lenses at two locations in the City of Lansing.

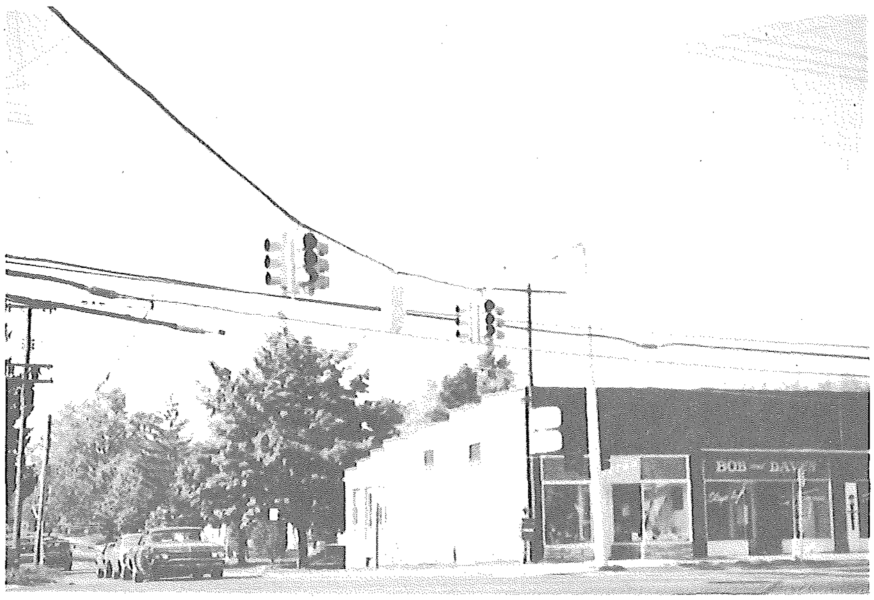
2. No appreciable difference in installation costs and time were apparent. The installation crew however stated that the lighter weight polycarbonate signal was easier to handle during installation.

3. Operation of the signal was subjectively evaluated by periodic field observations.

At all times during the eighteen month field evaluation the polycarbonate signal operated properly and could not be distinguished from the aluminum signal, except for the black visors. The signal required no additional maintenance other than the routine relamping and cleaning performed on all vehicular traffic signals.

4. The evaluations and tests show no apparent permanent degradation to the polycarbonate housing or lens due to weathering. There was a slight change in lens color, negative for the red and green and positive for the yellow due to prolonged weathering. The changes are not perceptible to the naked eye and may be attributable to allowable testing error. No prediction can be made at this time to possible lens color changes due to weathering.

The original green lenses did not meet Institute of Traffic Engineers color requirements and were replaced by the manufacturer with lenses which met the requirements.



Photograph #3 - Field Evaluation Site, Cedar Street (I-96BL) And Cavanaugh Road - City Of Lansing. Polycarbonate Signal on Left.

Advantages

A. Polycarbonate Lens

1. The polycarbonate lenses meet or exceed all I.T.E. requirements, are approximately one-third the weight of a glass lens, and are highly resistant to breakage. Although only the eight inch lenses were tested, the twelve inch lenses, traffic signal arrows and pedestrian signal polycarbonate lenses should be considered for use.

B. Polycarbonate Housing

1. The polycarbonate signal unit is approximately 30 percent lighter than the aluminum with glass lens signal. A four-way, three color eight inch aluminum signal with brackets and glass lenses weighs 141 pounds. A four-way, three color eight inch polycarbonate signal with polycarbonate lenses and aluminum brackets weighs 94 pounds. This provides considerable advantage in new installations and may allow the addition of twelve inch signals and/or other traffic control devices on existing span wires or mast arm, eliminating the cost of installing new poles, span wires or mast arms.

2. High winds create a horizontal and vertical movement of span mounted signals. The horizontal movement is allowed for in the installation design and is not a serious problem for the aluminum or polycarbonate signal. The vertical movement creates the serious problem and is caused partly by the "dead weight" of the signal. Since the polycarbonate

signal is lighter weight, this vertical movement is reduced considerably as compared to the aluminum signal. 16MM movies were taken of the polycarbonate and aluminum signals during a period of 50-60 MPH winds and confirm the above statement.

3. Maintenance should be reduced since repainting is not necessary. The color is molded into the material during fabrication.

4. The signal has a high impact resistance, and may be reusable even if struck by a high load. In the case of a vehicle knockdown it is very probable that the polycarbonate signal can be reused on the site.

Disadvantages

A. Polycarbonate Housing

1. The visor attachment to the signal housing is weak and easily broken during handling. The signal should be installed before visors are attached, or a better method of attachment should be devised. Once the visor tabs break, the visor must be replaced.

2. The method used to fasten the door is adequate but very cumbersome.

3. Changing the lens in the polycarbonate signal is extremely difficult and nearly impossible in cold weather. With the present design, it is suggested that the entire door assembly be changed in the field when a lens needs replacement. This

allows the lens change to be performed under better working conditions.

4. Although operation of the signal is not affected, there is no gasket between the door and housing area behind the reflector, allowing dust and dirt to accumulate in this area, which contains the terminal block. Some method of protection may be advantageous.

Appendix - 1.

Traffic Control Device - Project Study Plan

Evaluation of Polycarbonate Vehicular Traffic Signal Head

INTRODUCTION

The vehicular traffic signal as used by the Bureau of State Highways has traditionally been constructed of metal.

With rapid advancements in the field of plastics, manufacturers have produced a polycarbonate signal with possible weight reduction and maintenance advantages.

OBJECTIVES

It is planned to install a polycarbonate signal with polycarbonate lens and a standard cast aluminum signal with glass lens on a single span wire installation at two locations. This will enable evaluation of the performance, maintenance costs, wind effects and light characteristics under identical conditions for each signal head.

LOCATION

Two locations were selected in Lansing to facilitate the ease of observing and obtaining maintenance data.

The locations are:

1. I-96 BL (Cedar Street) at Holmes Road. (2 point span installation)
2. I-96 BL (Cedar Street) at Cavanaugh Road (3 point span installation) City of Lansing

BENEFITS

If this study determines the devices acceptable for operational use, it could provide a substantial maintenance cost savings. The lighter weight of the signal head should provide ease of installation and allow adding signals to existing span wire on mast arm location. Greater safety to the motoring public and maintenance crews will be provided if less maintenance is required, by eliminating closing lanes of traffic during maintenance operations.

RESEARCH PROCEDURE

Before the installation is completed, both type signals will be laboratory tested for the standard traffic signal characteristics. Such tests as light transmission, color and candlepower distribution plus other tests pertaining to plastic heads will be performed. After installation, observations will be made of the signal appearance, effects of high winds, and ease of installation due to lighter weight of the plastic signal. All required maintenance will be recorded along with costs and time required.

TIME REQUIREMENTS

If scheduling plans are followed the installation of signals would be completed in the summer of 1971, the observations by summer of 1972. The maintenance data would be reasonably completed the summer 1973 with the report written in the winter of 1973-4.

PERSONNEL REQUIREMENTS

The study can be performed by existing Traffic and Safety Division personnel.

COSTS

Purchase price of the "Lexan" signal is competitive with the cast aluminum vehicle signals. The signals have been purchased with Research and Development Section evaluation funds. Installation costs will be covered by work order, the only effort being to remove the existing signals and replace them with a "Lexan" and a new aluminum signal.

CANDLEPOWER CHART #1
Eight Inch Eagle Polycarbonate Vehicle Traffic Signal
Yellow Polycarbonate Lens in Polycarbonate Housing
Before One Year Field Installation

Angles left and right of vertical

	LEFT							RIGHT						
	27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	111	254	470	646	786	1030	--	932	974	755	557	357	175	- 2.5°
- 7.5°	109	320	514	660	792	836	--	830	858	751	580	421	186	- 7.5°
-12.5°	87	191	266	341	375	388	--	381	384	352	288	227	121	-12.5°
-17.5°	76	92	104	122	130	142	--	133	132	120	119	95	82	-17.5°

CANDLEPOWER CHART #2
Eight Inch Eagle Polycarbonate Vehicle Traffic Signal
Yellow Polycarbonate Lens in Polycarbonate Housing
After One Year Field Installation

Angles left and right of vertical

	LEFT							RIGHT						
	27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	---	---	519.0	702.0	833.0	1066.0		977.0	977.0	757.0	574.0	---	---	- 2.5°
- 7.5°	146.0	389.0	604.0	771.0	940.0	997.0	--	945.0	972.0	855.0	657.0	469.0	188.0	- 7.5°
-12.5°	114.0	261.0	341.0	428.0	470.0	488.0	--	489.0	495.0	451.0	354.0	277.0	142.0	-12.5°
-17.5°	87.2	113.0	128.0	148.0	157.0	176.0	--	170.0	171.0	156.0	143.0	113.0	93.2	-17.5°

CANDLEPOWER CHART #3
Eight Inch Eagle Polycarbonate Vehicle Traffic Signal
Red Polycarbonate Lens in Polycarbonate Housing
Before One Year Field Installation

Angles left and right of vertical

			LEFT								RIGHT			
	27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	27	58	110	151	182	240	--	215	223	179	134	89	41	- 2.5°
- 7.5°	26	73	118	149	178	188	--	186	189	169	130	94	41	- 7.5°
-12.5°	19	43	59	73	79	82	--	80	80	74	60	47	26	-12.5°
-17.5°	16	19	21	24	26	28	--	26	27	24	24	19	17	-17.5°

CANDLEPOWER CHART #4
Eight Inch Eagle Polycarbonate Vehicle Traffic Signal
Red Polycarbonate Lens in Polycarbonate Housing
After One Year Field Installation

Angles left and right of vertical

			LEFT								RIGHT			
	27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	---	---	104.0	144.0	171.0	233.0	--	210.0	215.0	170.0	129.0	---	---	- 2.5°
- 7.5°	26.8	74.6	130.0	166.0	204.0	222.0	--	207.0	212.0	188.0	143.0	103.0	40.5	- 7.5°
-12.5°	219.0	52.2	74.6	93.6	103.0	106.0	--	105.0	105.0	94.1	72.2	55.8	30.2	-12.5°
-17.5°	17.2	23.0	25.4	29.6	31.3	35.0	--	33.8	34.3	30.7	28.3	22.3	19.0	-17.5°

CANDLEPOWER CHART #5
Eight Inch Eagle Polycarbonate Vehicle Traffic Signal
Green Polycarbonate Lens in Polycarbonate Housing
Before One Year Field Installation

	LEFT 27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	RIGHT 2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	45	110	199	267	316	404	--	362	368	309	232	157	78	- 2.5°
- 7.5°	46	145	221	279	326	336	--	330	349	316	249	188	84	- 7.5°
-12.5°	37	116	116	147	157	161	--	157	161	152	125	101	54	-12.5°
-17.5°	29	36	40	49	52	56	--	52	53	48	48	38	32	-17.5°

CANDLEPOWER CHART #6
Eight Inch Eagle Polycarbonate Vehicle Traffic Signal
Green Polycarbonate Lens in Polycarbonate Housing
After One Year Field Installation

	LEFT 27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	RIGHT 2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	---	---	173.0	235.0	288.0	385.0	--	341.0	343.0	288.0	221.0	---	---	- 2.5°
- 7.5°	44.3	130.0	223.0	275.0	317.0	358.0	--	316.0	309.0	283.0	210.0	145.0	61.7	- 7.5°
-12.5°	37.0	95.6	144.0	164.0	172.0	169.0	--	160.0	155.0	139.0	95.6	66.7	42.6	-12.5°
-17.5°	29.0	43.8	50.8	55.7	55.4	58.9	--	56.1	56.2	49.9	44.5	34.1	31.0	-17.5°

CANDLEPOWER CHART 7
ITE Standard for 8-in. lens
(Values corrected to minimum for red lens)

Angles left and right of vertical

	LEFT 27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	RIGHT 2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
0.0	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0
-2.5°	--	--	28	66	114	157	--	157	114	66	28	--	--	-2.5
-7.5°	12	21	48	76	104	119	--	119	104	76	48	21	12	-7.5
-12.5°	10	14	24	33	38	43	--	43	38	33	24	14	10	-12.5
-17.5°	5	6	10	12	16	19	--	19	16	12	10	6	5	-17.5

CANDLEPOWER CHART 8
ITE Standard for 8-in. lens
(Values corrected to minimum for yellow lens)

Angles left and right of vertical

	LEFT 27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	RIGHT 2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
0.0	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0
-2.5°	--	--	132	308	528	726	--	726	528	308	132	--	--	-2.5
-7.5°	55	99	220	352	484	550	--	550	484	352	220	99	55	-7.5
-12.5°	44	66	110	154	194	198	--	198	194	154	110	66	44	-12.5
-17.5°	22	33	44	55	77	88	--	88	77	55	44	33	22	-17.5

CANDLEPOWER CHART 9
ITE Standard for 8-in. lens
(Values corrected to minimum for green lens)

Angles left and right of vertical

	LEFT 27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	RIGHT 2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
0.0	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0
-2.5°	--	--	60	140	240	330	--	330	240	140	60	--	--	-2.5
-7.5°	25	45	100	160	220	250	--	250	220	160	100	45	25	-7.5
-12.5°	20	30	50	70	80	90	--	90	80	70	50	30	20	-12.5
-17.5°	10	15	20	25	35	40	--	40	35	25	20	15	10	-17.5

NOTE: Intensity values based on 60 watt traffic signal lamp with 665 lumen output.

CANDLEPOWER CHART #10
Eight Inch Eagle Vehicle Traffic Signal
Yellow Glass Lens In Polycarbonate Housing

Angles left and right of vertical

	LEFT							RIGHT						
	27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	158	222	337	554	838	1220	--	1170	1000	671	400	248	183	- 2.5°
- 7.5°	164	228	332	504	712	827	--	829	756	570	382	268	19	- 7.5°
-12.5°	116	148	191	251	308	348	--	353	339	282	224	177	136	-12.5°
-17.5°	82	93	108	128	147	161	--	164	159	143	120	105	90	-17.5°

CANDLEPOWER CHART #11
Eight Inch Eagle Vehicle Traffic Signal
Yellow Glass Lens In Metal Housing

Angles left and right of vertical

	LEFT							RIGHT						
	27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	110	147	229	410	745	996	--	960	686	376	218	149	112	- 2.5°
- 7.5°	149	216	335	560	819	888	--	856	723	488	302	204	143	- 7.5°
-12.5°	129	189	268	382	493	499	--	465	401	307	220	165	120	-12.5°
-17.5°	84	105	132	165	192	201	--	196	172	142	112	89	74	-17.5°

CANDLEPOWER CHART #12
Eight Inch Eagle Vehicle Traffic Signal
Yellow Polycarbonate Lens In Metal Housing

Angles left and right of vertical

	LEFT							RIGHT						
	27.5°	22.5°	17.5°	12.5°	7.5°	2.5°	0.0	2.5°	7.5°	12.5°	17.5°	22.5°	27.5°	
- 2.5°	103	248	462	627	850	984	--	999	976	718	557	349	140	- 2.5°
- 7.5°	109	365	586	716	939	935	--	852	914	747	558	431	155	- 7.5°
-12.5°	87	251	346	423	461	460	--	436	432	368	277	206	111	-12.5°
-17.5°	73	109	118	136	140	150	--	140	147	123	111	90	81	-17.5°

Appendix 3 Independent Laboratory Test on Polycarbonate Vehicular Traffic Signal Lenses*

A photometric study was made of the two three section plastic signals. The study of an unweathered and weathered unit was to determine loss of optical performance due to lens or reflector degradation.

The study consisted of measuring candlepower at various test points of the weathered and unweathered components in various combinations. Comparisions of candlepower data and calculated lumen data will indicate the conditions found. All tests were made with a 50W TS Lamp.

__STUDY OF RED SECTION:__

Lens: Unweathered Red. Reflector: Unweathered.

	27½	22½	17½	12½	7½	2½	2½	7½	12½	17½	22½	27½
2½			99	141	176	214	200	185	145	113		
7½	17	60	105	144	175	173	190	175	154	122	62	18
12½	14	32	47	63	73	71	74	77	72	62	38	14

Lens: Weathered Red, as received. Reflector: Unweathered.

	27½	22½	17½	12½	7½	2½	2½	7½	12½	17½	22½	27½
2½			78	108	142	164	152	142	115	87		
7½	18	51	83	110	131	132	143	134	116	92	47	17
12½	15	29	40	52	60	60	61	63	58	50	31	15

Lens: Weathered Red, front surface cleaned. Reflector: Unweathered.

	27½	22½	17½	12½	7½	2½	2½	7½	12½	17½	22½	27½
2½			105	145	191	220	204	192	150	115		
7½	19	64	107	148	173	172	190	175	153	124	60	17
12½	14	32	46	62	72	69	71	74	69	71	35	15

Lens: Unweathered Red: Reflector: Unweathered.

Total lumens in	−2½ scan:	9.68
"	−7½ "	10.61
"	−12½ "	4.85
Total lumens in beam		25.14

Lens: Weathered Red. (as received) Reflector: Unweathered

Total lumens in	−2½ scan:	7.51
"	−7½ "	8.16
"	−12½ "	4.05
Total lumens in beam		19.72

Lens: Weathered Red, front surface cleaned. Reflector: Unweathered.

Total lumens in	−2½ scan:	10.05
"	−7½ "	10.65
"	−12½ "	4.78
Total lumens in beam		25.48

Comparison of lumen output, Unweathered Red lens to weathered, as received Red lens:

Percent loss in	−2½ scan	due to weathering and dirt accumulation:	22.5%
"	−7½	"	23.1%
"	−12½	"	16.5%
"	total beam	"	21.6%

Comparison of lumen output, Weathered Red lens after cleaning of front surface to Unweathered Red lens:

Percent loss due to weathering only, after removal of front surface dirt accumulation: NONE. Note a GAIN of 1.3% in total beam lumens due to weathering. This could be due to a difference in the molding between the two lenses or a possible lightening of the color to a very slight degree, not apparent to the unaided eye.

Conclusion: There is no apparent permanent degradation to the lens due to weathering. All loss of performance is caused by dirt accumulation on the front surface of the lens. This dirt accumulation is readily removed by water and paper towel.

STUDY OF GREEN SECTION

Lens: Unweathered Green. Reflector: Unweathered.

	27½	22½	17½	12½	7½	2½	2½	7½	12½	17½	22½	27½
2½			235	315	400	396	390	375	310	220		
7½	32	88	167	218	275	280	280	270	255	183	126	45
12½	30	59	77	95	96	96	100	99	93	80	46	24

Lens: Weathered Green, as received. Reflector: Unweathered.

2½			141	210	290	320	320	320	260	192		
7½	37	89	144	186	214	215	214	204	170	130	84	41
12½	31	54	77	95	103	103	96	89	79	68	49	29

Lens: Weathered Green, front surface cleaned. Reflector: Unweathered.

2½			240	330	445	430	430	430	345	232		
7½	44	108	162	218	270	275	290	290	250	182	114	38
12½	28	52	72	86	97	100	108	108	107	92	61	28

Lens: Unweathered Green. Reflector: Unweathered.

Total lumens in	-2½	scan:	20.06
"	-7½	"	16.86
"	-12½	"	6.80
Total lumens in beam			43.72

Lens: Weathered Green, as received. Reflector: Unweathered.

Total lumens in	-2½	scan:	15.60
"	-7½	"	13.13
"	-12½	"	6.63
Total lumens in beam			35.36

Lens: Weathered Green, front surface cleaned. Reflector: Unweathered.

Total lumens in	-2½	scan:	21.90
"	-7½	"	17.03
"	-12½	"	7.14
Total lumens in beam			46.07

Comparison of lumen output, weathered Green lens as received as compared to unweathered Green lens:

Percent loss in	-2½ scan	due to weathering and dirt accumulation:	22.3%
"	-7½	"	22.2%
"	-12½	"	2.5%
"	total beam	"	19.2%

Comparison of lumen output, weathered Green lens after cleaning of front surface to unweathered Green lens:

Percent loss due to weathering only, after removal of front surface dirt accumulation: NONE. Note a <u>gain</u> of 5.3% in total beam lumens due to weathering. This is probably due to a perceptible lightening in the color of the weathered lens. Some difference could also be due to a difference in molding between the two lenses.

Conclusion: There is no apparent permanent degradation of the lens due to weathering. All loss of performance was caused by dirt accumulation on the front surface of the lens, readily removed by washing with water and paper towel.

REFLECTOR STUDY

Lens: Unweathered Yellow. Reflector: Weathered from Yellow Section.

	27½	22½	17½	12½	7½	2½	2½	7½	12½	17½	22½	27½
2½			410	590	710	830	790	780	640	480		
7½	86	204	345	490	550	570	590	580	535	420	255	88
12½	62	115	151	198	224	222	228	228	220	200	134	67

Lens: Unweathered Yellow. Reflector: Unweathered from Yellow Section.

	27½	22½	17½	12½	7½	2½	2½	7½	12½	17½	22½	27½
2½			550	725	800	865	955	740	590	380		
7½	120	218	320	420	440	440	460	465	380	270	122	65
12½	64	98	122	136	151	153	157	157	149	129	73	56

Lens: Weathered Yellow,as received. Reflector: Weathered from Yellow Sect.

	27½	22½	17½	12½	7½	2½	2½	7½	12½	17½	22½	27½
2½			355	490	640	680	690	650	525	380		
7½	83	167	280	390	465	495	530	510	460	350	200	90
12½	66	101	136	170	198	210	230	224	216	186	127	71

Lens: Unweathered Yellow. Reflector: Weathered.

Total lumens in	$-2\frac{1}{2}$ scan:	39.75
"	$-7\frac{1}{2}$ "	35.82
"	$-12\frac{1}{2}$ "	15.57
Total lumens in beam		91.14

Lens: Unweathered Yellow. Reflector: Unweathered.

Total lumens in	$-2\frac{1}{2}$ scan:	42.60
"	$-7\frac{1}{2}$ "	28.27
"	$-12\frac{1}{2}$ "	10.98
Total lumens in beam		81.85

Lens: Weathered Yellow, as received. Reflector: Weathered.

Total lumens in	$-2\frac{1}{2}$ scan:	33.52
"	$-7\frac{1}{2}$	30.55
"	$-12\frac{1}{2}$	14.71
Total lumens in beam		78.78

This data indicates that the weathered reflector is out-performing the unweathered reflector by 11% in total beam lumens. There is, however, a difference in beam distribution as evident by the differences between the $-2\frac{1}{2}$ and $-7\frac{1}{2}$ scan relative performances. Since the same lens was used in both studies, the difference could be either in the reflector shape or in the test setup. The reference point for the test setup was the rear neck of the reflector which might have been slightly different between the two. In any event, total beam lumens show that there could not be much degradation in the weathered reflector.

Conclusion: Although difficult to conclude positively because of the non-uniformity of the reflector beam, it appears that there is little optical degradation of the reflector due to weathering.

Comparison of weathered to unweathered Yellow lenses:
(weathered lens as received, front surface not cleaned)

Percent loss in	-2½ scan	due to weathering and dirt accumulation:	16.00%
"	-7½	"	15.00%
"	-12½	"	6.00%
"	total beam	"	14.00%

The weathered Yellow lens was left uncleaned for future record of dirt accumulation. As in the case of the weathered green lens, there is a perceptible lightening of the color.

SUMMARY OF STUDY

Loss of lens performance due to front surface dirt accumulation, average 18%.

Loss of lens performance due to permanent degradation: None.

Loss of reflector performance due to degradation: Probably negligible.

Color change due to weathering (assuming identical colors originally)

Red: Possibly very slight, not apparent to unaided eye.

Green: Slight but perceptible lightening in weathered lens.

Yellow: Slight but perceptible lightening in weathered lens.

*This data compiled by the Nagel Optics Company, 6560 North Sheridan Road, Chicago, Illinois 60626 and reprinted by permission of Eagle Signal Company.

Appendix 4 Environmental Testing of the 8-inch Polycarbonate Traffic Signal*

1. ABSTRACT

1.1 A preliminary pressure-temperature test was conducted on one 8-inch Polycarbonate Traffic Signal per Eagle Signal Procedure dated September 30, 1970. This test revealed that the optical unit seal was insufficient to prevent the unit from breathing during normal operation.

1.2 A Humidity Test was performed on the test unit per Eagle Signal Purchase Order Number 711065. The test unit showed no evidence of damage, deterioration, or condensation within the optical unit, as a result of the imposed test conditions.

1.3 A Rain Test was performed on the test unit per Eagle Signal Purchase Order Number 711065. The test sample revealed no damage, deterioration, or water penetration as a result of the Rain Test exposure.

1.4 Salt Spray exposure was conducted on the test sample per Eagle Signal Purchase Order Number 711065. No deterioration was found in the optical unit, but the hinge pins for the cover sustained a slight rusting.

1.5 A Sand and Dust Test was conducted on the test sample per Eagle Signal Purchase Order Number 711065. No damage, deterioration or dust penetration was found.

2. TEST PROCEDURE AND RESULTS

2.1 Temperature and Pressure Test

2.1.1 Requirements

Eagle Signal Procedure of 30 September 1970 requires that the signal be cycled 90 seconds on and 90 seconds off, while the maximum and minimum temperatures are measured. The temperature rise above ambient for a signal constantly on shall be measured. The larger change in temperature shall be used to compute the possible change in pressure within the optical unit.

2.1.2 Procedure

Two holes were drilled in the lens of the unit and tire valves were mounted with silicone rubber cement. A small hole was drilled near the top of the lens, and a thermocouple was extended one inch into the optical unit and cemented. A timer was used to cycle the unit 90 seconds on and off; air was admitted through the tire valve. A manometer and a Honeywell Recorder were used to measure pressure and temperature changes within the optical unit.

2.1.3 Results

A temperature change from 70 °F to 280 °F was observed for a signal constantly on; a change from 175 °F to 216 °F was observed in the unit while cycling on and off. The larger temperature change computed to a pressure change of 11.7 inches of mercury. During the test run, air was admitted by means of a hand pump; a pressure difference of two inches of mercury was achieved before the reflector portion of the optical unit lifted free of the rubber gasket. This was caused by a relatively rapid stroke of the pump, as slow pumping produced only audible leaking inside the test unit and no measurable increase in pressure. It was noted that the reflector of the test sample was fitted loosely enough in the gasket to be turned easily by hand. The test sample was thus incapable of holding the pressure change caused by the observed rise in temperature.

2.2 Humidity Test

2.2.1 Requirements

Eagle Signal Purchase Order Number 711065 requires that one test sample shall be humidity tested at 60 percent relative humidity, at 75 ^{o}F to 95 ^{o}F, for 24 hours. The light shall be cycled 90 seconds on and 90 seconds off, and pressure and temperature measurements shall be taken.

2.2.2 Procedure

The test unit was placed in the chamber and the manometer, Honeywell Recorder, and cycle timer were attached. The chamber was stabilized at the above conditions and held for 24 hours. The unit was cycled continuously, and pressure and temperature were monitored. Chamber temperature was 85 ^{o}F.

2.2.3 Results

No damage, deterioration, or internal water condensation, as a result of the imposed test conditions, could be found. No pressure differential could be detected. Test unit temperature fluctuated between 125 °F and 150 °F. A draft of air from the chamber fans prevented any further rise in temperature.

2.3 Rain Test

2.3.1 Requirements

Eagle Signal Purchase Order Number 711065 requires that the test sample shall be rain tested at 4 inches per hour with wind up to 40 miles per hour, for a period of 2 hours. The light shall be cycled 90 seconds on and 90 seconds off, and pressure and temperature measurements shall be taken.

2.3.2 Procedure

The test unit was placed in the chamber and the instrumentation attached. Rain at 40 miles per hour and 4 inches per hour was directed at the test unit from four different angles: 45° to the left of center, 45° to the right of center, 20° up from the center axis of the lens, and directly toward the center of the lens. The unit received 1/2 hour exposure from each direction for a total test duration of two hours. Pressure and temperature were monitored and the unit was continuously cycled.

4.3.3 Results

No damage, deterioration, or water penetration, as a result of the imposed test conditions, could be detected. No pressure differential could be found. Test unit temperature fluctuated between 60 °F and 100 °F.

2.4 Salt Spray Test

2.4.1 Requirements

Eagle Signal Purchase Order Number 711065 requires that the test sample shall be salt spray tested with a 5 percent solution at 95°F for 48 hours. The light shall be cycled 90 seconds on and off, and pressure and temperature measurements shall be taken.

2.4.2 Procedure

The test unit was placed in the chamber and the instrumentation attached. Chamber conditions were stabilized and held for 48 hours. The unit was cycled continuously, and pressure and temperature were monitored.

2.4.3 Results

No damage or deterioration of the optical unit, as a result of the imposed test conditions, could be observed. Slight rusting on the ends of the cover plate hinge pins was found. No pressure differential could be detected. Test unit temperature fluctuated between 165°F and 210°F.

2.5 Sand and Dust Test

2.5.1 Requirements

Eagle Signal Purchase Order Number 711065 requires that the test sample shall be sand and dust tested with blowing sand at a velocity of 100 to 500 feet per minute, at a temperature of 77° for one hour and at 160°F for one hour. The unit shall be cycled at 90 seconds on and off, and pressure and temperature measurements shall be taken.

2.5.2. Procedure

The test unit was placed in the chamber and the instrumentation attached. The chamber conditions were stabilized with a dust density of 0.1 to 0.5 grams per cubic foot. The test unit was cycled to a stable temperature before the start of the test. Chamber temperature was stabilized a second time for the 160°F portion of the test. The light was cycled continuously, and pressure and temperature were monitored. Total test time was 2 hours.

2.5.3. Results

No damage, deterioration, or dust penetration, as a result of the imposed test conditions, could be found. No pressure differential could be detected. Test unit temperatures fluctuated between 142°F and 178°F during the first hour, and between 206°F and 242°F during the second hour.

*This data compiled by the Environ Laboratories, Inc., 9725 Dicard Avenue South, Minneapolis, Minnesota and reprinted by permission of Eagle Signal Company.