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STUDY OF FLEXIBLE DELINEATOR POST PERFORMANCE AND REVISION OF EXISTING PRE-QUALIFICATION SPECIFICATIONS

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16. Abstract

Flexible post-mounted delineators are typically ground-mounted plastic posts with reflective sheeting that are used to delineate roadsides, interchanges, and other areas in which safety is a concern. These devices are designed to withstand multiple impacts as opposed to metal guide posts; flexible delineator posts (FDPs) limit damage to the impacting vehicle along with alleviating the potential for injury to vehicle occupants.

Some products that meet current acceptance criteria and are on the Nevada Department of Transportation's (NDOT's) Qualified Product List (QPL) have exhibited dissatisfactory in-service performance. The excessive replacement of FDPs that have cracked or broken, have lost large portions of reflective sheeting, or have lost a significant degree of stiffness has led to higher life-cycle costs than expected. This study was undertaken to address these problems and to develop realistic pre-qualification specifications/criteria so that such problems can be mitigated in the future.

The procedure adopted in the study included the following activities: (1) a well-designed statewide survey of NDOT FDP field performance, (2) a FDP field performance survey of other states with similar climate, (3) analysis of vehicle-impact data collected by the National Transportation Product Evaluation Program (NTPEP), (4) correlation of NTPEP test (impact and UV exposure tests) data with actual FDP field performance in Nevada, (5) review of current pre-qualification pass/fail criteria used by other states, (6) development of a pre-qualification procedure for FDPs for Nevada, and (6) re-qualification of FDPs that are currently on NDOT's QPL. The recommended guidelines for pre-qualification of FDPs along with a commentary that summarizes the details of the procedure are presented in Appendix E of the report.

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STUDY OF FLEXIBLE DELINEATOR POST PERFORMANCE AND REVISION OF EXISTING PRE-QUALIFICATION SPECIFICATIONS

1.0 INTRODUCTION

Flexible delineator posts (FDPs) which are widely used along roadways are ground-mounted plastic posts with reflective sheeting that is used to delineate roadsides, interchanges and other areas in which safety is a concern. The *National Cooperative Highway Research Program Report 350* (NCHRP 350) describes these devices as "small and lightweight Category 1 Devices which cause very little change in speed of an impacting vehicle, and the passenger compartment of the striking vehicle is unlikely to be penetrated by any part of these devices." Specifically, these devices are designed to yield rather than resist an impact, avoiding both personal injury and damage to the striking vehicle. In addition to the NCHRP 350, the *Manual on Uniform Traffic Control Devices* (MUTCD) gives specific standards regarding size, color, placement etc. In many states such general federal guidelines have been set as the first level of pre-qualification of FDPs.

The Nevada Department of Transportation (NDOT) has identified another level of pre-qualification that addresses the *durability* of the FDPs. Products that satisfy these specifications are put on the Qualified Product List (QPL) and subsequently, only those products that are on QPL are selected for use either by NDOT maintenance personnel or accepted for use on construction projects. Some products that meet current pre-qualification specifications and are on the Nevada Department of Transportation's (NDOT's) Qualified Product List (QPL) have exhibited dissatisfactory in-service performance. The excessive replacement of FDPs that have cracked or broken, have lost large portions of reflective sheeting, or have lost a significant degree of stiffness has led to higher life-cycle costs than expected. This study was undertaken to address these problems and to develop realistic pre-qualification specifications so that such problems can be prevented in the future.

The activities that were undertaken in this study shall be summarized as follows:

1) Identify the problem,
2) Critically review existing NDOT's QPL specifications and their applicability,
3) Conduct a well-designed statewide survey of NDOT FDP field performance and determine the dominant failure modes for FDPs and the extent of those failure modes,
4) Undertake a field performance survey in a few other states with a similar climate,
5) Review and analyze vehicle impact data collected by the National Transportation Product Evaluation Program (NTPEP),
6) Correlate NTPEP impact response data collected under a controlled testing environment to data collected regarding actual field performance in Nevada,

7) Develop similar comparisons between other test response data and field performance for other failure modes,
8) Review current pass/fail criteria used by other states in the western United States in the specifications included in their FDP pre-qualification procedure,
9) Synthesize Items 6 and 7 to arrive a set of defensible pass/fail criteria that can be used as specifications to pre-qualify FDPs, and
10) Re-qualify products that are currently on NDOT's Qualified Products List.

The recommended pre-qualification criteria along with a commentary are provided in Appendix E.

2.0 FLEXIBLE DELINEATOR POSTS SELECTED FOR THIS STUDY

Earlier on it was decided that the FDP acceptance criteria/specifications to be developed should be solidly based on the field performance of FDPs in Nevada. Therefore, only those products that have been pre-qualified by the existing Nevada QPL specifications have been considered in the study. A list of those products is presented in Table 1.

Table 1: FDP Products on NDOT's QPL

Products
Carsonite CGD1,CGDU
Carsonite HWD1, HWDU
Carsonite CFRM-400 (Curve Flex)
Carsonite CRM-375 (Roadmarker)
Safe-Hit 248-GP3
Davidson Plastics FG500
Flexstake HD
Carsonite Survivor

Although all these products were included in NDOT field-performance survey, Flexstake HD and Carsonite Survivor (bottom two) were subsequently disregarded due to a lack of nationally available testing data for those products. Only the first six products identified above were considered in the study.

3.0 RESEARCH METHODLGY

3.1 Statement of the Problem

The first step in any problem-solving situation is to first understand the breadth of the problem. At the onset of our project we conducted several meetings with NDOT personnel to get a better understanding of

two things: the extent of FDP problems and the general causes of these problems. It was made clear in those meetings that the FDP problems are common and substantial resources are being spent to replace FDPs. The existing acceptance criteria/specifications are not working well in terms of predicting the field performance of FDPs. They need to be revised so that unacceptable FDPs will not be pre-qualified for use. We also came away from the meetings with a clear understanding about how the FDPs are failing. The following four distresses were identified as dominant modes of failure: impact failure, wind loading failure, reflective sheeting failure, and ultraviolet light (UV) or brittleness failure.

Another important issue that transpired at the meetings relates to the final recommendation of pass/fail criteria. These specifications should be impartial, without preference to any particular product; and they should be, if possible, based on readily available test data, preferably a national database of test responses collected under a set of reliable, well-documented, and consistent test procedures. Such a database has indeed been generated under a well-designed testing program undertaken by the National Transportation Product Evaluation Program (NTPEP). It will be seen later that we have utilized this national database in the development of the FDP acceptance/specifications. In addition, the specifications to be formulated should utilize Nevada FDP field performance in the development.

The research philosophy adopted in this study may be summarized as follows:

- Step 1: Rank the field performance of FDPs relative to each of the four failure modes identified above.

- Step 2: Rank the test response data (e.g. from NTPEP) of FDPs. As pointed out subsequently in this report, many different attributes may be used to rank the data.

- Step 3: Select a failure mode (e.g. impact failure), and compare the rankings obtained in Step 1 and 2 and see which attribute used in Step 2 gives the "best correlation" between the rankings.

- Step 4: Use Spearman Correlation Coefficient, which is a widely-used statistical parameter, to evaluate the strength (or significance) of the "best-correlation" obtained in Step 3. If it passes the criterion specified by Spearman, then the correlation is considered to be "significant" (i.e. not considered random coincidence). More details on the calculation of this coefficient and the corresponding significance evaluation criterion are presented subsequently.

- Step 5: Repeat Steps 3 and 4 for all the modes of failure.

3.2 Summary of Current NDOT Pre-qualification Specifications

Pre-qualification specifications are not exactly the same in all states but there seems to be a general consistency (theme) among most of them. Altogether four tests in a lab environment and one test in the field are currently required. A brief summary of these tests are provided below:

- Heat Resistance Bend Test: Determine whether a product is capable of straightening itself after bending without evidence of cracking or fracture when subject to an oven at 120˚ F for two hours.
- Cold Resistance Bend Test: Determine whether a product is capable of straightening itself after bending without evidence of cracking or fracture when subject to freezing at -10˚ F for four hours.
- Cold Resistance Impact Test: Determine whether a FDP suspended horizontally can withstand an impact to its mid-span from a 2 pound ball that is dropped from a vertical distance of 5 feet. The FDP should show no signs of fracturing, cracking, or splitting.
- Colorfastness Test: Determine whether a FDP can maintain its coloring after 1000 hours in a weatherometer machine (ASTM G26).
- Impact Resistance Field Test: Determine whether a sample population of three FDPs can withstand 15 impacts each while at 90˚ to oncoming vehicle moving at 35 mph, and 10 impacts each while at 75˚ to oncoming vehicle moving at 50 mph. Failure is defined as the post's inability to self-erect, withdrawal from ground such that it can be easily removed, loss of a significant portion of post due to fracture and shear, and loss of 50% reflectivity.

A close examination of the existing specifications raises many concerns and questions. These include: (1) What is the limit to the amount of permanent tilt after a vehicle impact that can be considered acceptable? (2) How does one objectively evaluate "self-erecting"? (3) What are the effects of changing material properties (e.g. strength and brittleness etc.) caused by weathering and UV light exposure have on the FDP performance in Nevada and how are they accounted for? (4) What is the environmental condition (e.g. winter or summer) under which the vehicle impact tests are to be performed? (5) How is the problem of inconsistency between FDP specifications of Nevada and others states addressed?

Furthermore, there is another general concern relative to these specifications. The question is how are these tests and the corresponding pass/fail criteria related to "actual" FDP performance in Nevada (i.e. local loading and environmental conditions). As pointed out earlier, in essence what is needed is a set of specific and readily quantifiable guidelines, which should preferably be based on correlating response data collected from a nationally accepted testing program and field performance of FDPs in Nevada. In such an undertaking, all FDP performance problems should be addressed.

3.3 NDOT Field Performance Survey

It was decided that a survey should be conducted among NDOT maintenance crews to understand the extent of FDP performance problems and to collect field information that can be used later in the study in conjunction with test response data (e.g. NTPEP test data). A well-designed questionnaire with the help of NDOT personnel was developed so that we can identify and readily rate the performance of various FDPs used in Nevada. This questionnaire included product specific questions such as,

- What products do they use?
- Relative percentages of each product used,
- How long does each product last?
- What kinds of problems modes are predominant with each product?
- Relative distribution of performance problems per product, etc.

In addition, the questionnaire also included general non-product specific questions such as,

- How a "failure" in each mode is defined by the maintenance crew?
- In which season do most problems occur? etc.

Subsequently, a second questionnaire was also sent to NDOT maintenance districts to get additional product specific data and to gain better understanding of not only the overall longevity of the FDPs, but also how each specific product was failing. A complete list of the questionnaire is presented in Appendix A.

As many as eleven maintenance crews responded to the survey. In some cases, repeated telephone calls were made to clarify the responses to the survey and the survey was updated when required. The maintenance crews that responded are: Reno, Fallon (two crews in Fallon), Elko, Winnemucca, Hawthorne, Gardnerville, Wadsworth, Wellington, Tonopah, and Las Vegas.

The completed surveys are presented in Appendix A. The first useful information for this survey is how each crew viewed "what constitutes as failure". The final pass/fail criteria (average values) as defined by NDOT field crews are shown in Table 2.

Additional useful information from the survey was the data on the extent of each of the FDP failure modes. The number one cause of failure is Impact at 38%, followed by Wind Loading at 27%, Delamination of Sheeting at 21%, and Ultraviolet (UV) or Brittleness at 14%.

The survey also produced important data on relative field performance for each product. This data enabled us to rank the performance of each product, relative to all four modes of failure: vehicle impact, wind loading, reflective sheeting, and ultraviolet light (UV) or brittleness.

Table 2 – Average Values from Field Defined Pass/Fail Cut-Off Criteria

Performance Problems	Pass/Fail Cut-off Value
Leaning Out of Plumb	4.5 inches
Cracks in Body	2 inches
Pulling Out of Ground	3 inches
Excessive Flapping Out of Plumb	6 inches
Loss of Sheeting Adhesion	30%
Breaking Off of Body from Top	1 in.

In order to make the field data from one maintenance crew comparable with that of another, we manipulated the field response data so that a "common denominator" exists. We accomplished this by first assigning 100 units to each product reported by the maintenance crew. We then multiplied this by the fraction of the product that fails within its expected service life to come up with a survival index (SI).

Table 3 – Field Ranking of Products by Failure Mode Based on Survival Index/Year (1 = Best; 6 = Worst)

Product Name	Impact Failure	Wind Load Failure	Sheet Failure	UV Brittleness
Carsonite CGDU	3	3	3	5
Carsonite HWDU	5	4	4	4
Carsonite CFRM 400	1	2	5	3
Carsonite CRM 375	6	5	6	6
Safe-Hit 248 GP3	2	1	2	2
Dav. Plastics FG 500	4	6	1	1

Dividing this by the expected lifespan of the product gives us the Survival Index per year (SI/yr). This Survival Index per year was evaluated for each of the four failure modes. The final step is to compute the statewide average SI/yr data from individual sets of data provided by the maintenance crew. Table 3 presents the ranking evaluated based on the statewide data on field performance. This field performance data was subsequently used to undertake the Spearman Correlation Coefficient calculations.

We also attempted to gather data from other states to arrive at the field performance of FDPs. With the help of NDOT personnel, who are familiar with the protocol associated with nationwide surveys, a much shorter and less extensive questionnaire was prepared and mailed to other states. Unfortunately, though there were questions and clarifications communicated via e-mail to the investigators of this study, no response was received. This left us no choice except to rely solely on the NDOT field-performance survey.

3.3 Synthesis of Vehicle Impact Response: NTPEP Data

It has been pointed out that the acceptance specifications to be developed should integrate field performance of FDPs in Nevada and data collected under a controlled environment that simulates field conditions. The Tennessee Department of Transportation conducts such a field test program for AASHTO called the National Transportation Product Evaluation Program (NTPEP). Over the years, extensive field response data under vehicle impact loading have been collected for a variety of FDPs. The manufacturers are informed about the tests and are requested to supply samples of their product for testing. Typically, the testing is carried out over two seasons (winter and summer) in Tennessee. These test data are well-documented and are readily available. The data extracted for the six FDP products are presented in Appendix A.

In the test, a car impacts eight flexible delineator posts at a speed of 55 mph for ten consecutive impacts (five in the winter and five in the summer). Four of the posts are in line with the tires of the car, while the other four are centered on the car's bumper (see Fig. 1). NTPEP test response data are presented in terms of list percentage for each impact defined in terms of permanent angle (θ_{impact} given in degrees) out of plumb, and the original angle (i.e. before test - $\theta_{initial}$ given in degrees) as,

$$\text{List } (\%) = (\theta_{impact} - \theta_{initial}) \left(\frac{100}{90}\right) \qquad (1)$$

These list percentage values are available for each FDP sample for all ten impacts. The list percentages are measured after each vehicle pass and reported relative to the start of the test (i.e. change caused by each impact) for each impact, rather than incremental for each progressive impact. Contradictory to conventional view, the data show that the list values do not continually increase in subsequent impacts due to complex plastic (healing) behavior of the material. Other types of failure indications such as cracking, withdrawal from the ground, sheeting damage due to impact, and breakage etc. have also been recorded as footnotes in the NTPEP database. A careful synthesis of such data from footnotes, though cumbersome, was undertaken so that product failures with these indications can also be investigated.

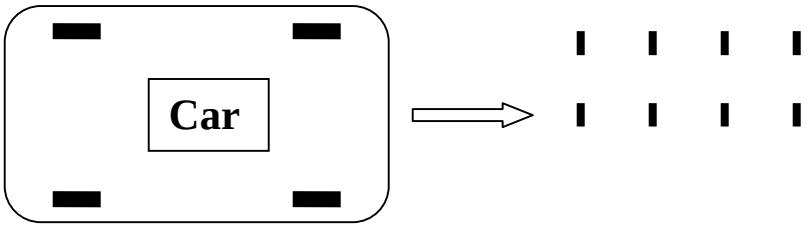


Figure 1 - NTPEP Impact Test

A review of the NTPEP test procedure reveals that every vehicle impact can be treated as an independent event (or data sample). In every vehicle pass, there are eight list response vales (four center and four bumper) and there are ten vehicle passes (five in winter and five in summer), giving a total of as much as 80 list values per FDP in a typical fully completed test. Table 4 shows the results (average) evaluated from the data extracted from the NTPEP database and corresponding ranking of performance (Rank 1 – for lowest list) for the six FDP products under study.

Table 4 - NTPEP Impact Performance Data (Ranking Based on 1 = Best and 6 = Worst)

	Average list of eight samples per product for each impact (%)										10 Impact Ave (%)	10 Impact Ranking
	1	2	3	4	5	6	7	8	9	10		
Carsonite CGDU	1.10	3.46	4.01	6.66	5.14	0.96	1.79	2.20	2.63	2.90	2.44	2
Carsonite CGDU	1.38	1.53	1.10	1.80	1.65	1.80	1.38	1.79	2.63	2.90		
Carsonite HWDU	2.76	4.16	5.85	3.88	6.68	14.29	27.06	39.70	39.70	39.84	18.39	5
Carsonite CFRM 400	2.76	3.45	3.46	3.74	4.99	0.55	0.69	0.83	0.28	0.41	2.12	1
Carsonite CRM 375	4.43	5.41	5.70	6.41	35.29	51.10	51.53	51.53	51.53	52.35	31.53	6
Safe-Hit 248 GP3	1.39	3.05	3.18	2.76	3.18	1.39	2.91	3.18	2.76	3.18	2.70	3
Dav. Plastics FG 500	2.49	2.49	2.63	3.04	15.26	13.19	13.88	14.43	14.43	14.84	9.67	4

The NTPEP database was also analyzed for a pass/fail cutoff value of list using statistical modeling techniques. Calculations and worksheets associated with the statistical analysis are presented in Appendix B. The entire population of list responses (Appendix B, Table B1) for the six FDPs under study consists of 934 independent values (instead of product averages as shown in Table 4). The mean and the standard deviation of this population are 3.3% list and 2.9% list, respectively. The histogram for this population is presented in Appendix B, Figure B1. The Normal Scores Plot associated with this population reveals a near perfect linear relationship as depicted in Figure 2. This indicates that, in deed, we have a normal distribution. Normalized list response data are presented in Figure 3.

Two methods have been attempted to identify possible pass/fail cut-off list values that define unacceptable performance. One method was based on the average list value that corresponds to a 95% level of confidence. Table 5 shows average % list as a function of confidence interval and number of independent impacts and a 95% confidence level.

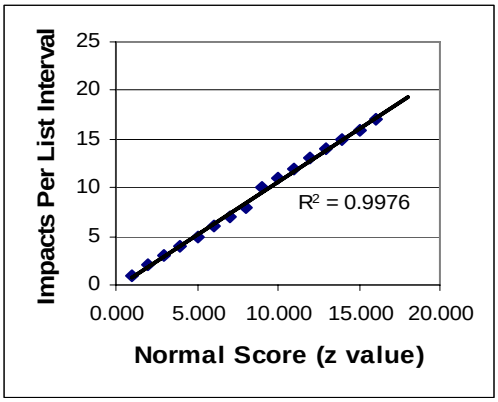


Figure 2 – Normal Scores Plot for NTPEP Listing Data

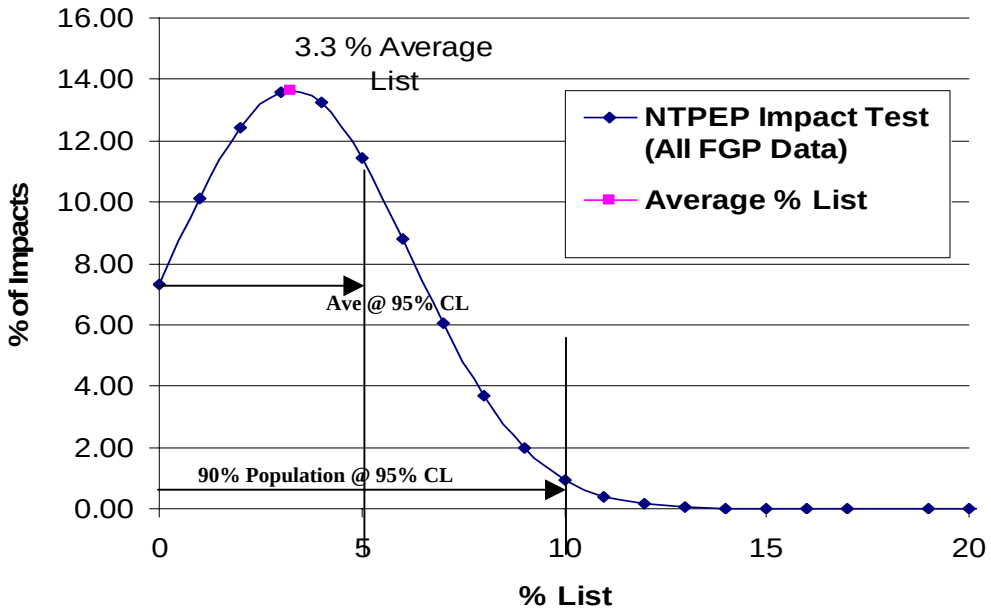


Figure 3 – Normalized NTPEP Data Showing Overall % List Distribution

The other method was based on evaluating % list value within 90% of the population and with 95% confidence. A one-tailed tolerance limit was used to find such values at different sample sizes as shown in Table 6. Subsequently, the results shown in Tables 5 and 6 have been used to arrive at the pass/fail criterion for list caused by vehicle impacts (see Section 3.8)

Table 5 – Confidence Interval for Various Sample Sizes (95% Confidence Level)

Number of Impacts	Confidence Interval (List %)	Pass/Fail Cut-off (List %)	Pass/Fail Cut-off (deg)	Pass/Fail Cut-off (in. out of plumb)
934	0.2	3.5	3.2	2.7
80	0.6	3.9	3.5	2.9
40	0.9	4.2	3.8	3.2
10	1.8	5.1	4.6	3.9
5	2.6	5.8	5.2	4.4

Table 6 – Tolerance Limit for Various Sample Sizes and 90% of the Population (95% Confidence Level)

Number of Impacts	Tolerance Interval (%)	Pass/Fail Cut-off (List %)	Pass/Fail Cut-off (deg)	Pass/Fail Cut-off (in. out of plumb)
934	4.0	7.2	6.5	5.5
80	4.5	7.8	7.0	5.9
40	4.9	8.2	7.4	6.2
10	6.8	10.0	9.0	7.6
5	9.9	13.1	11.8	10.0

3.5 Correlation Between NDOT Field and NTPEP Data: Impact Failure

The rankings developed for all failure modes from NDOT field data (Table 3) and NTPEP vehicle impact data (Table 4) have been reproduced in Table 7 for convenience. A technique known as Spearman Correlation Coefficient method is widely used to find out if in deed there is significant correlation (similarity) between any two rankings. In this method, the Spearman Correlation Coefficient (R), defined as,

$$R = 1 - \frac{6\sum D^2}{N(N^2 - 1)} \qquad (2)$$

is first computed. Here D is the difference between rankings for each sample (i.e. FDP product) and N is the number of samples (= 6 in our case). Depending on the number of samples used, Spearman gives critical values of the correlation coefficient (R_{min}) as a function of sample size (i.e. N) to check the significance of the correlation. For N = 6, the critical value $R_{min} = 0.829$. In other words, if computed value R (Equn. 2) satisfies the following limit state,

$$R \geq 0.829 \qquad (3)$$

then the correlation between the two rankings is considered significant. This technique has found many applications in science and engineering and has been proven to be effective and robust.

Table 7 - Comparison Between NTPEP Impact and NDOT Field Rankings (1 = Best; 6 = Worst)

NTPEP Impact Ranking	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking
2	Carsonite CGDU	3	3	3	5
5	Carsonite HWDU	5	4	4	4
1	Carsonite CFRM 400	1	2	5	3
6	Carsonite CRM 375	6	5	6	6
3	Safe-Hit 248 GP3	2	1	2	2
4	Dav. Plastics FG 500	4	6	1	1
Measure of Similarity Between NTPEP Impact and NDOT Field Rankings, *R (Spearman Correlation Coefficient)*		.976	.657	.200	.314

The Spearman Correlation Coefficient values between rankings for each of the failure mode from NDOT field and NTPEP impact data have also been included in the table. It is clear from the table that for impact mode of failure, the R value between rankings from NDOT and NTPEP data is 0.976. Since this is well above R_{min} (0.829), this correlation is significant. It may be noted that R values between other modes of failure and NTPEP data are all much lower than R_{min} (i.e. insignificant correlation). An indication of insignificant correlation is an important result. Knowing that the factors that affect vehicle impact and other failure modes are not the same, a good correlation between two vehicle impact based rankings only (NDOT field and NTPEP data), lends credibility to the proposed approach.

3.6 Methodology for Other Modes of Failure

Other important failure modes are: wind loading, delamination of sheeting, and UV brittleness. Unlike the vehicle impact database of NTPEP, there is no well-documented study that has focused on these problems . However, as a part of the NTPEP test program, results of tests conducted using a weatherometer (ASTM D638) on the same FDPs for which the vehicle impact data exist have been documented. The test procedure adopted includes three samples (specimens) of each product and the use of the weatherometer to age (1000 hours) them. Subsequently, measurements of strength (tensile) and elongation to reach tensile failure were made for each specimen. In addition, strength and elongation results are also available for the three control specimens (i.e. no aging). Tables B3 and B4 in Appendix B show many material and shape attributes that can be formulated from this data. The six products in this study can then be ranked based on these material and shape attributes and then compared to the failure mode rankings in the field survey to find any similarity. Similarity is still measured using Spearman Correlation Coefficient where a value greater than .829 constitutes a valid correlation for a sample size of N = 6. Tables B5 through B12 in Appendix B show all our attempts at the comparisons. Only the most promising results have been selected and presented below.

Table 8 - Comparison Between NTPEP Absolute Elongation and NDOT Field Rankings (1 = Best; 6 = Worst)

NTPEP Ranking	Product Name	NDOT Field Rankings					
Δ Absolute Elongation [1]		Impact Ranking	Wind Load Ranking	Sheet Failure Ranking	UV Brittleness Ranking	Sheeting/UV Ranking	Wind/UV Ranking
5	Carsonite CGDU	3	3	3	5	5	3
4	Carsonite HWDU	5	4	4	4	3	4
3	Carsonite CFRM 400	1	2	5	3	4	2
6	Carsonite CRM 375	6	5	6	6	6	5
1	Safe-Hit 248 GP3	2	1	2	2	2	1
2	Dav. Plastics FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation and NDOT Field Rankings, *R*		.600	.371	.714	.943	.885	.714

[1] See Appendix D for calculation definitions

Field rankings along with ranking obtained for the absolute change in elongation (NTPEP UV tests) are shown in Table 8. This table also includes two additional field performance rankings that combined two failure modes. These combined modes of failures are from (1) sheeting and UV brittleness and (2) wind and UV brittleness. As Table 8 points out, there is similarity between the field ranking for UV brittleness failure and ranking of NTPEP data (R = 0.943) for the change in absolute elongation (change of weathered specimen from the control specimen relative to elongation at failure). See Appendix D for definition of terms. Also, a similarity between the change in absolute elongation ranking and the combined field sheeting and UV brittleness failure (column 7, Table 8) ranking (R = 0.885) is observed. This suggests a link between material property changing with time and the delamination of reflective sheeting from the delineator post. This signifies that failures resulting from brittleness and sheeting failures may in fact be related and are affected more so by the UV exposure than by temperature changes. This is because NTPEP data on elongation change are obtained from a weatherometer that simulated UV exposure. It should be noted that temperature does in fact also play a role on sheeting performance, however, its role may already be represented in UV test results. The difference between the elongation of the original FDP (simulated by the control specimen in NTPEP UV test) and the weathered FDP (simulated by weathered specimen) indicates the ability of the selected FDP to deform (pliability). A higher difference signifies more flexibility to deform, which can result in a better performance relative to UV brittleness and sheeting delamination. Therefore, it is not surprising that a good match among the rankings in terms of Δ absolute elongation (column 1), field failure relative to UV brittleness alone (column 6), and the combined failure from sheeting and UV brittleness (column 7). The effects of UV exposure are irreversible for plastic materials properties but the effects of temperature are not wholly so. At certain temperatures for various types of plastic materials, plastics undergo what is called glass temperature. This is the temperature at which failure characteristics change from cold form bending (plastic behavior) to sudden breaking (brittle behavior). Although a FDP may be brittle in the winter, it may return to a more pliable state in the summer

as temperature increases. A FDP that shows little change in its ability to elongate after UV weathering may in fact already be close to its glass temperature (some plastics do in deed have glass temperatures close to room temperature). It appears that the inability to elongate directly correlates with delamination of sheeting.

Table 9 – Average Sheeting Damage for FDP Products from NTPEP Impact Tests (1 = Best; 6 = Worst)

Products	First Season Ave. Sheeting Damage (%)	Second Season Ave. Sheeting Damage (%)	Δ Ave. Sheeting Damage (%) [(1)]	Δ Ave. Sheeting Damage Ranking
Carsonite CGDU	2.000	1.125	.875	3
Carsonite HWDU	10.625	17.625	-7.000	5
Carsonite CFRM 400	.625	14.875	-14.250	6
Carsonite CRM 375	10.000	10.000	0	4
Safe-Hit 248 GP3	5.125	.688	4.437	2
Dav. Plastics FG 500	7.500	.625	6.875	1

(1) See Appendix D for calculation definitions

Table 10 - Comparison Between NTPEP Change in Reflective Sheeting Damage and NDOT Field Rankings (1 = Best; 6 = Worst)

NTPEP Ranking	Product Name	NDOT Field Rankings					
Δ Ave. Sheeting Damage Ranking[(1)]		Impact Ranking	Wind Load Ranking	Sheet Failure Ranking	UV Brittleness Ranking	Sheeting/UV Ranking	Wind/UV Ranking
3	Carsonite CGDU	3	3	3	5	5	3
5	Carsonite HWDU	5	4	4	4	3	4
6	Carsonite CFRM 400	1	2	5	3	4	2
4	Carsonite CRM 375	6	5	6	6	6	5
2	Safe-Hit 248 GP3	2	1	2	2	2	1
1	Dav. Plastics FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Change in Sheet Damage and NDOT Field Rankings, *R*		-0.086	-0.257	0.829	0.486	0.543	-0.257

(1) See Appendix D for calculation definitions

The sheeting failure can also be investigated utilizing the data from NTPEP vehicle impact tests. A part of the NTPEP data includes footnotes on such observations such as sheeting tearing off, splits in the body, pulling out of ground, and breaks in the FDP body. This data is presented in Appendix A. Cracking and splitting are too erratic and complex to define and therefore, any trends associated with such failures were not possible to quantify. However, the NTPEP data on sheeting damage show some parallel trends with that of the NDOT field survey on sheeting damage. The NTPEP data has been compiled by season and the difference in average sheeting damage between seasons for each product has been ranked and is shown in Table 9.

Table 10 shows the relationship between the NTPEP ranking for seasonal changes in sheeting damage and the NDOT field ranking for sheeting damage. A Spearman Correlation Coefficient of .829, which is right at the cut-off for similarity, confirms a strong relationship between the two rankings. The average sheeting damage data presented in Table 9 is a measure of damage caused by environmental exposure at the site. Since the vehicle impact loading is uniformly applied to all FDPs, the change in sheeting damage in two consecutive impact tests reflect the role of temperature and UV exposure on the post. Both the NTPEP UV test (Table 9) and the impact test (Table 10), when looked at together, represent the combined effects of temperature and weathering (UV exposure) on sheeting delamination. It should be noted that when the NDOT field crews report a failure that is due to delaminated sheeting, the FDP in question has most likely been in place for a season or two.

The last mode of failure to consider is wind loading. As mentioned before, wind loading is the second most significant cause of failure, according to the field survey results, constituting to as much as 27% of all the failures. Table 11 summarizes calculations from the NTPEP UV test and shows very strong similarity between NTPEP strain energy ranking and the field wind loading ranking.

Table 11 - Comparison Between NTPEP Change in Strain Energy and NDOT Field Rankings (1 = Best; 6 = Worst)

NTPEP Ranking	Product Name	NDOT Field Rankings					
Δ Strain Energy[(1)]		Impact Ranking	Wind Load Ranking	Sheet Failure Ranking	UV Brittleness Ranking	Sheeting/UV Ranking	Wind/UV Ranking
3	Carsonite CGDU	3	3	3	5	5	3
4	Carsonite HWDU	5	4	4	4	3	4
2	Carsonite CFRM 400	1	2	5	3	4	2
5	Carsonite CRM 375	6	5	6	6	6	5
1	Safe-Hit 248 GP3	2	1	2	2	2	1
6	Dav. Plastics FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Change in Strain Energy Ranking and NDOT Field Rankings, *R*		.771	1.00	-.029	.086	-.029	1.00

[(1)] See Appendix D for calculation definitions

The strain energy (see Appendix D for definition) is a measure of energy a FDP stores when the yield tensile load is applied and its change (weathered sample) reflects the role of weathering on energy stored. A common performance attribute, which relates to a measure of flexibility, between these rankings is the ability to stand up to repetitious loading after a period of weathering. Shape may also be expected to play a role because the drag forces and bending moments are a function of FDP shape. In particular, the shape will play a significant role in the first season. However, observations in Table B4, Appendix B that deal with wind drag effects, stiffness, deflection and maximum loads show very little correlation with the wind load failures reported by the NDOT field crews. That being said, there may be a very significant correlation between shape and wind loading failures when it comes to properties such as vortex shedding,

damping, repetitious twisting, etc. that can only be confirmed in a lab setting. The actual wind drag effects for each of the FDPs has only been hypothesized for this study through the use of published bluff shapes (basic shapes). See Theoretical Wind Effect calculations shown in Table B4, Appendix B for details.

Another important observation from Table 11 is the perfect correlation between change in strain energy and the combined wind and UV brittleness failure. Both of the failure modes (wind and UV brittleness) are in fact related to the flexibility of the post and the strain energy measure seems to capture this phenomenon quite correctly.

3.7 Summary Other States' FDP Pre-qualification Specifications

Appendix C lists other states' FDP pre-qualification specifications, which include descriptions of tests along with pass/fail cut-off values in those tests for qualification. Some states do not offer their own methods of testing, but rather rely directly on NTPEP data. Three states in the west give specific numbers regarding the degree of list that a FDP is allowed to lean without being considered as failure. These states are Arizona, Colorado, and Washington. For example, Arizona's pre-qualification specifications require that FDPs are to straighten themselves to within 5 degrees of their original position after ten impacts. Colorado does not currently pre-qualify their flexible delineator posts; nevertheless, they have specifications for FDP selection in their written specifications. Colorado's specifications require that a single FDP must return to within 10 degrees of vertical after 10 impacts head-on at 35 mph and after 5 impacts at an angle of 75˚ to the traffic face of the post at 55 mph. Washington's requirements are similar to Colorado's for pre-qualifying their flexible delineator posts except that the impact test must include 10 posts subjected to 7 impacts at 35 mph and 3 impacts at 55 mph. All impacts are head-on and must return to within 10 degrees of vertical, show no signs of cracking, pull out of ground no more than 3 inches, and lose no more than 50% of its sheeting. At least 7 out of 10 posts must pass the criteria.

For wind loading, only Arizona has any specific guidelines for failure identification. Arizona's specifications require that a 50 mph wind must not deflect devices more than 2 inches from the at-rest position. Washington does not have direct wind load testing guidelines but proposes a cyclic load test to be performed in a lab. A flexible delineator post must be able to maintain 80% of its bending strength after being subjected to 30,000 cycles in a cyclic testing machine with amplitude of 2 inches at 60 cycles per minute.

For weathering requirements, all states call for no discoloration or loss of pliability after 1000 hours in a weatherometer. However, Washington specifies that a FDP must maintain 80% of its unconditioned tensile strength in addition to the discoloration and pliability requirements.

3.8 Development of New Pre-qualification Pass/Fail Criteria

By reviewing information such as NDOT field performance, NTPEP data analysis, rank correlations, and pre-qualification specifications adopted by other states, a set of criteria can be formulated to specifically suit the needs of NDOT.

Vehicle Impact

It is clear that the impact failure ranking that was derived from the field performance (Table 3) fits best with that of the NTPEP vehicle impact ranking (Table 4) as opposed to other modes of failure. See also the composite Table 7 for details. Table 2 shows how the different NDOT field crews have set their own failure criteria. The overall average for the out-of-plumb condition is roughly 4.5 inches which corresponds to 5.4 degrees out of plumb for a 48 inch tall FDP. This level of out-of-plumb also corresponds to a list of 6%. Knowing that (1) most of the pre-qualification tests from other states refer to a sample size of around 10 and (2) a list of 10% represents 90% of the population at a 95% confidence level (see Table 6), we have selected this level of list as the cut-off for FDP failure. It may be noted that Colorado and Washington specify 11.1% list (10 degrees) as their cut-off. Using this criterion the six FDPs considered here can be assigned pass/fail as shown in Table 12.

Table 12 – Re-Qualification of FDPs Baseed on NTPEP Impact Testing: Impact Mode of Failure

Qualified Product list	10 Impact Ave (List %) (NTPEP Test Results [(1)]	Pass/Fail
Carsonite CGDU	2.44	Pass
Carsonite HWDU	18.39	Fail
Carsonite CFRM 400	2.12	Pass
Carsonite CRM 375	31.53	Fail
Safe-Hit 248 GP3	2.70	Pass
Davidson Plastics FG 500	9.67	Pass

[(1)] From Table 4

Wind Loading and UV Brittleness

It may be recalled that the rank correlation comparison (Table 11) between field wind-loading failure and NTPEP data on change in strain energy (ΔE_s) resulted in a perfect match. The combined ranking of both wind loading and UV brittleness failures also yielded the same result. The strain energy calculations are reproduced in Table 13. A plot of change in strain energy versus the field ranking is shown in Fig. 4. The lowest ranking FDP (Davison Plastics) and the highest ranking FDP (Safe-Hit) seem to be

Table 13 – Strain Energy Values from NTPEP UV Data and Rankings

(1 = Best; 6 = Worst)

Product	Strain Energy to Yield Point, E_s (lb-in) [1]			**Rankings for** Δ Energy and Field Wind Loading
	Control	**Weather**	ΔE_s **(%)** [2]	
Carsonite CGDU/CGD1	719.7	703.5	-2.26	3
Carsonite HWDU/HWD1	839.8	784.9	-6.53	4
Carsonite CFRM 400	1550.5	1616.6	4.26	2
Carsonite CRM 375	407.1	380.3	-6.58	5
Safe-Hit 248 GP3	830.9	1090.7	31.27	1
Davidson Plastics FG 500	1133.1	915.8	-19.17	6

[1] [2] See Appendix D for calculation definitions

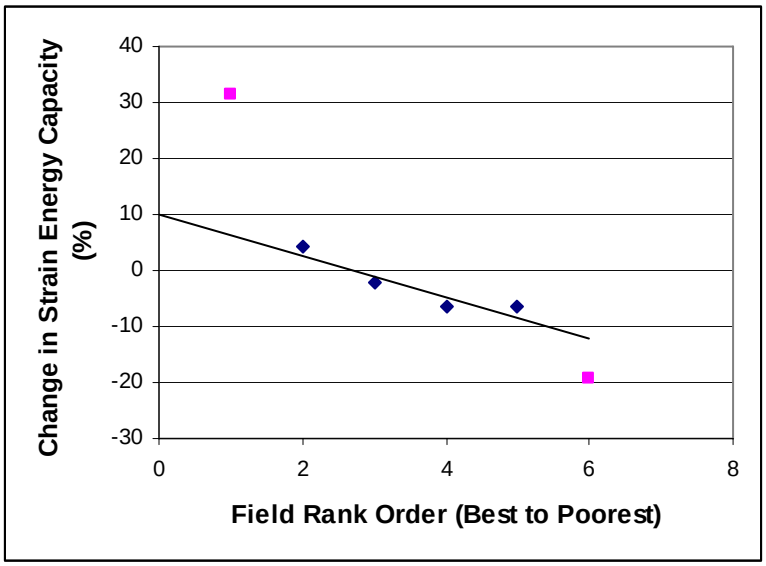


Figure 4 – Changes in Strain Energy after 1000 hours in a Weatherometer

the outliers as shown in figure. When these two data sets are removed, there exists a trend line and the average of the remaining ΔE_s values is –2.8%. A decision was made to round this value to –3% and specify this as the cut-off criteria for the wind-loading mode of failure. In other words, a FDP should be able to loose only up to 3% of its original strain energy after being subjected to weathering in a weatherometer for 1000 hrs. Using this criterion the six FDPs considered here can be assigned pass/fail as shown in Table 13.

Delamination of Sheeting

A similar approach can be followed for the delamination of sheeting mode of failure. NTPEP test results of change in sheeting damage over the season (shown in Table 9) along with NDOT field ranking for sheeting damage (see Table 3 and Table 10) are reproduced in Table 15. It may be recalled that the

Spearman correlation coefficient between these rankings is right at the cut-off value of 0.829 (sample size = 6). When the bottom performer in the NTPEP test data (Carsonite CRM 375) is removed from

Table 14 – Re-Qualification of FDPs Based on NTPEP UV Testing Data: Wind Loading Mode of Failure

Qualified Product list	ΔE_s (%) [1]	Pass/Fail
Carsonite CGDU	-2.26	Pass
Carsonite HWDU	-6.53	Fail
Carsonite CFRM 400	4.26	Pass
Carsonite CRM 375	-6.58	Fail
Safe-Hit 248 GP3	31.27	Pass
Davidson Plastics FG 500	-19.17	Fail

[1] See Appendix D for calculation definitions

Table 15 – Average Sheeting Damage for FDP Products from NTPEP Impact Tests and Rankings (1 = Best; 6 = Worst)

Product	**Δ Ave. Sheeting Damage (%)** [1,2]	**Δ Ave. Sheeting Damage Ranking (Table 9)**	**NDOT Field Sheeting Damage Ranking (Table 3)**
Carsonite CGDU/CGD1	0.875	3	3
Carsonite HWDU/HWD1	-7.000	5	4
Carsonite CFRM 400	-14.250	6	5
Carsonite CRM 375	0.0	4	6
Safe-Hit 248 GP3	4.437	2	2
Davidson Plastics FG 500	6.875	1	1

[1] See Appendix D for calculation definitions
[2] See Table 9

consideration, both the rankings become identical, indicating a strong correlation between field performance with change in sheeting damage over the season. A plot of change in sheeting damage and the field ranking is shown in Fig. 5. There is an outlier, which seems to be a discrepancy between field and NTPEP UV test data results. As shown in Fig. 5, once this data set is removed, there is a good linear correlation between change in sheeting damage over the season and field ranking. The average of the change in sheeting damage of the remaining data sets is –1.8%. A decision was made to specify a cut-off value to Δ Ave Sheeting Damage at –2% (change in sheeting damage after one season). In other words, roughly up to 2% more sheeting damage in the second season can be permitted before failure is indicated. Using this criterion the six FDPs considered here can be assigned pass/fail as shown in Table 16.

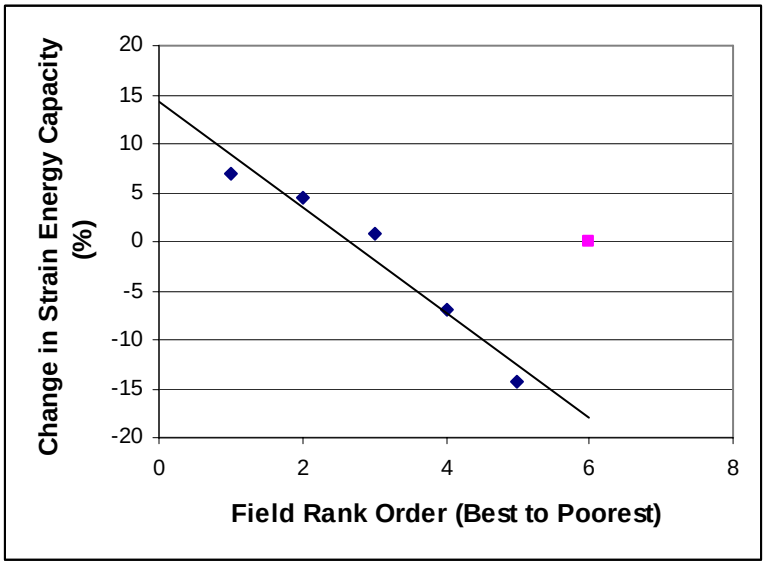


Figure 5 – Changes in Sheeting Damage Due to Impact after One Season

Table 16 – Re-Qualification of FDPs Based on NTPEP Impact Testing: Delamination of Sheeting Failure

Qualified Product list	Δ Ave. Sheeting Damage (%) (1,2)	Pass/Fail
Carsonite CGDU	.875	Pass
Carsonite HWDU	-7.000	Fail
Carsonite CFRM 400	-14.250	Fail
Carsonite CRM 375	0	Pass
Safe-Hit 248 GP3	4.437	Pass
Davidson Plastics FG 500	6.875	Pass

(1) See calculation definitions, Appendix D
(2) See Table 9

Cracking and Flexibility

As it has been argued before, cracking and breaking is a behavior that is hard to quantify and no apparent trends could be recognized from the available NTPEP data. There are many factors at work when it comes to cracking and breaking. A crack or break at the top of a post is not nearly as significant as a crack or break developing near its base. Also there is the issue of how to treat multiple cracks and breaks as opposed to just one large crack or break. Additionally, another concern is how big can a crack or break, get before FDP flexibility or stiffness is compromised? It is recommended, therefore, to treat these failure symptoms as service issues. Since this study achieves good correlation with NTPEP impact tests using

percent list values, products pre-qualified with those results alone may also perform well against cracking and breaking. Cracking and breaking do play an indirect role in NTPEP vehicle impact tests because when the flexibility has diminished as a result of cracking and breaking, the net outcome is excess sheeting damage and higher list values.

Discoloration of FDPs

There are no national tests on this issue. The current NDOT specification is based on ASTM G26 and it seems to have worked well as this has not been flagged as a problem by the NDOT maintenance crews. We recommend (i.e. optional) that the current NDOT specification be kept as it is.

3.9 Recommended Pre-Qualification Specifications and Re-Qualification of FDPs Listed in NDOT's QPL

A review of pre-qualification specifications criteria adopted by other states suggest that it is best to specify "cut-off" values and if that cut-off value (upper limit) is exceeded for given product, then that product has failed the corresponding criterion. This step will lead to a set of consistent requirements and is also much easier to interpret. To achieve this goal, it was required that the criteria associated with two of the modes of failure (wind loading and delamination of sheeting) be multiplied by –1. The Table 17 summarizes the recommended final pass/fail criteria for flexible delineator posts submitted for pre-qualification. Many cut-off criteria have been derived using NTPEP testing data.

Keeping with NTPEP data is a convenient means of verifying the performance of a FDP without the hassle and cost of developing a new test. The first criterion that must be met is available testing by NTPEP or similar testing by the manufacturer. Using a 10% list (9.0 degrees) as the cut-off criterion for vehicle impact loading, the pass/fail results achieved for existing FDP products on NDOT's QPL are reproduced in Table 18. Table 19 shows a similar table for the wind loading mode of failure with a pass/fail cut-off value of 3% change in strain energy followed by Table 20 that shows the sheeting damage mode of failure with its 2% change in seasonal sheeting damage criteria. Finally, Table 21 gives the overall re-qualification result obtained for all the FDPs on the NDOT's QPL. A summary of the pre-qualification requirements and data interpretation procedure that need to be adopted to check against the failure modes are summarized in Appendix E.

Table 17 – Recommended Pre-Qualification Specifications

Mode of Failure	Recommended Cut-off Criteria *	Description for Pass
Impact Loading	Listing average not to exceed 10% (9 degrees) for 10 impacts	Average of eight products being impacted simultaneously. See NTPEP test procedure.
Wind Loading	Loss of strain energy capacity after 1000 hrs in a weatherometer not to exceed 3% of the original strain energy capacity of the control specimen.	$E = \frac{P}{2\delta}$; $\frac{E_{contol} - E_{weathered}}{E_{control}} x100 \leq 3\%$
Delamination of Sheeting	Average loss of sheeting in the second season impact testing not to exceed 2% above the average loss of sheeting in the first season impact testing.	$\%Loss_{2nd\ season} - \%Loss_{1st\ season} \leq 2\%$
UV Brittleness	Same as wind loading criteria	Same as wind loading criteria
Discoloration (optional)	Subject FDP to 1000 hrs in a weatherometer (ASTM G26)	No discoloration should be observed (optional)

* The first pre-qualification requirement is that all flexible delineator posts to be considered must have been tested by NTPEP.

Table 18 – Re-Qualification of FDPs on NDOT's QPL Based on NTPEP Impact Testing: Impact Mode of Failure

Qualified Product list	Pass/Fail
Carsonite CGDU	Pass
Carsonite HWDU	Fail
Carsonite CFRM 400	Pass
Carsonite CRM 375	Fail
Safe-Hit 248 GP3	Pass
Davidson Plastics FG 500	Pass

Table 19 – Re-Qualification of FDPs in NDOT's QPL Based on NTPEP UV Testing Data: Wind Loading Mode of Failure

Qualified Product list	Pass/Fail
Carsonite CGDU	Pass
Carsonite HWDU	Fail
Carsonite CFRM 400	Pass
Carsonite CRM 375	Fail
Safe-Hit 248 GP3	Pass
Davidson Plastics FG 500	Fail

Table 20 – Re-Qualification of FDPs on NDOT's QPL Based on NTPEP Impact Testing: Delamination of Sheeting Failure

Qualified Product list	Pass/Fail
Carsonite CGDU	Pass
Carsonite HWDU	Fail
Carsonite CFRM 400	Fail
Carsonite CRM 375	Pass
Safe-Hit 248 GP3	Pass
Davidson Plastics FG 500	Pass

Table 21 – Overall Re-Qualification of FDPs on NDOT's QPL

Qualified Product list	Pass/Fail
Carsonite CGDU	Pass
Carsonite HWDU	Fail
Carsonite CFRM 400	Fail
Carsonite CRM 375	Fail
Safe-Hit 248 GP3	Pass
Davidson Plastics FG 500	Fail

Appendix A
Raw Data

Questionnaire Regarding Flexible Delineator Posts (FDP) within NDOT Districts

Please help our research and fill out the following questionnaire. Thank you for your time.

District Name: _____

Respondent: _____

General Inquiry

1) What is the break down percentage between flexible delineator posts and metal delineator posts?

   Flexible Delineator Posts _____%

   Metal Delineator Posts _____%

2) What is the current total number of flexible delineator posts in this district?

3) What is the average minimum and maximum life span for flexible delineator posts?

   Minimum life span _____years

   Maximum life span_____years

4) What is the average minimum and maximum life span for metal delineator posts?

   Minimum life span _____years

   Maximum life span_____years

5) During which season do most flexible delineator post failures occur? Circle one.

   Winter Spring Summer Fall

6) We have identified the primary distress modes for flexible delineator posts as follows: vehicle impact failure, wind fatigue failure, reflective sheeting adhesive failure, and U.V. (weathering/aging) brittleness failure.

   a) Please assign an average percentage to each mode of failure for all flexible delineator posts within this district.

      i) Vehicle Impact Failure _____%

      ii) Wind Loading Failure_____%

      iv) U.V. Brittleness Failure _____%

      v) Other (please specify) _____%
      _____

iii) Sheeting Adhesive Failure _____%

6b) Please quantify the criteria that are currently used to identify and replace failed flexible delineator posts in this district. Circle one answer per category.

i) Permanently out of plumb by:

1 to 4 in. 4 to 10 in. more than 10 in.

ii) Cracks in body of:

any length 1 to 2 in. 2 to 4 in. more than 4 in.

iii) Pulling out of ground by:

any amount 2 to 4 in. more than 4 in.

iv) Excessive flapping out of plumb by:

1 to 4 in. 4 to 10 in. more than 10 in.

v) % Loss of reflective sheeting or % loss of sheeting adhesion by:

less than 10 % 10 to 30 % 30 to 50% more than 50 %

vi) Breaking off of body from top by:

Any amount 2 to 4 in. 4 to 6 in. more than 6in.

Product Specific Inquiry

7) For each of the following products, please assign average percentages showing the extent of use in this district.

Carsonite CGD1:	_____%	Carsonite CRM-375:	_____%
Carsonite CGDU:	_____%	Safe-Hit 248-GP3:	_____%
Carsonite HWD1:	_____%	Flexstake HD	_____%
Carsonite HWDU:	_____%	Other	_____%
Carsonite CFRM-400:	_____%	Total	100%

8) When applicable, please assign a percentage showing the average extent of failure for each product in this district as well as its corresponding average service life.

Carsonite CGD1:	_____%	_____yrs
Carsonite CGDU:	_____%	_____yrs
Carsonite HWD1:	_____%	_____yrs
Carsonite HWDU:	_____%	_____yrs
Carsonite CFRM-400:	_____%	_____yrs
Carsonite CRM-375:	_____%	_____yrs
Safe-Hit 248-GP3:	_____%	_____yrs
Flexstake HD	_____%	_____yrs
Other	_____%	_____yrs
Total	100%	

9) For each of the following products, if applicable, please assign average percentages corresponding to the various modes of failure shown.

	Modes of Failure				
	Vehicle Impact	Wind Loading	Adhesive Failure	U.V. (Aging)	Other (Specify)_____
Carsonite CGD1:	_____%	_____%	_____%	_____%	_____%
Carsonite CGDU:	_____%	_____%	_____%	_____%	_____%
Carsonite HWD1:	_____%	_____%	_____%	_____%	_____%
Carsonite HWDU:	_____%	_____%	_____%	_____%	_____%
Carsonite CFRM-400:	_____%	_____%	_____%	_____%	_____%
Carsonite CRM-375:	_____%	_____%	_____%	_____%	_____%
Safe-Hit 248-GP3:	_____%	_____%	_____%	_____%	_____%
Flexstake HD	_____%	_____%	_____%	_____%	_____%
Other	_____%	_____%	_____%	_____%	_____%

10) Specify the top three locations for flexible delineator post failures in this district and state the corresponding site specific conditions that make the flexible delineator posts more vulnerable to failure. Site specific conditions may include factors such as poor road visibility, high wind, heavy snow removal, etc..

Location 1: _____

Conditions: _____

_____

Location 2: _____

Conditions: _____

_____

Location 3: _____

Conditions: _____

_____

Please email, fax or send the completed questionnaire to:

Raj Siddharthan, Ph.D., P.E. Voice: (775) 784-1411
Department of Civil Engineering/258 Fax: (775) 784-1390

University of Nevada, Reno
Reno, NV 89557

Email: siddhart@unr.edu

Results of Questionnaire

		District 1									
		Las Vegas					Tonopah				
		flexible		metal			flexible		metal		
1	What is the break down percentage between flexible delineator posts and metal delineator posts?	80%		20%			60%		40%		
2	What is the current total number of flexible delineator posts in this district?	20,000 to 25,000					10,999				
3	What is the average minimum and maximum life span for flexible delineator posts?	min		max			min		max		
		.5 to 1yrs		6 to 10 yrs			1.00 yrs		3.00 yrs		
4	What is the average minimum and maximum life span for metal delineator posts?	min		max			min		max		
		1 to 3 yrs		15 to 20 yrs			0.50 yrs		10.00 yrs		
5	During which season do most flexible delineator post failures occur?	Year round					Year Round				
6a	Please assign an average percentage to each mode of failure for all flexible delineator posts within this district.	Impact	Wind	Sheet Fail	UV Brittle	Other	Impact	Wind	Sheet Fail	UV Brittle	Other (animals)
		40	18	40	2	0	50	10	80	10	30
6b	Please quantify the criteria that are currently used to identify and replace failed flexible delineator posts in this district.										
	Permanently out of plumb by:	4 to 10 in.					1 to 4 in.				
	Cracks in body of:	N/A					2 to 4 in.				
	Pulling out of ground by:	more than 4 in.					2 to 4 in.				
	Excessive flapping out of plumb by:	4 to 10 in.					4 to 10 in.				
	% loss of sheeting adhesion by:	more than 50 %					10 to 30 %				
	Breaking off of body from top by:	N/A					2 to 4 in.				
7	For each of the following products, please assign average percentages showing the extent of use in this district.										
	Carsonite CGD1(1)	19									
	Carsonite CGDU (2)										
	Carsonite HWD1 (3)	10									
	Carsonite HWDU (4)										
	Carsonite (Curve Flex) CFRM-400 (5)										
	Carsonite (Roadmarker) CRM-375 (6)	20									
	Safe-Hit 248-GP3 (7)	50					100				
	Flexstake HD (8)	1									
	Davidson Plastics FG500 (9)										
	Carsonite Survivor (10)										
	Other:										

		District 1			
		Las Vegas		Tonopah	
		flexible	metal	flexible	metal
8	When applicable, please assign a percentage showing the average extent of failure for each product in this district as well as its corresponding average service life.	% / Years		% / Years	
	Carsonite CGD1(1)	50	4		
	Carsonite CGDU (2)				
	Carsonite HWD1 (3)	70	6		
	Carsonite HWDU (4)				
	Carsonite (Curve Flex) CFRM-400 (5)				
	Carsonite (Roadmarker) CRM-375 (6)	40	6		
	Safe-Hit 248-GP3 (7)	20	10	10	10
	Flexstake HD (8)	80	4		
	Davidson Plastics FG500 (9)				
	Carsonite Survivor (10)				
	Other:				

9	For each of the following products, if applicable, please assign average percentages corresponding to the various modes of failure shown.	Impact	Wind	Sheet Fail	UV Brittle	Other		Impact	Wind	Sheet Fail	UV Brittle	Other	
	Carsonite CGD1(1)	70		30									
	Carsonite CGDU (2)												
	Carsonite HWD1 (3)	95		5									
	Carsonite HWDU (4)												
	Carsonite (Curve Flex) CFRM-400 (5)												
	Carsonite (Roadmarker) CRM-375 (6)	40	50	10									
	Safe-Hit 248-GP3 (7)	90		10				10	5	65	20		
	Flexstake HD (8)	100											
	Davidson Plastics FG500 (9)												
	Carsonite Survivor (10)												
	Other:												

		District 2			
		Fallon I		Fallon II	
		flexible	metal	flexible	metal
1	What is the break down percentage between flexible delineator posts and metal delineator posts?	75%	25%	85%	15%
2	What is the current total number of flexible delineator posts in this district?	---		---	
3	What is the average minimum and maximum life span for flexible delineator posts?	min: 1.00 yrs	max: 3.00 yrs	min: 0.02 yrs	max: 1.00 yrs
4	What is the average minimum and maximum life span for metal delineator posts?	min: 1.00 yrs	max: 10.00 yrs	min: 0.02 yrs	max: 5.00 yrs
5	During which season do most flexible delineator post failures occur?	Winter		Spring	
6a	Please assign an average percentage to each mode of failure for all flexible delineator posts within this district.	Impact: 20; Wind: 30; Sheet Fail: 30; UV Brittle: 20; Other: 0		Impact: 35; Wind: 45; Sheet Fail: 5; UV Brittle: 5; Other (animals): 10	
6b	Please quantify the criteria that are currently used to identify and replace failed flexible delineator posts in this district.				
	Permanently out of plumb by:	1 to 4 in.		1 to 4 in.	
	Cracks in body of:	any length		any length	
	Pulling out of ground by:	any amount		more than 4 in.	
	Excessive flapping out of plumb by:	1 to 4 in.		4 to 10 in.	
	% loss of sheeting adhesion by:	10 to 30 %		30 to 50 %	
	Breaking off of body from top by:	any amount		4 to 6 in.	
7	For each of the following products, please assign average percentages showing the extent of use in this district.				
	Carsonite CGD1(1)				
	Carsonite CGDU (2)	50			
	Carsonite HWD1 (3)				
	Carsonite HWDU (4)			100	
	Carsonite (Curve Flex) CFRM-400 (5)				
	Carsonite (Roadmarker) CRM-375 (6)	50			
	Safe-Hit 248-GP3 (7)	<1			
	Flexstake HD (8)				
	Davidson Plastics FG500 (9)				
	Carsonite Survivor (10)				
	Other:				

		District 2			
		Fallon I		Fallon II	
		flexible	metal	flexible	metal
8	When applicable, please assign a percentage showing the average extent of failure for each product in this district as well as its corresponding average service life.	%	Years	%	Years
	Carsonite CGD1(1)				
	Carsonite CGDU (2)	50	5		
	Carsonite HWD1 (3)				
	Carsonite HWDU (4)			30	1
	Carsonite (Curve Flex) CFRM-400 (5)				
	Carsonite (Roadmarker) CRM-375 (6)	50	5		
	Safe-Hit 248-GP3 (7)	50	5		
	Flexstake HD (8)				
	Davidson Plastics FG500 (9)				
	Carsonite Survivor (10)				
	Other:				

9	For each of the following products, if applicable, please assign average percentages corresponding to the various modes of failure shown.	Impact	Wind	Sheet Fail	UV Brittle	Other		Impact	Wind	Sheet Fail	UV Brittle	Other	
	Carsonite CGD1(1)												
	Carsonite CGDU (2)	50	50										
	Carsonite HWD1 (3)												
	Carsonite HWDU (4)							35	45	5	5	10	
	Carsonite (Curve Flex) CFRM-400 (5)												
	Carsonite (Roadmarker) CRM-375 (6)	30	20	20	30								
	Safe-Hit 248-GP3 (7)			50	30	20							
	Flexstake HD (8)												
	Davidson Plastics FG500 (9)												
	Carsonite Survivor (10)												
	Other:												

		District 2									
		Gardnerville					Wadsworth				
		flexible		metal			flexible		metal		
1	What is the break down percentage between flexible delineator posts and metal delineator posts?	42%		58%			75%		25%		
2	What is the current total number of flexible delineator posts in this district?	1385					---				
3	What is the average minimum and maximum life span for flexible delineator posts?	min		max			min		max		
		1.00 yrs		10.00 yrs			0.50 yrs		1.00 yrs		
4	What is the average minimum and maximum life span for metal delineator posts?	min		max			min		max		
		1.00 yrs		17.00 yrs			1.00 yrs		3.00 yrs		
5	During which season do most flexible delineator post failures occur?	Winter					Summer				
6a	Please assign an average percentage to each mode of failure for all flexible delineator posts within this district.	Impact	Wind	Sheet Fail	UV Brittle	Other	Impact	Wind	Sheet Fail	UV Brittle	Other (animals)
		75	30	60	60	0	35	25	15	15	10
6b	Please quantify the criteria that are currently used to identify and replace failed flexible delineator posts in this district.										
	Permanently out of plumb by:	1 to 4 in.					1 to 4in.				
	Cracks in body of:	2 to 4 in.					1 to 2 in.				
	Pulling out of ground by:	2 to 4 in.					2 to 4 in.				
	Excessive flapping out of plumb by:	4 to 10 in.					1 to 4 in.				
	% loss of sheeting adhesion by:	30 to 50 %					10 to 30%				
	Breaking off of body from top by:	any amount					2 to 4 in.				
7	For each of the following products, please assign average percentages showing the extent of use in this district.										
	Carsonite CGD1(1)										
	Carsonite CGDU (2)										
	Carsonite HWD1 (3)										
	Carsonite HWDU (4)										
	Carsonite (Curve Flex) CFRM-400 (5)										
	Carsonite (Roadmarker) CRM-375 (6)						100				
	Safe-Hit 248-GP3 (7)	80									
	Flexstake HD (8)	20									
	Davidson Plastics FG500 (9)										
	Carsonite Survivor (10)										
	Other:										

		District 2			
		Gardnerville		Wadsworth	
		flexible	metal	flexible	metal
8	When applicable, please assign a percentage showing the average extent of failure for each product in this district as well as its corresponding average service life.	%	Years	%	Years
	Carsonite CGD1(1)				
	Carsonite CGDU (2)				
	Carsonite HWD1 (3)				
	Carsonite HWDU (4)				
	Carsonite (Curve Flex) CFRM-400 (5)				
	Carsonite (Roadmarker) CRM-375 (6)			100	.5 to 1
	Safe-Hit 248-GP3 (7)	20	4		
	Flexstake HD (8)	20	3		
	Davidson Plastics FG500 (9)				
	Carsonite Survivor (10)				
	Other:				

9	For each of the following products, if applicable, please assign average percentages corresponding to the various modes of failure shown.	Impact	Wind	Sheet Fail	UV Brittle	Other		Impact	Wind	Sheet Fail	UV Brittle	Other	
	Carsonite CGD1(1)												
	Carsonite CGDU (2)												
	Carsonite HWD1 (3)												
	Carsonite HWDU (4)												
	Carsonite (Curve Flex) CFRM-400 (5)												
	Carsonite (Roadmarker) CRM-375 (6)							25	50	10	15	0	
	Safe-Hit 248-GP3 (7)	45	25	15	10	5							
	Flexstake HD (8)	80			20								
	Davidson Plastics FG500 (9)												
	Carsonite Survivor (10)												
	Other:												

		District 2									
		Smith Valley					Hawthorne				
		flexible		metal			flexible		metal		
1	What is the break down percentage between flexible delineator posts and metal delineator posts?	60%		40%			90%		10%		
2	What is the current total number of flexible delineator posts in this district?	1505					---				
3	What is the average minimum and maximum life span for flexible delineator posts?	min		max			min		max		
		0.00 yrs		2.00 yrs			2.00 yrs		15.00 yrs		
4	What is the average minimum and maximum life span for metal delineator posts?	min		max			min		max		
		0.00 yrs		7.00 yrs			10.00 yrs		30.00 yrs		
5	During which season do most flexible delineator post failures occur?	Spring/Summer					Winter				
6a	Please assign an average percentage to each mode of failure for all flexible delineator posts within this district.	Impact	Wind	Sheet Fail	UV Brittle	Other	Impact	Wind	Sheet Fail	UV Brittle	Other (animals)
		30	25	25	20	0	65	10	15	10	0
6b	Please quantify the criteria that are currently used to identify and replace failed flexible delineator posts in this district.										
	Permanently out of plumb by:	4 to 10 in.					1 to 4 in.				
	Cracks in body of:	2 to 4 in.					1 to 2 in.				
	Pulling out of ground by:	more than 4 in.					2 to 4 in.				
	Excessive flapping out of plumb by:	4 to 10 in.					4 to 10 in.				
	% loss of sheeting adhesion by:	10 to 30 %					30 to 50 %				
	Breaking off of body from top by:	any amount					any amount				
7	For each of the following products, please assign average percentages showing the extent of use in this district.										
	Carsonite CGD1(1)										
	Carsonite CGDU (2)						10				
	Carsonite HWD1 (3)	50									
	Carsonite HWDU (4)										
	Carsonite (Curve Flex) CFRM-400 (5)						5				
	Carsonite (Roadmarker) CRM-375 (6)						10				
	Safe-Hit 248-GP3 (7)						50				
	Flexstake HD (8)										
	Davidson Plastics FG500 (9)										
	Carsonite Survivor (10)	50					25				
	Other:										

		District 2			
		Smith Valley		Hawthorne	
		flexible	metal	flexible	metal
8	When applicable, please assign a percentage showing the average extent of failure for each product in this district as well as its corresponding average service life.	%	Years	%	Years
	Carsonite CGD1(1)				
	Carsonite CGDU (2)			70	5
	Carsonite HWD1 (3)	50	2		
	Carsonite HWDU (4)				
	Carsonite (Curve Flex) CFRM-400 (5)			60	5
	Carsonite (Roadmarker) CRM-375 (6)			60	5
	Safe-Hit 248-GP3 (7)			30	8
	Flexstake HD (8)				
	Davidson Plastics FG500 (9)				
	Carsonite Survivor (10)	50	1	50	8
	Other:				

9	For each of the following products, if applicable, please assign average percentages corresponding to the various modes of failure shown.	Impact	Wind	Sheet Fail	UV Brittle	Other		Impact	Wind	Sheet Fail	UV Brittle	Other	
	Carsonite CGD1(1)												
	Carsonite CGDU (2)							20	50	10	20		
	Carsonite HWD1 (3)	30	40		30								
	Carsonite HWDU (4)												
	Carsonite (Curve Flex) CFRM-400 (5)							20	40	20	20		
	Carsonite (Roadmarker) CRM-375 (6)							40	10	10	40		
	Safe-Hit 248-GP3 (7)							10	10	40	40		
	Flexstake HD (8)												
	Davidson Plastics FG500 (9)												
	Carsonite Survivor (10)	70	10	20				10	20	40	30		
	Other:												

		District 2					
		Reno					
		flexible				metal	
1	What is the break down percentage between flexible delineator posts and metal delineator posts?	95%				5%	
2	What is the current total number of flexible delineator posts in this district?	---					
3	What is the average minimum and maximum life span for flexible delineator posts?	min				max	
		1.00 yrs				3.00 yrs	
4	What is the average minimum and maximum life span for metal delineator posts?	min				max	
		3.00 yrs				4.00 yrs	
5	During which season do most flexible delineator post failures occur?	Winter					
6a	Please assign an average percentage to each mode of failure for all flexible delineator posts within this district.	Impact	Wind	Sheet Fail	UV Brittle	Other	
		80	5	5	10	0	
6b	Please quantify the criteria that are currently used to identify and replace failed flexible delineator posts in this district.						
	Permanently out of plumb by:	4 to 10 in.					
	Cracks in body of:	more than 4 in.					
	Pulling out of ground by:	2 to 4 in.					
	Excessive flapping out of plumb by:	4 to 10 in.					
	% loss of sheeting adhesion by:	10 to 30 %					
	Breaking off of body from top by:	2 to 4 in.					
7	For each of the following products, please assign average percentages showing the extent of use in this district.						
	Carsonite CGD1(1)						
	Carsonite CGDU (2)						
	Carsonite HWD1 (3)						
	Carsonite HWDU (4)						
	Carsonite (Curve Flex) CFRM-400 (5)						
	Carsonite (Roadmarker) CRM-375 (6)	100					
	Safe-Hit 248-GP3 (7)						
	Flexstake HD (8)						
	Davidson Plastics FG500 (9)						
	Carsonite Survivor (10)						
	Other:						

		District 2	
		Reno	
		flexible	metal
8	When applicable, please assign a percentage showing the average extent of failure for each product in this district as well as its corresponding average service life.	%	Years
	Carsonite CGD1(1)		
	Carsonite CGDU (2)		
	Carsonite HWD1 (3)		
	Carsonite HWDU (4)		
	Carsonite (Curve Flex) CFRM-400 (5)		
	Carsonite (Roadmarker) CRM-375 (6)	75	2
	Safe-Hit 248-GP3 (7)		
	Flexstake HD (8)		
	Davidson Plastics FG500 (9)		
	Carsonite Survivor (10)		
	Other:		

9	For each of the following products, if applicable, please assign average percentages corresponding to the various modes of failure shown.	Impact	Wind	Sheet Fail	UV Brittle	Other	
	Carsonite CGD1(1)						
	Carsonite CGDU (2)						
	Carsonite HWD1 (3)						
	Carsonite HWDU (4)						
	Carsonite (Curve Flex) CFRM-400 (5)						
	Carsonite (Roadmarker) CRM-375 (6)	80	5	5	10	0	
	Safe-Hit 248-GP3 (7)						
	Flexstake HD (8)						
	Davidson Plastics FG500 (9)						
	Carsonite Survivor (10)						
	Other:						

		District 3									
		Winnemucca					Elko				
		flexible		metal			flexible		metal		
1	What is the break down percentage between flexible delineator posts and metal delineator posts?	1%		99%			20%		80%		
2	What is the current total number of flexible delineator posts in this district?	---					---				
3	What is the average minimum and maximum life span for flexible delineator posts?	min		max			min		max		
		2.00 yrs		8.00 yrs			1.00 yrs		5.00 yrs		
4	What is the average minimum and maximum life span for metal delineator posts?	min		max			min		max		
		10.00 yrs		15.00 yrs			3.00 yrs		10.00 yrs		
5	During which season do most flexible delineator post failures occur?	winter, spring, fall					Winter				
6a	Please assign an average percentage to each mode of failure for all flexible delineator posts within this district.	Impact	Wind	Sheet Fail	UV Brittle	Other	Impact	Wind	Sheet Fail	UV Brittle	Other (animals)
		20	25	25	25	5	20	50	20	10	0
6b	Please quantify the criteria that are currently used to identify and replace failed flexible delineator posts in this district.										
	Permanently out of plumb by:	4 to 10 in.					1 to 4 in.				
	Cracks in body of:	any length					2 to 4 in.				
	Pulling out of ground by:	more than 4 in.					any amount				
	Excessive flapping out of plumb by:	4 to 10 in.					1 to 4 in.				
	% loss of sheeting adhesion by:	10 to 30 %					30 to 50%				
	Breaking off of body from top by:	any amount					any amount				
7	For each of the following products, please assign average percentages showing the extent of use in this district.										
	Carsonite CGD1(1)										
	Carsonite CGDU (2)						5				
	Carsonite HWD1 (3)										
	Carsonite HWDU (4)										
	Carsonite (Curve Flex) CFRM-400 (5)										
	Carsonite (Roadmarker) CRM-375 (6)	100									
	Safe-Hit 248-GP3 (7)						90				
	Flexstake HD (8)										
	Davidson Plastics FG500 (9)						5				
	Carsonite Survivor (10)										
	Other:										

		District 3			
		Winnemucca		Elko	
		flexible	metal	flexible	metal
8	When applicable, please assign a percentage showing the average extent of failure for each product in this district as well as its corresponding average service life.	% / Years		% / Years	
	Carsonite CGD1(1)				
	Carsonite CGDU (2)			75	3
	Carsonite HWD1 (3)				
	Carsonite HWDU (4)				
	Carsonite (Curve Flex) CFRM-400 (5)				
	Carsonite (Roadmarker) CRM-375 (6)	50	2		
	Safe-Hit 248-GP3 (7)			50	3
	Flexstake HD (8)				
	Davidson Plastics FG500 (9)			100	1
	Carsonite Survivor (10)				
	Other:				

9	For each of the following products, if applicable, please assign average percentages corresponding to the various modes of failure shown.	Impact	Wind	Sheet Fail	UV Brittle	Other		Impact	Wind	Sheet Fail	UV Brittle	Other	
	Carsonite CGD1(1)												
	Carsonite CGDU (2)							25			75		
	Carsonite HWD1 (3)												
	Carsonite HWDU (4)												
	Carsonite (Curve Flex) CFRM-400 (5)												
	Carsonite (Roadmarker) CRM-375 (6)	20	25	25	25	5							
	Safe-Hit 248-GP3 (7)							75		25			
	Flexstake HD (8)												
	Davidson Plastics FG500 (9)							5	95				
	Carsonite Survivor (10)												
	Other:												

NTPEP List Raw Data for Flexible Delineator Posts (%)

Products	First Season Testing					Second Season Testing				
	1	2	3	4	5	6	7	8	9	10
Carsonite	2.2	5.6	10.0	17.8	17.8	1.1	3.3	4.4	8.9	7.8
CGDU	2.2	5.6	7.8	12.2	8.9	1.1	2.2	3.3	0.0	2.2
	1.1	4.4	4.4	7.8	4.4	2.2	3.3	3.3	3.3	4.4
	0.0	2.2	4.4	10.0	5.6	1.1	1.1	0.0	1.1	0.0
	0.0	3.3	1.1	1.1	1.1	0.0	2.2	3.3	1.1	3.3
	0.0	2.2	1.1	1.1	1.1	0.0	0.0	1.1	2.2	1.1
	2.2	2.2	1.1	1.1	1.1	1.1	1.1	2.2	3.3	2.2
	1.1	2.2	2.2	2.2	1.1	1.1	1.1	0.0	1.1	2.2
Carsonite	1.1	0.0	0.0	1.1	1.1	1.1	0.0	1.1	1.1	1.1
CGDU	0.0	0.0	0.0	0.0	1.1	1.1	1.1	1.1	3.3	3.3
	0.0	1.1	1.1	3.3	3.3	1.1	2.2	3.3	7.8	7.8
Aug 95/Feb 96	3.3	5.6	4.4	7.8	3.3	1.1	2.2	2.2	2.2	2.2
	2.2	2.2	2.2	1.1	2.2	1.1	1.1	1.1	1.1	1.1
	1.1	2.2	0.0	1.1	1.1	6.7	1.1	2.2	2.2	3.3
	2.2	1.1	1.1	0.0	1.1	1.1	2.2	2.2	2.2	3.3
	1.1	0.0	0.0	0.0	0.0	1.1	1.1	1.1	1.1	1.1
Carsonite	0.0	1.1	1.1	2.2	0.0	100.0	100.0	100.0	100.0	100.0
HWDU	2.2	1.1	7.8	1.1	10.0	3.3	1.1	100.0	100.0	100.0
	2.2	3.3	8.9	3.3	6.7	1.1	3.3	3.3	3.3	2.2
Aug 95/Feb 96	1.1	1.1	1.1	2.2	3.3	2.2	100.0	100.0	100.0	100.0
	4.4	7.8	8.9	6.7	10.0	2.2	2.2	4.4	4.4	4.4
	4.4	6.7	6.7	4.4	7.8	2.2	4.4	3.3	3.3	4.4
	5.6	7.8	6.7	6.7	7.8	2.2	2.2	3.3	3.3	3.3
	2.2	4.4	5.6	4.4	7.8	1.1	3.3	3.3	3.3	4.4
Carsonite	2.2	2.2	2.2	2.2	4.4	0.0	1.1	1.1	0.0	1.1
"Curve-flex"	5.6	7.8	5.6	7.8	8.9	1.1	0.0	0.0	0.0	0.0
CFRM 400	3.3	3.3	4.4	4.4	5.6	0.0	1.1	1.1	1.1	1.1
	4.4	4.4	6.7	6.7	8.9	2.2	1.1	1.1	1.1	1.1
Aug 95/Feb 96	0.0	1.1	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0
	2.2	3.3	4.4	3.3	3.3	0.0	0.0	1.1	0.0	0.0
	1.1	1.1	0.0	1.1	2.2	1.1	1.1	1.1	0.0	0.0
	3.3	4.4	4.4	4.4	4.4	0.0	1.1	1.1	0.0	0.0
Carsonite	3.3	4.4	4.4	5.6	5.6	100.0	100.0	100.0	100.0	100.0
"Roadmarker"	4.4	4.4	3.3	5.6	5.6	2.2	2.2	2.2	2.2	3.3
CRM 375	4.4	5.6	6.7	8.9	11.1	3.3	5.6	5.6	6.7	7.8
	2.2	4.4	4.4	5.6	44.4	100.0	100.0	100.0	100.0	100.0
Feb 94 / June 94	6.7	6.7	7.8	6.7	100.0	100.0	100.0	100.0	100.0	100.0
	3.3	5.6	5.6	5.6	6.7	2.2	3.3	3.3	3.3	4.4
	6.7	7.8	7.8	8.9	8.9	1.1	1.1	1.1	0.0	3.3
	4.4	4.4	5.6	4.4	100.0	100.0	100.0	100.0	100.0	100.0
Safe-Hit	6.7	6.7	5.6	5.6	5.6	12.2	13.3	13.3	12.2	15.6
248 GP3	4.4	5.6	4.4	4.4	4.4	8.9	8.9	7.8	100.0	7.8
	5.6	5.6	4.4	5.6	6.7	7.8	8.9	8.9	6.7	6.7
Feb 95 / Aug 95	5.6	5.6	3.3	4.4	6.7	10.0	10.0	11.1	11.1	13.3
	5.6	5.6	5.6	5.5	5.6	1.1	2.2	2.2	2.2	2.2
	3.3	3.3	4.4	4.4	3.3	12.2	12.2	14.4	14.4	13.3
	3.3	3.3	3.3	2.2	3.3	2.2	2.2	2.2	2.2	3.3
	6.7	5.6	5.6	5.6	6.7	6.7	8.9	8.9	7.8	8.9
Safe-Hit	0.0	2.2	2.2	0.0	3.3	0.0	2.2	2.2	0.0	3.3
248 GP3	0.0	2.2	2.2	2.2	2.2	0.0	2.2	2.2	2.2	2.2
	1.1	3.3	4.4	2.2	4.4	1.1	3.3	4.4	2.2	4.4
Aug 95/Feb 96	0.0	1.1	1.1	1.1	0.0	0.0	1.1	1.1	1.1	0.0
	0.0	0.0	1.1	1.1	0.0	0.0	0.0	1.1	1.1	0.0
	1.1	5.6	4.4	4.4	4.4	1.1	5.6	4.4	4.4	4.4
	6.7	6.7	6.7	7.8	7.8	6.7	6.7	6.7	7.8	7.8
	2.2	3.3	3.3	3.3	3.3	2.2	2.2	3.3	3.3	3.3
Davidson Plastics	2.2	2.2	2.2	4.4	3.3	1.1	1.1	1.1	0.0	2.2
Flexiguide 500	1.1	1.1	2.2	2.2	2.2	1.1	0.0	2.2	2.2	2.2
	1.1	1.1	1.1	0.0	1.1	1.1	2.2	2.2	2.2	2.2
Feb 96/July 96	2.2	2.2	2.2	3.3	100.0	100.0	100.0	100.0	100.0	100.0
	8.9	10.0	8.9	8.9	8.9	1.1	2.2	3.3	3.3	3.3
	3.3	2.2	3.3	3.3	3.3	0.0	1.1	1.1	2.2	3.3
	1.1	1.1	1.1	1.1	1.1	0.0	2.2	3.3	3.3	3.3
	0.0	0.0	0.0	1.1	2.2	1.1	2.2	2.2	2.2	2.2

NTPEP Breaking-Off-from-Top Raw Data for Flexible Delineator Posts (in.)

Products	First Season Testing					Second Season Testing				
	1	2	3	4	5	6	7	8	9	10
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CGDU	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**	**1.0**	**1.0**	**1.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CGDU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	0.0	0.0	0.0	0.0	0.0	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**
HWDU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	**24.0**	**24.0**	**24.0**	**24.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	**8.0**	**8.0**	**8.0**	**8.0**
"Curve-flex"	0.0	0.0	0.0	0.0	0.0	0.0	**6.0**	**6.0**	**6.0**	**6.0**
CFRM 400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
"Roadmarker"	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**12.0**	**12.0**
CRM 375	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**12.0**	**12.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb 94 / June 94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	**4.0**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**	**8.0**	**8.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Safe-Hit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
248 GP3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb 95 / Aug 95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Safe-Hit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
248 GP3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Davidson Plastics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flexiguide 500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb 96/July 96	0.0	0.0	0.0	0.0	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NTPEP Splitting Raw Data for Flexible Delineator Posts (in)

Products	First Season Testing					Second Season Testing				
	1	2	3	4	5	6	7	8	9	10
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CGDU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CGDU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	0.0	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
HWDU	0.0	0.0	**1.0**	**1.0**	**1.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
	0.0	0.0	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	0.0	0.0	0.0	0.0	0.0	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**
"Curve-flex"	0.0	0.0	0.0	0.0	0.0	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**
CFRM 400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	**7.0**	**7.0**	**14.0**	**14.0**	**14.0**
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
"Roadmarker"	0.0	0.0	0.0	0.0	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
CRM 375	0.0	0.0	0.0	0.0	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb 94 / June 94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
	0.0	0.0	0.0	0.0	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Safe-Hit	0.0	**2.0**	**2.0**	**2.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
248 GP3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb 95 / Aug 95	0.0	0.0	0.0	**2.0**	**2.0**	**2.0**	**2.0**	**3.0**	**3.0**	**3.0**
	0.0	0.0	0.0	**1.0**	**2.0**	**2.0**	**2.0**	**3.0**	**3.0**	**3.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.0	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
	0.0	0.0	0.0	0.0	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Safe-Hit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
248 GP3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**3.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**8.0**	**8.0**
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	**2.0**	**2.0**	**4.0**	**4.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Davidson Plastics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flexiguide 500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb 96/July 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NTPEP Sheet Loss Raw Data for Flexible Delineator Posts (%)

Products	First Season Testing					Second Season Testing				
	1	2	3	4	5	6	7	8	9	10
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CGDU	0.0	0.0	0.0	0.0	0.0	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
	0.0	0.0	0.0	0.0	0.0	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
	0.0	0.0	0.0	0.0	**2.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
	0.0	0.0	**1.0**	**1.0**	**3.0**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**
	0.0	0.0	**2.0**	**2.0**	**3.0**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**
	0.0	**1.0**	**4.0**	**4.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**
	0.0	**4.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**
Carsonite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CGDU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.0	**4.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**10.0**	**10.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.0	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
Carsonite	0.0	**5.0**	**20.0**	**25.0**	**25.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
HWDU	0.0	0.0	0.0	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**15.0**	**20.0**
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4.0	**4.0**	**10.0**	**12.0**	**12.0**	**12.0**	**12.0**	**20.0**	**20.0**	**20.0**
	4.0	**4.0**	**10.0**	**18.0**	**18.0**	**18.0**	**18.0**	**25.0**	**25.0**	**35.0**
	4.0	**4.0**	**10.0**	**12.0**	**12.0**	**12.0**	**12.0**	**20.0**	**20.0**	**25.0**
	4.0	**4.0**	**10.0**	**12.0**	**12.0**	**12.0**	**12.0**	**20.0**	**20.0**	**20.0**
Carsonite	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**45.0**	**70.0**	**70.0**	**70.0**
"Curve-flex"	0.0	0.0	0.0	0.0	0.0	0.0	**50.0**	**50.0**	**50.0**	**50.0**
CFRM 400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 95/Feb 96	0.0	0.0	0.0	0.0	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carsonite	**1.0**	**1.0**	**1.0**	**10.0**	**10.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
"Roadmarker"	**1.0**	**1.0**	**1.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
CRM 375	**1.0**	**1.0**	**2.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
	1.0	**1.0**	**1.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
Feb 94 / June 94	**1.0**	**1.0**	**1.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
	1.0	**1.0**	**1.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
	1.0	**1.0**	**1.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
	1.0	**1.0**	**1.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
Safe-Hit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
248 GP3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb 95 / Aug 95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20.0	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**45.0**	**45.0**	**45.0**
	0.0	0.0	**6.0**	**6.0**	**8.0**	**8.0**	**8.0**	**10.0**	**10.0**	**10.0**
	0.0	**5.0**	**6.0**	**8.0**	**10.0**	**10.0**	**10.0**	**12.0**	**12.0**	**12.0**
	0.0	**7.0**	**7.0**	**8.0**	**10.0**	**10.0**	**10.0**	**12.0**	**12.0**	**12.0**
Safe-Hit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
248 GP3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 95/Feb 96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	**8.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**
Davidson Plastics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flexiguide 500	0.0	0.0	0.0	0.0	0.0	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**
	0.0	**15.0**	**15.0**	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**
Feb 96/July 96	0.0	**20.0**	**30.0**	**30.0**	**30.0**	**30.0**	**30.0**	**30.0**	**30.0**	**30.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5.0	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**

Appendix B

Worksheets and Calculations

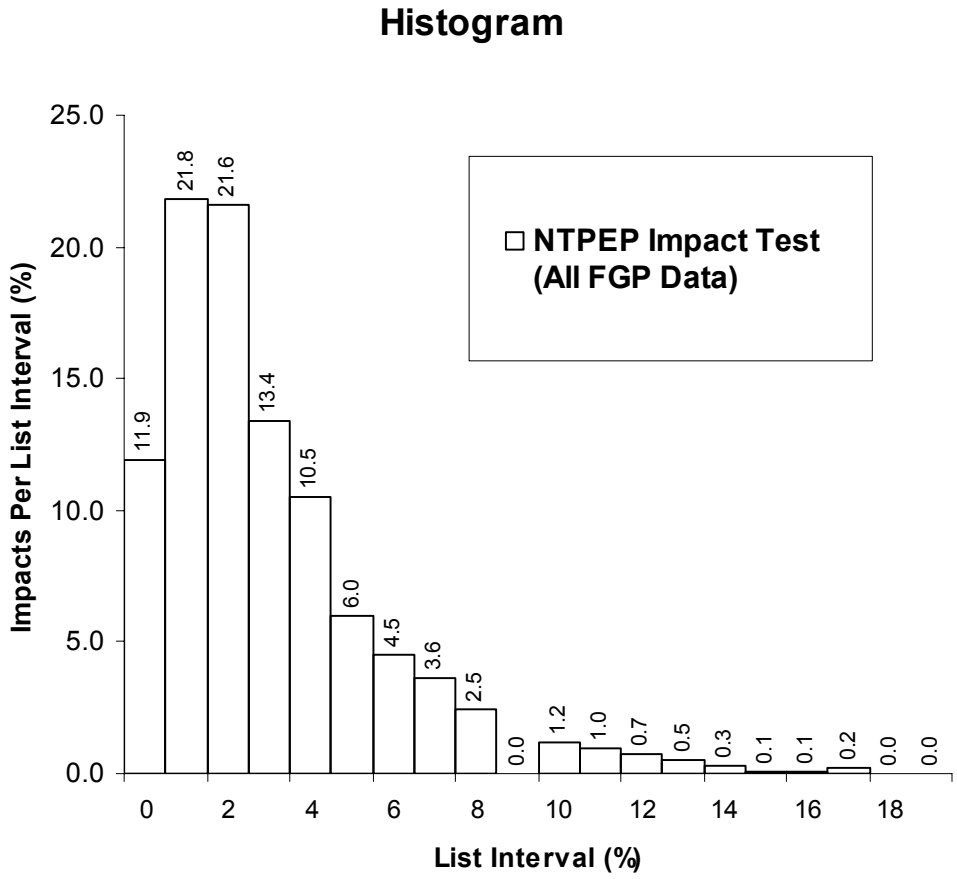
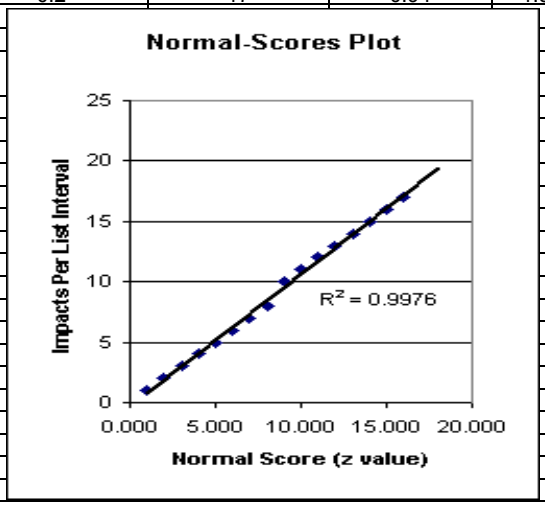


Figure B1 - Histogram Showing Percent of Total Impacts for Every One Degree List Interval

Table B1 - NTPEP Impact Data Normalized

Histogram For Lists Less Than **20 %**						Normal-Scores				Normalized Mass Probability for Each % List
% List Interval		% Impacts / Interval	% List Interval		% Impacts / Interval	% Impacts / Interval Sorted	% List Interval (Lower Bound)	Confidence Level	z Values	
0	to 0.9	11.9	50	to 50.9	0.0	11.9	0	0.06	-1.593	7.31
1	to 1.9	21.8	51	to 51.9	0.0	21.8	1	0.11	-1.221	10.11
2	to 2.9	21.6	52	to 52.9	0.0	21.6	2	0.17	-0.967	12.43
3	to 3.9	13.4	53	to 53.9	0.0	13.4	3	0.22	-0.765	13.60
4	to 4.9	10.5	54	to 54.9	0.0	10.5	4	0.28	-0.589	13.23
5	to 5.9	6.0	55	to 55.9	0.0	6.0	5	0.33	-0.431	11.45
6	to 6.9	4.5	56	to 56.9	0.0	4.5	6	0.39	-0.282	8.81
7	to 7.9	3.6	57	to 57.9	0.0	3.6	7	0.44	-0.140	6.03
8	to 8.9	2.5	58	to 58.9	0.0	2.5	8	0.50	0.000	3.67
9	to 9.9	0.0	59	to 59.9	0.0	1.2	10	0.56	0.140	1.99
10	to	1.2	60	to 60.9	0.0	1.0	11	0.61	0.282	0.96
11	to	1.0	61	to 61.9	0.0	0.7	12	0.67	0.431	0.41
12	to	0.7	62	to 62.9	0.0	0.5	13	0.72	0.589	0.16
13	to	0.5	63	to 63.9	0.0	0.3	14	0.78	0.765	0.05
14	to	0.3	64	to 64.9	0.0	0.1	15	0.83	0.967	0.02
15	to	0.1	65	to 65.9	0.0	0.1	16	0.89	1.221	0.00
16	to	0.1	66	to 66.9	0.0	0.2	17	0.94	1.593	0.00
17	to	0.2	67	to 67.9	0.0					0.00
18	to	0.0	68	to 68.9	0.0					0.00
19	to	0.0	69	to 69.9	0.0					0.00
20	to	0.0	70	to 70.9	0.0					0.00
21	to	0.0	71	to 71.9	0.0					0.00
22	to	0.0	72	to 72.9	0.0					0.00
23	to	0.0	73	to 73.9	0.0					0.00
24	to	0.0	74	to 74.9	0.0					0.00
25	to	0.0	75	to 75.9	0.0					0.00
26	to	0.0	76	to 76.9	0.0					0.00
27	to	0.0	77	to 77.9	0.0					0.00
28	to	0.0	78	to 78.9	0.0					0.00
29	to	0.0	79	to 79.9	0.0					0.00
30	to	0.0	80	to 80.9	0.0					0.00
31	to	0.0	81	to 81.9	0.0					0.00
32	to	0.0	82	to 82.9	0.0					0.00
33	to	0.0	83	to 83.9	0.0					0.00
34	to	0.0	84	to 84.9	0.0					0.00
35	to	0.0	85	to 85.9	0.0					0.00
36	to	0.0	86	to 86.9	0.0					0.00
37	to	0.0	87	to 87.9	0.0					0.00
38	to	0.0	88	to 88.9	0.0					0.00
39	to	0.0	89	to 89.9	0.0					0.00
40	to	0.0	90	to 90.9	0.0					0.00
41	to	0.0	91	to 91.9	0.0					0.00
42	to	0.0	92	to 92.9	0.0					0.00
43	to	0.0	93	to 93.9	0.0					0.00
44	to	0.0	94	to 94.9	0.0					0.00
45	to	0.0	95	to 95.9	0.0					0.00
46	to	0.0	96	to 96.9	0.0					0.00
47	to	0.0	97	to 97.9	0.0					0.00
48	to	0.0	98	to 98.9	0.0					0.00
49	to	0.0	99	to 99.9	0.0					0.00
			100	to 100.9	0.0					



Data appears to have a normal distribution when eliminating outliers that have greater than a 20 % list.

Tot.	934
Average	3.3 %
Std Dev.	2.9 %

Table B2 - NTPEP Impact Data Statistical Analysis

Confidence Interval

$CI = z_{\alpha/2}(\sigma/n^{1/2})$
n = no. of samples
α = (100 - CL)/100
$z_{\alpha/2}$ = two-tail z distribution
σ = standard deviation

2-tail confidence level:	95 %	
Confidence interval with 934 impacts:	0.2 %	Max list: 3.5 %
Confidence interval with 80 impacts:	0.6 %	Max list: 3.9 %
Confidence interval with 40 impacts:	0.9 %	Max list: 4.2 %
Confidence interval with 10 impacts:	1.8 %	Max list: 5.1 %
Confidence interval with 5 impacts:	2.6 %	Max list: 5.8 %

Tolerance Interval

$TI = K\sigma$
K = one-sided tolerance limit factor
σ = standard deviation

Proportion of population:	90 %	
1-tail confidence level:	95 %	
Tolerance limit with 934 impacts:	4.0	Max list: 7.2 %
Tolerance limit with 80 impacts:	4.5	Max list: 7.8 %
Tolerance limit with 40 impacts:	4.9	Max list: 8.2 %
Tolerance limit with 10 impacts:	6.8	Max list: 10.0 %
Tolerance limit with 5 impacts:	9.9	Max list: 13.1 %

Summary
Population = 934 samples
Data Average = 3.3 %
Data Standard Deviation = 2.9 %

Using a two-tailed 95 % confidence Level:
The Confidence Interval is 0.2 % with 934 impacts and the maximum average list is 3.5 %
The Confidence Interval is 0.6 % with 80 impacts and the maximum average list is 3.9 %
The Confidence Interval is 0.9 % with 40 impacts and the maximum average list is 4.2 %
The Confidence Interval is 1.8 % with 10 impacts and the maximum average list is 5.1 %
The Confidence Interval is 2.6 % with 5 impacts and the maximum average list is 5.8 %

Using a one-tailed, 95 % Confidence Level for 90 % of the population:
The tolerance limit is 4 % with 934 impacts and the maximum list is 7.2 %
The tolerance limit is 4.5 % with 80 impacts and the maximum list is 7.8 %
The tolerance limit is 4.9 % with 40 impacts and the maximum list is 8.2 %
The tolerance limit is 6.8 % with 10 impacts and the maximum list is 10 %
The tolerance limit is 9.9 % with 5 impacts and the maximum list is 13.1 %

Table B3 - Changes in Strength and Energy Due to Weathering

Product	-Raw Data- Ave Strength, P (lbs)			-Raw Data- Ave Elongation, δ (in)			Rank Absolute Elongation
	Control	Weather	Δ (%) (2)	Control	Weather	|Δ| (%) (3)	
Carsonite CGDU/CGD1	537.5	550.0	2.33	1.339	1.279	4.48	5
Carsonite HWDU/HWD1	494.0	503.0	1.82	1.700	1.561	8.21	4
Carsonite CFRM 400	4307.0	4124.0	-4.25	0.360	0.392	8.89	3
Carsonite CRM 375	938.0	912.0	-2.77	0.434	0.417	3.92	6
Safe-Hit 248 GP3	575.0	578.0	0.52	1.445	1.887	30.59	1
Davidson Plastics FG 500	592.0	592.0	0.00	1.914	1.547	19.17	2

Product	-Raw Data- X-Section Areas (in^2)		Ave Tensile Stress, σ (psi) (1)				Ave Stress Rank	Δ Stress Rank
	Control	**Weather**	**Control**	**Weather**	**Δ (%) (2)**	**Average**		
Carsonite CGDU/CGD1	0.0685	0.0700	7852.4	7862.8	0.13	7857.6	3	3
Carsonite HWDU/HWD1	0.0650	0.0647	7600.0	7780.4	2.37	7690.2	5	1
Carsonite CFRM 400	0.0515	0.0550	83631.1	74981.8	-10.34	79306.4	1	6
Carsonite CRM 375	0.0610	0.0644	15377.0	14161.5	-7.91	14769.3	2	5
Safe-Hit 248 GP3	0.0735	0.0745	7823.1	7758.4	-0.83	7790.8	4	4
Davidson Plastics FG 500	0.0811	0.0803	7299.6	7372.4	1.00	7336.0	6	2

Product	Volume Energy to Yield Point, E_V (lbs/in) (4)					Δ Vol Energy Rank	Δ Absol. Vol Energy Rank
	Control	**Weather**	**Δ (%) (2)**	**|Δ| (%) (3)**	**Average**		
Carsonite CGDU/CGD1	10514.4	10056.5	-4.36	4.36 %	10285.4	4	5
Carsonite HWDU/HWD1	12920.0	12141.2	-6.03	6.03 %	12530.6	3	4
Carsonite CFRM 400	30107.2	29392.9	-2.37	2.37 %	29750.0	5	6
Carsonite CRM 375	6673.6	5905.3	-11.51	11.51 %	6289.5	2	3
Safe-Hit 248 GP3	11304.4	14640.1	29.51	29.51 %	12972.3	6	1
Davidson Plastics FG 500	13971.5	11405.0	-18.37	18.37 %	12688.3	1	2

Product	Energy to Yield Point, E_S (lb-in) (4)			Δ Energy Rank
	Control	**Weather**	**Δ (%) (2)**	
Carsonite CGDU/CGD1	359.9	351.8	-2.26	3
Carsonite HWDU/HWD1	419.9	392.5	-6.53	4
Carsonite CFRM 400	775.3	808.3	4.26	2
Carsonite CRM 375	203.6	190.2	-6.58	5
Safe-Hit 248 GP3	415.5	545.4	31.27	1
Davidson Plastics FG 500	566.6	457.9	-19.17	6

(1) (2) (3) (4) See calculation definitions, Appendix B

Table B4 - Theoretical Wind Effects on FDP's

Theoretical Bluff Shapes	Wind Velocity, V (mph)	Reynold's No., R_e	Shape Drag Coef., C_D	Dynamic Wind Head, q **(psf)** (8)	Width, D (in)	Distributed Load, ω **(plf)** (9)	Moment at Base, M (lb-ft) (10)
Round, R	20	4.67E+04	1.17	1.01	3	0.29	2.36
	50	1.17E+05	1.17	6.29	3	1.84	14.72
Half -circle (wind to front), HC_f	20	4.67E+04	1.20	1.01	3	0.30	2.42
	50	1.17E+05	1.20	6.29	3	1.89	15.10
Half -circle (wind to back), HC_b	20	4.67E+04	2.30	1.01	3	0.58	4.63
	50	1.17E+05	2.30	6.29	3	3.62	28.94
Flat, F	20	4.67E+04	1.98	1.01	3	0.50	3.99
	50	1.17E+05	1.98	6.29	3	3.11	24.92

Product	Moment of Inertia, I (in^4)	Centroid From Front, $\bar{y}$ (in)	Ave Nominal Strain, ε (in/in) (5)	Young's Modulus, E (psi) (7)			Stiffness, EI_{xx} ($lb\text{-}in^2$)	Stiffness Ranking
				Control	**Weather**	**Average**		
Carsonite CGDU/CGD1	0.01247	0.23430	0.655	11997.6	12013.4	12005.5	149.7	6
Carsonite HWDU/HWD1	0.01714	0.25550	0.815	9323.7	9545.0	9434.4	161.7	5
Carsonite CFRM 400	0.00844	0.21470	0.188	444846.1	398839.5	421842.8	3560.8	2
Carsonite CRM 375	0.00409	0.38900	0.213	72277.6	66564.0	69420.8	284.1	3
Safe-Hit 248 GP3	0.47266	1.12500	0.833	9391.5	9313.8	9352.7	4420.6	1
Davidson Plastics FG 500	0.02250	0.28630	0.865	8436.4	8520.5	8478.5	190.8	4

Product	Shape (Worse Case)	Shape Drag Coef., C_D	Wind Velocity, V (mph)	Dynamic Wind Head, q **(psf)** (6)	Width, D (in)	Distributed Load, ω **(plf)** (9)
Carsonite CGDU/CGD1	HC_b to F	2.20	20	1.01	3.75	0.69
Carsonite HWDU/HWD1	HC_b to F	2.20	20	1.01	3.70	0.68
Carsonite CFRM 400	HC_b to F	2.20	20	1.01	4.00	0.74
Carsonite CRM 375	F	1.98	20	1.01	3.75	0.62
Safe-Hit 248 GP3	R	1.17	20	1.01	3.00	0.29
Davidson Plastics FG 500	HC_b to F	2.20	20	1.01	3.75	0.69

Product	Moment at Base, M (lb-ft) (10)	Bending Stress, σ (psi) (11)	$\sigma_{given}/\sigma_{allow}$ Control	$\sigma_{given}/\sigma_{allow}$ Weather	$\sigma_{given}/\sigma_{allow}$ Ranking	$\Delta\ \sigma_{given}/\sigma_{allow}$ Ranking (2)
Carsonite CGDU/CGD1	5.54	104.0	0.0132	0.0132	5	4
Carsonite HWDU/HWD1	5.46	81.4	0.0107	0.0105	4	6
Carsonite CFRM 400	5.91	150.2	0.0018	0.0020	2	1
Carsonite CRM 375	4.98	473.6	0.0308	0.0334	6	2
Safe-Hit 248 GP3	2.36	5.6	0.0007	0.0007	1	3
Davidson Plastics FG 500	5.54	70.5	0.0097	0.0096	3	5

(2) (6) (7) (8) (9) (10) (11) See calculation definitions, Appendix B

Table B5 - Comparison between NTPEP Absolute Elongation Ranking and Field Rankings

Rank Absolute Elongation	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking	Sheeting/UV Field Ranking	Wind/UV Field Ranking
5	Carsonite CGDU	3	3	3	5	5	3
4	Carsonite HWDU	5	4	4	4	3	4
3	Carsonite CFRM 400	1	2	5	3	4	2
6	Carsonite CRM 375	6	5	6	6	6	5
1	Safe-Hit 248 GP3	2	1	2	2	2	1
2	Dav. Plast. FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation Ranking and Field Rankings, $\sum D^2$		14	22	10	2	4	10

Table B6 - Comparison between NTPEP Average Allowable Stress Ranking and Field Rankings

Ave Stress Rank	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking	Sheeting/Uv Field Ranking	Wind/UV Field Ranking
3	Carsonite CGDU	3	3	3	5	5	3
5	Carsonite HWDU	5	4	4	4	3	4
1	Carsonite CFRM 400	1	2	5	3	4	2
2	Carsonite CRM 375	6	5	6	6	6	5
4	Safe-Hit 248 GP3	2	1	2	2	2	1
6	Dav. Plast. FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation Ranking and Field Rankings, $\sum D^2$		24	20	62	54	62	20

Table B7 - Comparison between NTPEP Change in Allowable Stress Ranking and Field Rankings

Δ Stress Rank	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking	Sheeting/Uv Field Ranking	Wind/UV Field Ranking
3	Carsonite CGDU	3	3	3	5	5	3
1	Carsonite HWDU	5	4	4	4	3	4
6	Carsonite CFRM 400	1	2	5	3	4	2
5	Carsonite CRM 375	6	5	6	6	6	5
4	Safe-Hit 248 GP3	2	1	2	2	2	1
2	Dav. Plast. FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation Ranking and Field Rankings, $\sum D^2$		50	50	16	28	18	59

Table B8 - Comparison between NTPEP Change in Volume Energy Ranking and Field Rankings

Δ Volume Energy Rank	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking	Sheeting/Uv Field Ranking	Wind/UV Field Ranking
4	Carsonite CGDU	3	3	3	5	5	3
3	Carsonite HWDU	5	4	4	4	3	4
5	Carsonite CFRM 400	1	2	5	3	4	2
2	Carsonite CRM 375	6	5	6	6	6	5
6	Safe-Hit 248 GP3	2	1	2	2	2	1
1	Dav. Plast. FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation Ranking and Field Rankings, $\sum D^2$		62	61	34	38	34	70

Table B9 - Comparison between NTPEP Change in Strain Energy Ranking and Field Rankings

Δ Strain Energy Rank	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking	Sheeting/Uv Field Ranking	Wind/UV Field Ranking
3	Carsonite CGDU	3	3	3	5	5	3
4	Carsonite HWDU	5	4	4	4	3	4
2	Carsonite CFRM 400	1	2	5	3	4	2
5	Carsonite CRM 375	6	5	6	6	6	5
1	Safe-Hit 248 GP3	2	1	2	2	2	1
6	Dav. Plast. FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation Ranking and Field Rankings, $\sum D^2$		8	0	36	32	36	0

Table B10 - Comparison between NTPEP Change in Stiffness Ranking and Field Rankings

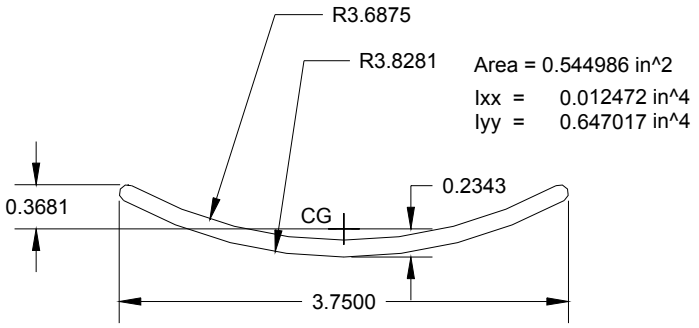
Stiffness Ranking	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking	Sheeting/Uv Field Ranking	Wind/UV Field Ranking
6	Carsonite CGDU	3	3	3	5	5	3
5	Carsonite HWDU	5	4	4	4	3	4
2	Carsonite CFRM 400	1	2	5	3	4	2
3	Carsonite CRM 375	6	5	6	6	6	5
1	Safe-Hit 248 GP3	2	1	2	2	2	1
4	Dav. Plast. FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation Ranking and Field Rankings, $\sum D^2$		20	18	38	22	28	18

Table B11 - Comparison between NTPEP Applied Stress by Wind / Allowable Stress Ranking and Field Rankings

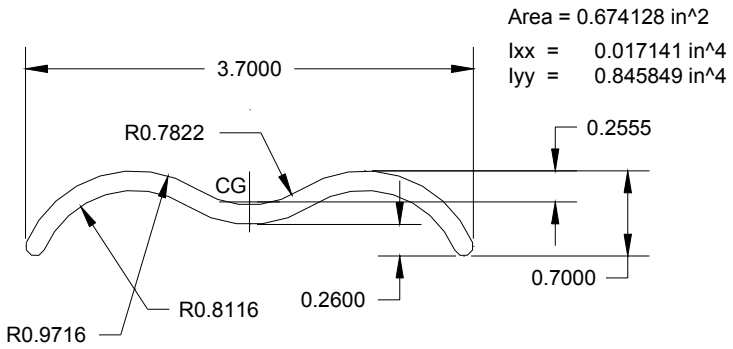
$\sigma_{given}/\sigma_{allow}$ **Ranking**	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking	Sheeting/Uv Field Ranking	Wind/UV Field Ranking
5	Carsonite CGDU	3	3	3	5	5	3
4	Carsonite HWDU	5	4	4	4	3	4
2	Carsonite CFRM 400	1	2	5	3	4	2
6	Carsonite CRM 375	6	5	6	6	6	5
1	Safe-Hit 248 GP3	2	1	2	2	2	1
3	Dav. Plast. FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation Ranking and Field Rankings, $\sum D^2$		8	14	18	6	10	14

Table B12 - Comparison between NTPEP Change in Strain Energy Ranking and Field Rankings

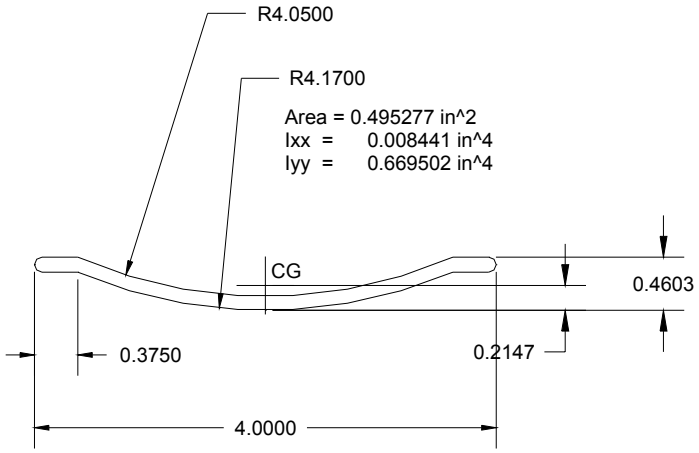
$\Delta\ \sigma_{given}/\sigma_{allow}$ **Ranking**	Product Name	Field Impact Ranking	Field Wind Load Ranking	Field Sheet Failure Ranking	Field UV Brittleness Ranking	Sheeting/Uv Field Ranking	Wind/UV Field Ranking
4	Carsonite CGDU	3	3	3	5	5	3
6	Carsonite HWDU	5	4	4	4	3	4
1	Carsonite CFRM 400	1	2	5	3	4	2
2	Carsonite CRM 375	6	5	6	6	6	5
3	Safe-Hit 248 GP3	2	1	2	2	2	1
5	Dav. Plast. FG 500	4	6	1	1	1	6
Measure of Similarity Between NTPEP Absolute Elongation Ranking and Field Rankings, $\sum D^2$		8	20	54	42	52	20



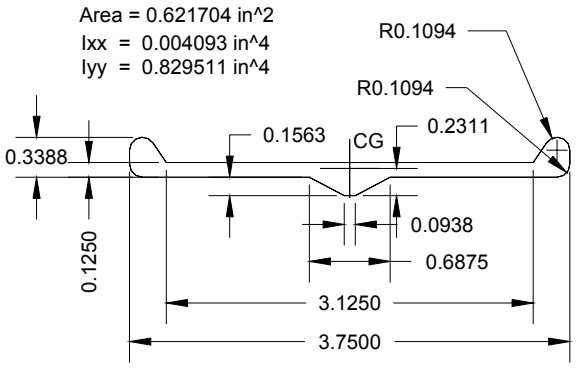
Carsonite CGDU, CGD1



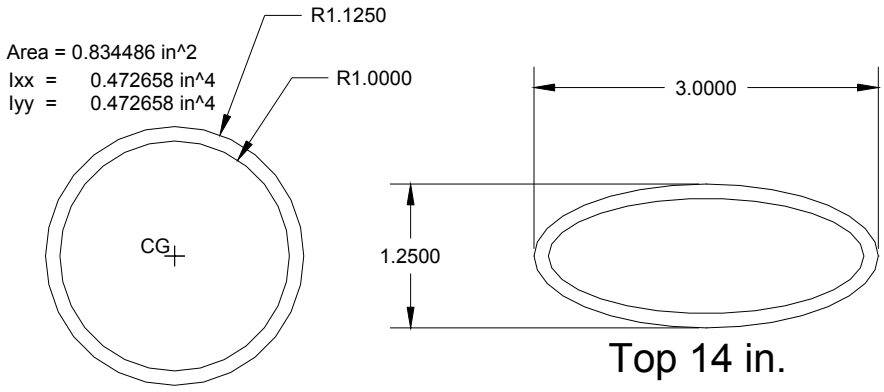
Carsonite HWDU, HWD1



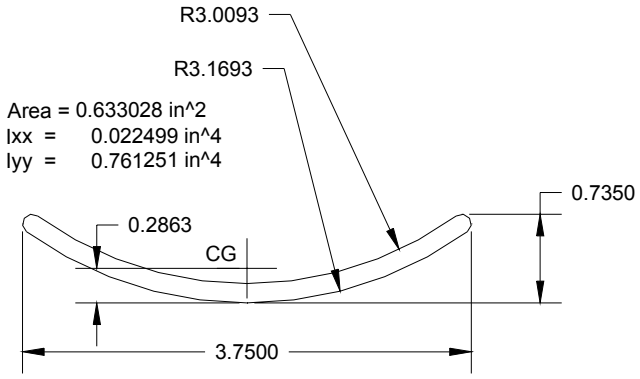
Carsonite Curve-Flex CFRM-400



Carsonite Roadmarker CRM-375



Safe-Hit SH 348-GP3



Davidson Plastics FG 500

Appendix C
Other Western States' Pre-qualifying Criteria

Other Western States' Pre-qualifying Criteria

Oregon

Qualified Product List

Carsonite "Curve-Flex" CFRM-400
Carsonite "Curve-Flex" CFGR-427
Carsonite "Roadmarker" CRM-375
Flexi-Guide (Davidson Plastics 500 Series)
Deltapost
Flexstake
Safe-Hit

Pre-qualification (Performance Only)

Heat Resistance:
Condition one post at 140 ^{o}F for two hours. Bend post 180^{o} at the middle with viewing face to the outside of bend. Post should straighten itself to within one inch of its original straightness within 30 seconds. Test to be repeated three more times within 3 minutes from removal of oven.

Cold Resistance:
Condition two posts at -5 ^{o}F for two hours. Bend one post 90^{o} at the middle with viewing face to the outside of bend. Post should straighten itself to within one inch of its original straightness within 60 seconds. Test to be repeated three more times within 3 minutes from removal of cold box. Second post to be place on two cylindrical bearings 36 inches apart. A 50 mm, I kg tup to be dropped at post's midpoint from a height of 1.5 m through a virtually frictionless guide. Cracking or splitting constitutes failure. Each test to be performed within 2 minutes from removal from cold box for a total of five impact tests.

Weatherometer:
One post to be exposed for 1000 hours in a weatherometer as per ASTM G 26. Significant yellowing or darkening or significant loss of pliability constitutes failure.

Impact Resistance:
Five posts with reflective sheeting attached to be subjected to impact hits from a typical sedan at a temperature of 40 ^{o}F or above. Post shall withstand 10 impact hits head-on at 35 mph and 5 impact hits at an angle of 75^{o} to the traffic face of post at 55 mph. 4 of the 5 posts must pass test.

General Observations
Impact test has no specific pass/ fail criteria.

Washington

(from 2000 standard specifications)

Qualified Product List

Carsonite "Roadmarker" CRM-375
Carsonite "Survivor"
Carsonite CGDU
Carsonite HWDU
Flexi-Guide (Davidson Plastics 500 Series)
Flexstake
Safe-Hit

Pre-qualification (Performance Only)
Heat Resistance:
Condition ten posts at 120 ^{o}F for two hours. Bend each post 90^{o} with viewing face to the outside of bend. Posts should straighten themselves, without cracking, to within ten degrees of their original straightness within 5 minutes. 70 percent of posts tested must pass for pre-approval.

Cold Resistance:
Same delineator post from heat test to be conditioned for 24 hours at –20 ^{o}F. Bend each post 90^{o} with viewing face to the outside of bend. Posts should straighten themselves, without cracking, to within ten degrees of their original straightness within 5 minutes. 70 percent of posts tested must pass for pre-approval.

Deflection Testing:
Three posts to be fixed at based such that 4 feet of body is cantilevered out. Posts to be loaded ½ in from free end until collapse is observed (can no-longer resist loading). Stress at collapse is calculated as follows:

P=K(Q/b)
P = equivalent stress in ponds per square foot
Q = load at collapse in pounds
B = post width (diameter of major axis) in inches
K = constant equal to 6 inches per square foot

P must be no less than 3.43 psf for round delineator posts and 5.30 psf for flat or elliptical delineator posts. Any load below these values or cracking constitutes failure.

Cyclic Loading:
Same three posts from deflection testing to be subject to cyclic loading with an amplitude of 2 inches at the tip with a cyclic testing machine. Each post to be cycled 30,000 times at 60 cycles per minute. After cycling is completed, each post to be subjected to deflection testing again. Average load of posts after cyclic testing should be a minimum of 80 percent of average load before cyclic testing.

5.5 Pound Deflection Testing:
Three posts to be fixed at based such that 4 feet of body is cantilevered out. Posts to be loaded ½ in from free end with 5.5 pound weight. A deflection greater than 29 inches constitutes failure.

Weatherometer:
9 inch specimen to be exposed for 1000 hours in a weatherometer as per ASTM G 53. Significant discoloration or distress constitutes failure. Physical properties of tensile strength and rigidity shall be maintained within 80 percent of the unconditioned values.

Impact Resistance:
Ten delineator posts with reflective sheeting attached to be subjected to impact hits from a typical sedan at a temperature of 50 ^{o}F or below. Tests to be performed at the Olympia Service Center Materials Laboratory designated test sight. Post shall withstand 7 impact hits at 35 mph and 2 impact hits at 55 mph. At each impact the following criteria must be met:

1) At least 50 % of reflective sheeting must remain.
2) Delineator post must lean no more than 10^{o} from vertical.
3) Any cracking on two faces of post is failure.
4) Pullout in excess of 3 inches is failure.

At least 70 % of the delineator posts must pass each criteria in the 35 mph series of impacts.

General Observations
In lieu of the required testing at the Olympia Service Center Materials Laboratory designated test sight, the manufacturer may submit a certified test report including test data developed by an approved testing laboratory.

California

Qualified Product List
Carsonite "Curve-Flex" CFRM-400
Carsonite "Roadmarker" CRM-375
Carsonite CGD1,CGDU
Carsonite HWD1,HWDU
Carsonite "Survivor"
Davidson Plastics Flexi-Guide 500 Series
Flexstake 654 TM & 604
Safe-Hit

Pre-qualification (Performance Only)
Heat Resistance:
Condition one post at 140 ^{o}F for two hours. Bend post 90^{o} at the middle with viewing face to the outside of bend. Post should straighten itself within 5 minutes. Test to be repeated three more times within 3 minutes from removal of oven.

Cold Resistance:
Condition one posts at -5 ^{o}F for two hours. Bend one post 90^{o} at the middle with viewing face to the outside of bend. Post should straighten itself within 60 seconds. Test to be repeated three more times. A 2-pound ball is to be dropped at post's midpoint from a height of 5 feet through a virtually frictionless guide. Cracking or splitting constitutes failure. Each test to be performed for a total of five impact tests.

Weatherometer:
One post to be exposed for 1000 hours in a weatherometer as per ASTM G 26. Significant yellowing or darkening or significant loss of pliability constitutes failure.

Impact Resistance:
Five posts with reflective sheeting attached to be tested at the Caltrans Dynamic Test Facility in Sacramento. Two of the five posts to be skewed at a 15 degree angle, left and right, away from the vehicle's direction of travel. The other three to face the approaching vehicle head-on. Posts shall withstand 10 impacts at a speed of 55 mph and still be considered self-erecting and serviceable. Reflective sheeting shall not be damaged by more than 50%.

General Observations
Impact test has no specific pass/ fail criteria other than sheeting damage. Certified independent testing may be submitted for approval in lieu of Caltrans testing.

Idaho

Qualified Product List
Carsonite “Curve-Flex” CFRM-400
Carsonite “Roadmarker” CRM-375
Carsonite HWD Series
Davidson Plastics Flexi-Guide (500 Series)
Potter Industries “Guardian”

Pre-qualification (Performance Only)
None.

General Observations
Requirements only include vendor registration and self-certification that the product meets NCHRP-350 Category I criteria.

Arizona

Qualified Product List

Carsonite "Curve-Flex" CFRM-400
Carsonite "Roadmarker" CRM-375
Carsonite CGDB, CGDU
Carsonite HWDB
Carsonite "Survivor"
Davidson Plastics Flexi-Guide 500 Series
Flexstake HD 600 Series
Safe-Hit SR, SH

Pre-qualification (Performance Only)
Heat Resistance:
Condition posts at 180 ^{o}F for two hours. Post shall be sufficiently rigid to resist wilting.

Cold Resistance:
Condition two posts at -4 ^{o}F for two hours. Post to withstand 180^{o} bend at midpoint without cracking and be able to straighten itself to within 5 degrees of its original orientation in 60 seconds.

Weatherometer:
Posts to be exposed for 1000 hours in a weatherometer as per ASTM G 26 without any significant color fading.

Impact Resistance:
Delineator posts are to be subjected to 10 impact hits from a typical sedan at a temperature of 40 ^{o}F or above traveling at 55 mph. Delineator posts are to exhibit no breakage or loss of serviceability and to straighten themselves to within five degrees of their original orientation. Delineator posts shall also be capable of sustaining one wheel hit during testing at 55 mph without loss of serviceability.

Wind Resistance:
A 50 mph wind load shall not deflect devices more than 2 inches from the at-rest position.

General Observations
The above guidelines are merely what ADOT uses to interpret NTPEP data.

Colorado

Qualified Product List
None.

Pre-qualification (Performance Only)
Heat Resistance:
Condition one post at 140 ^{o}F for two hours. Bend post 90^{o} at the middle with viewing face to the outside of bend. Post should straighten itself to its original straightness within 5 minutes. Test to be repeated three more times.

Cold Resistance:
Condition two posts at -5 ^{o}F for two hours. Bend one post 90^{o} at the middle with viewing face to the outside of bend. Post should straighten itself to within one degree of its original position within 60 seconds. Test to be repeated three more times. Second post to be placed on two cylindrical bearings 36 inches apart. A steel ball weighing 1 kg is to be dropped at post's midpoint from a height of 1.5 m through a virtually frictionless guide. 5 tests are to result in no cracking or splitting.

Weatherometer:
One post is to be exposed for 500 hours in a weatherometer as per ASTM G 23. Significant yellowing or darkening or significant loss of pliability constitutes failure. Reflective sheeting shall not be removable from the post without damage.

Impact Resistance:
A post with reflective sheeting attached to be subjected to impact hits from a typical sedan at a temperature of 40 ^{o}F or above. Post shall withstand 10 impact hits head-on at 35 mph and 5 impact hits at an angle of 75^{o} to the traffic face of post at 55 mph. After impact the post shall:

1) Remain intact and securely anchored
2) Return to its original position within an angle of 10 degrees from vertical.
3) Show minimal signs of cracking and rigidity.
4) Retain a minimum of 50 % reflective sheeting.
5) Each post prior to and after installation shall be free of bends and twists.
6) Posts to have a minimum tensile strength of 1100 psi as determined in accordance with ASTM D 638

General Observations
Assumption is that 100% of the samples in a given test must pass for product to be accepted. No other criteria have been given. Pre-qualifying procedures are in place for flexible delineator posts but a qualified product list is not available.

Appendix D
Calculation Definitions

Calculation Definitions

(1) Tensile Strength, σ (psi)

$\sigma = \frac{P}{A}$ P = Tensile force (lbs), A = Cross sectional area (in^2)

(2) Weathered change as a percentage of control specimen value, Δ (%)

$\Delta = \frac{Weather - Control}{Control}$

(3) Absolute weathered change as a percentage of control specimen value, $|\Delta|$ (%)

$|\Delta| = \left| \frac{Weather - Control}{Control} \right|$

(4) Volume energy at yield point, E_V (lbs/in)

$E_V = \sigma\delta$ σ = Tensile Strength (psi), δ = Elongation (in)

(5) Strain energy to yield point along elastic region, E_S (lb-in)

$E_S = \frac{P\delta}{2}$ P = Tensile force (lbs), δ = Elongation (in)

(6) Tensile strain, ε (in/in)

$\varepsilon = \frac{\delta}{L_S}$ δ = Elongation (in), L_S = Un-deformed length of specimen (2 in)

(7) Modulus of elasticity, E (psi)

$E = \frac{\sigma}{\varepsilon}$ σ = Tensile Strength (psi), e = Tensile strain (in/in)

(8) Dynamic wind head, q (psf)

$q = C_D \rho V^2$ C_D = Drag coefficient, ρ = Air density at 70˚ F and 1 atm = 0.00234 slugs/ft3,
V = Wind Speed (mph) x 5280 ft/mile x 1 hr/3600 sec

(9) Distributed wind load, ω (plf)

$\omega = LD$ L = Length of post (4 ft), D = Width of post (in) x 1 ft/12 in

(10) Moment at base (lb-ft)

$M = \frac{\omega L^2}{2}$ ω = Distributed wind load (plf), L = Length of post (4 ft)

(11) Bending Stress (psi)

$\sigma = \frac{M\bar{y}}{I}$ M = Bending Moment at base (lb-ft), $\bar{y}$ = Centroid of FDP cross section (in),
I = Moment of inertia of FDP cross section (in^4)

(12) Change in seasonal sheeting damage (%)

Δ = %Sheet Loss from First Season - % Sheet Loss from Second Season

Note: The % sheeting loss data (from NTPEP) to be used in the above equation should be average values (net) for a given season at the end of the test series (i.e. 5th impact). The NTPEP data is synthesized from many tables of data is shown in Appendix A. It gives cumulative data on

sheeting damage for the entire NTPEP test (8 samples; 2 seasons with 5 impacts for each season). The first season % sheet loss is the average loss (of 8 samples) at the end of the 5^{th} impact. However, the sheeting loss in the second season is the average incremental value between the 6^{th} and the 10^{th} impact (impacts 6 – 10 are conducted during second season). Under such circumstances, Δ sheeting damage defined above can be positive and this happens when the damage from the second season is smaller than those from the first season.

Appendix E
Pre-Qualification Specifications and Commentary

Recommended Pre-Qualification Criteria

The following table summarizes the recommended pass/fail criteria for flexible delineator posts submitted for pre-qualification. Many cut-off criteria have been derived using NTPEP testing data.

Table E1 – Recommended Pre-Qualification Criteria

Mode of Failure	Recommended Cut-off Criteria *	Description for Pass
Impact Loading	Listing average not to exceed 10% (9 degrees) for 10 impacts	Average of eight products being impacted simultaneously. See NTPEP test procedure.
Wind Loading	Loss of strain energy capacity after 1000 hrs in a weatherometer not to exceed 3% of the original strain energy capacity of the control specimen.	$E = \frac{P}{2\delta}$; $\frac{E_{contol} - E_{weathered}}{E_{control}} x100 \le 3\%$
Delamination of Sheeting	Average loss of sheeting in the second season impact testing not to exceed 2% above the average loss of sheeting in the first season impact testing.	$\%Loss_{2nd\ season} - \%Loss_{1st\ season} \le 2\%$
UV Brittleness	Same as wind loading criteria	Same as wind loading criteria
Discoloration (optional)	Subject FDP to 1000 hrs in a weatherometer (ASTM G26)	No discoloration should be observed (optional)

* The first pre-qualification requirement is that all flexible delineator posts to be considered must have been tested by NTPEP.

Impact Loading Mode of Failure

The steps involved in the pre-qualification for a single flexible delineator post product relative to the impact loading mode of failure are as follows:

1. From the NTPEP impact testing data compute the average % list for all impacts (10 impacts and 8 samples for a total possible sample size of 80 individual impacts, i.e. obtain the average % list for 80 impacts).

2. To qualify, the average % list of the FDP under consideration should be below 10%. This step can be restated as, "the average % list out of eighty impacts (NTPEP testing) should be less than 10%".

Wind Loading Mode of Failure and UV Brittleness Mode of Failure

The steps involved in the pre-qualification relative to the wind loading and the UV brittleness modes of failure are as follows:

1. From the NTPEP UV testing data compute the strain energy E_s at failure for both weathered and controlled specimens using,

$$(E_s)_{weathered\ /\ control} = (\frac{P}{2\delta})_{weathered\ /\ control}$$

in which P and δ are the failure load and the corresponding deflection for the specimens.

2. Compute the normalized change in strain energy ΔE_s as a percentage using,

$$\Delta E_s(\%) = \frac{(E_s)_{control} - (E_s)_{weathered}}{(E_s)_{control}} \times 100\%$$

3. To qualify, the ΔE_s should be below 3%. This step can be restated as, "the reduction in strain energy at failure of the weather specimen should be less than 3% of the original (control specimen) strain energy at failure".

Delamination of Sheeting Mode of Failure

The steps involved in the pre-qualification relative to the delamination of sheeting mode of failure are as follows:

1. From the NTPEP impact testing data compute the average sheet loss, in percent, for a given FDP in the first season's test only. Repeat for the second season's test.

2. Compute the average percent sheeting damage difference from the first season to that of the second season. This difference represents the seasonal change in sheet loss damage behavior.

$$(\%\ \text{Loss})_{2\text{nd Season}} - (\%\ \text{Loss})_{1\text{st Season}} = \Delta(\%\ \text{Loss})$$

3. To qualify, the Δ(% Loss) should be below 2%. This step can be restated as, "an increase in the average sheet loss damage in the second season impact tests should be limited to 2%".

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