STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION
44 HAWLEY STREET
BINGHAMTON, N.Y. 13901-3200

JOSEPH H. BOARDMAN
COMMISSIONER

January 18, 2002

Shelley J. Row, P. E.
Office of Traffic Operations, HOTO-1
Federal Highway Administration
400 7th Street, S. W.
Washington, DC 20590

Dear Ms. Row:

Re: VI-117(E) - STOP SLOW Paddle

Enclosed is the report for Experiment VI-117(E) - STOP SLOW Paddle. The results were very favorable and the report recommends that the device be included in the Manual of Uniform Traffic Control Devices.

If you have any questions, please contact me at 607-721-8080. My fax number is 607-721-8070 and my e-mail address is dpaddick@gw.dot.state.ny.us

Very Truly Yours,

Daniel Paddick

Daniel Paddick, P. E.
Regional Traffic Engineer

Effectiveness of STOP SLOW Paddles Equipped With Flashing Red and Flashing Yellow Lights

Experiment VI-117(E) STOP SLOW PADDLE

by

Daniel Paddick, P. E.

New York State Department of Transportation

ABSTRACT

Traffic is controlled through many work zones by flaggers using the STOP SLOW paddle. Light conditions and distractions can affect the visibility and conspicuity of this device. Section 6E.03 of the Manual of Uniform Traffic Control Devices only allows the use of flashing white lights on the STOP SLOW paddle. Numerous developers are marketing or are desiring to market, the traditional STOP SLOW paddle supplemented with flashing red lights on the STOP face of the paddle and flashing yellow lights on the SLOW face of the paddle. They believe that flashing red or yellow lights provide a more understandable message and attract more attention than the allowable flashing white lights.

The purpose of this experiment was twofold. The first was to determine if a STOP SLOW paddle equipped with flashing red lights on the STOP face of the paddle and flashing yellow lights on the SLOW face of the paddle was safe. The second was to determine if the experimental paddle was more effective and more visible than the traditional STOP SLOW paddle. Since objective measures were difficult or impossible to define, a subjective questionnaire was used.

Judging by the ratings and the number of favorable comments, the device was determined to be as safe as or safer than the traditional paddle. The experimental STOP SLOW paddle was also judged to be more effective and more visible than the traditional paddle.

INTRODUCTION

Numerous developers are marketing or are desiring to market, the traditional STOP SLOW paddle supplemented with flashing red lights on the STOP face of the paddle and flashing yellow lights on the SLOW face of the paddle. Section 6E.03 of the Manual of Uniform Traffic Control Devices only allows the use of flashing white lights on the paddle, and then only on the STOP face of the paddle. One developer approached the New York State Department of Transportation (NYSDOT) for permission to use the traditional STOP SLOW paddle supplemented with flashing red lights on the STOP face of the paddle and flashing yellow lights on the SLOW face of the paddle. Permission was denied because the device did not conform to either the Federal or the New York State Manual of Uniform Traffic Control Devices. NYSDOT then petitioned FHWA for permission to experiment.

This experimental device conforms closely to the philosophy of the Manual of Uniform Traffic Control Devices in that the flashing lights associated with STOP face of the paddle are similar to the red flashing beacons allowed to supplement a STOP sign (Section 4K.05 of the Manual of Uniform Traffic Control Devices). Similarly, the flashing lights associated with SLOW face of the paddle are yellow which corresponds to the yellow flashing beacons used to supplement warning and construction signs (Sections 4K.03, 6F.02, 6F.71 and 6F.72 of the Manual of Uniform Traffic Control Devices).

The lighting pattern on the experimental device is also in closer conformance to normal driver expectations than the approved lighting pattern. Red means stop and yellow means caution while white does not have a universal meaning.

The only difference between the proposed device and the previously approved device is the color of the flashing lights. When the original device was approved, the technology for lighting was not as advanced as it is today. The only effective lights developed in a size and power appropriate for use on a sign were white. In recent years the technology has advanced to the point where red and yellow lights of the appropriate size and power are available. The device used in the experiment was equipped with red and yellow light emitting diode (LED) lights.

With the color of the flashing lights being the critical difference between the proposed device and the approved device, there are a couple of reasons to support the use of red and yellow lights on the proposed device. Besides the color of the lights on the proposed device conforming with the lighting pattern of the MUTCD, there appears to scientific evidence that flashing red and flashing yellow lights attract more attention than flashing white lights. The Appendix to this report contains copies of two letters (November 15, 2000 and December 28, 2000) from J. Louis Pecora M.D., an Ophthalmologist, concerning the use of colored lights on signs. These letters cite the scientific evidence behind the postulation that flashing red and flashing yellow lights

attract more attention than flashing white lights.

EVALUATION METHODOLOGY

As previously stated, the only difference between the proposed device and an approved device is the color of the flashing lights. The scientific data presented by the developer supports their claims that flashing red or yellow lights are more effective than flashing white lights. Our field test is not an attempt to verify this claim but a practical test of whether the device is safe, is effective and provides improved visibility. The experimental plan was to observe the use of the device, question the flaggers and the contractor's staff to obtain their opinion, and to obtain the observations of Department staff.

NYSDOT's Transportation Maintenance group and NYSDOT's Construction group in the Binghamton Region (NYSDOT Region 9) used the experimental STOP SLOW paddle instead of the traditional STOP SLOW paddle in numerous work zones between May 2001 and November 2001. A questionnaire was developed and provided to the Department's and the Contractor's staff along with instructions for the use of the equipment and the filling out of the questionnaire. Users of the equipment were instructed to terminate the test if they felt the equipment or the test was unsafe. A copy of the questionnaire is contained in the Appendix to this report.

Completed questionnaires were received from three NYSDOT construction projects (D258533, D258549, and D258423) and two NYSDOT County Residencies (Otsego County and Broome County).

Replacement batteries were provided and the users were instructed to replace the batteries as needed. Except for one construction project (D258423), the batteries were replaced in a timely manner.

ANALYSIS OF COLLECTED DATA

Thirty-one questionnaires were returned. Sixteen were from the Department's Transportation Maintenance work zones and fifteen were from the three construction projects. On the construction projects, questionnaires were filled out by the Department's engineering staff, the contractor's supervisory staff and the contractor's flaggers. At the Department's Transportation Maintenance work zones, questionnaires were filled out by the Department's supervisory staff and the Department's flaggers.

The questionnaires asked two questions and provided a space for comments. The first question was:

> "In your opinion, compared to the traditional non lighted STOP/SLOW paddle, how effective is the tested device (CIRCLE ONE) in controlling traffic: MUCH MORE EFFECTIVE, MORE EFFECTIVE, ABOUT THE SAME, LESS EFFECTIVE, MUCH LESS EFFECTIVE."

The second question was:

> "In your opinion, compared to the traditional non lighted STOP/SLOW paddle, is the tested device (CIRCLE ONE) more visible or less visible: MUCH MORE VISIBLE, MORE VISIBLE, ABOUT THE SAME, LESS VISIBLE, MUCH LESS VISIBLE."

The results to the first question on the effectiveness of the experimental paddle compared to the traditional paddle are contained in the following table. The results from all thirty-one questionnaires are listed in the first line. The results from the sixteen questionnaires received from the Maintenance work zones are listed in the second line. The results from the Construction projects are listed on the third and fourth lines. The results from the two Construction projects that changed the batteries in a timely manner are listed the third line and the results from the project that did not change the batteries in a timely manner are in the fourth line.

	MUCH MORE	MORE	SAME	LESS	MUCH LESS	
OVERALL	11	14	4	2	0	= 31
MAINTENANCE	6	10	0	0	0	= 16
CONSTRUCTION (D258533 & D258549)	5	4	1	0	0	= 10
D258423	0	0	3	2	0	= 5

The results to the second question on the visibility of the experimental paddle compared to the traditional paddle are contained in the following table. The results are listed in the same manner as the first table.

Visibility

	MUCH MORE	MORE	SAME	LESS	MUCH LESS	
OVERALL	8	18	3	2	0	31
MAINTENANCE	6	10	0	0	0	6
CONSTRUCTION (D258533 & D258549)	2	8	0	0	0	10
D258423	0	0	3	2	0	5

Using a weighting system of 5 for much more effective or visible and 4 for more effective or visible and so on down to 1 for much less effective or visible than the traditional paddle, the overall average for the effectiveness of the experimental paddle to the traditional paddle was 4.1. Eliminating the five questionnaires on the project, which allowed the batteries to perceptively weaken, raises the average to 4.4. The overall rating for the visibility of the experimental sign compared to the traditional sign is 4.0. Eliminating the five questionnaires on the project, which allowed the batteries to perceptively weaken, raises the visibility average to 4.3. These results indicate that the experimental paddle is considerably more effective and more visible than the traditional paddle.

Comments were made on all but four of the questionnaires. Many of the questionnaires had multiple comments. Many of the comments were not germane to the experiment because they dealt with subjects like the actual maintenance of the paddles, the care of the paddles or suggestions about the type of power source. The comments not germane to the experiment will not be discussed.

The comments pertinent to the experiment could be sorted into seven general categories. The most prevalent was that the experimental paddle was very good in poor light conditions or the shade, or that it was better in poor light conditions or in the shade than in bright sunlight. A comment of this type was made eleven times. This bolsters the developer's claim that the experimental paddle improves the visibility of the flagger and flagging station in poor light conditions.

The second most prevalent comment with ten responses was that the paddle should be larger. This comment is understandable because most flaggers in New York State use a twenty-four inch paddle and the prototype experimental paddles provided by the developer were only eighteen inches wide. While Section 6E.03 of the Manual of Uniform Traffic Control Devices allows the use of an eighteen inch wide STOP SLOW

paddle, NYSDOT Transportation Maintenance guidelines require that a STOP SLOW paddle used in their work zones have a minimum width of twenty-four inches. Twenty-four inch wide STOP SLOW paddles are also used in most work zones on Department construction projects. All five of the questionnaires submitted on the project that did not change the batteries in a timely manner made the comment that the paddle should be larger. This was the only project where the experimental paddle was rated less visible or less effective than the traditional paddle. Part of the reason may be because a smaller paddle was being used. A sign or paddle with poor lights should be as visible and as effective as a sign or paddle of similar size with no lights but a smaller size sign or paddle without lights or with poor lights should not be as visible or as effective as a larger sign or paddle with no lights.

Two other comments were received six times. The first of these was that the experimental paddle was lighter than the traditional paddle. This was cited as an advantage because it was easier to handle and caused less fatigue. It is reasonable to assume that a paddle that reduces flagger fatigue is a safer paddle. The other comment that received six mentions was that the experimental paddle was highly visible or highly visible, even in bright sun.

Five of the questionnaires mentioned something along the line that the experimental paddle was better than the old paddle, safer, that they would recommend the experimental paddle or they want to use the experimental paddle on all future projects.

The prototype paddle supplied by the developer was not reflective. There were four comments that the paddle was not reflective. Section 6F.03 of the Manual of Uniform Traffic Control Devices does not require a STOP SLOW paddle to be retroreflective unless it is used at night. All four instances were on questionnaires that also mentioned that the paddle should be bigger.

In the past, NYSDOT's Transportation Maintenance has used white strobe lights attached to the STOP SLOW paddle with mechanical clips. Two comments mentioned the white strobe lights. Both said the battery life was longer with the experimental paddle. One also said that the experimental paddle "worked better" than the traditional paddle with clip on white strobe lights. The context of "worked better" is unclear.

One unsafe incident was reported. A vehicle drove through a flagging station with flagger using the experimental paddle while the flagger attempted to stop traffic. The driver was talking on a cell phone and was distracted. The rest of the comments on the questionnaire reporting this incident were highly favorable and the device was rated "much more effective" and "more visible."

CONCLUSIONS

The purpose of this experiment was twofold. The first was to determine if a STOP SLOW paddle equipped with flashing red lights on the STOP face of the paddle and flashing yellow lights on the SLOW face of the paddle was safe. The second was to determine if the experimental paddle was more effective and more visible than the traditional STOP SLOW paddle.

Before using the experimental paddle, the field supervisors and field personnel were instructed to terminate the experiment if, for any reason, they felt that the device was unsafe. There was no indication on any of the questionnaires or from the verbal feedback that anyone felt that the device was unsafe. Judging by the ratings and the number of favorable comments, the device appears to be as safe or safer than the traditional paddle. Even the comments received from the one construction project that did not change the batteries did not indicate that using the device was unsafe.

Except for the one construction project that allowed the batteries in the experimental STOP SLOW paddle to run down, the effectiveness and visibility ratings were highly favorable. Based on the ratings and comments, the experimental STOP SLOW paddle appears to be more effective and more visible than the traditional paddle.

While an experiment based solely on a subjective survey can seldom reach definitive results, it appears, based on the survey's ratings and comments, that the use of flashing red and yellow lights on the STOP SLOW paddle is a significant improvement over the non lighted paddle, especially in poor light conditions. We recommend that the Manual of Uniform Traffic Control Devices be revised to allow the optional use of red and yellow lights on the paddle sign face.

Appendix A1

STOP/SLOW PADDLE QUESTIONNAIRE

NAME: _____ DATE: ___/___/___

EMPLOYER: _____ TITLE: _____
(NYSDOT, Contractor's Name) (HMS 1, CE 1, Laborer, etc.)

PROJECT: _____
(D or PIN #)

LOCATION _____
(or REFERENCE MARKER)

TOWN _____ COUNTY: _____
(If known)

TIME: _____ TO _____

WEATHER CONDITIONS: _____ LIGHT CONDITIONS _____
(Clear, Rain, etc.) (Sunny, Cloudy, Overcast, Rain, Dawn, Dusk, etc)

- In your opinion, compared to the traditional non lighted STOP/SLOW paddle, how effective is the tested device (CIRCLE ONE) in controlling traffic:

  MUCH MORE EFFECTIVE
  MORE EFFECTIVE
  ABOUT THE SAME
  LESS EFFECTIVE
  MUCH LESS EFFECTIVE

- In your opinion, compared to the traditional non lighted STOP/SLOW paddle, is the tested device (CIRCLE ONE) more visible or less visible:

  MUCH MORE VISIBLE
  MORE VISIBLE
  ABOUT THE SAME
  LESS VISIBLE
  MUCH LESS VISIBLE

COMMENTS: _____
_____

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TELEPHONE (607) 785-3043

J. LOUIS PECORA, M.D.

OPHTHALMOLOGIST

November 15, 2000

Ref. 'Traffic Safety Alert' Lighted Traffic Control Sign
Advantec Development Inc.

To Whom It May Concern:

The above has a sound idea concerning light, motion, and color to attract attention.
The scientifically proven Stiles-Crawford phenomenon states that the eye is more sensitive to certain wave lengths of light. Therefore, colored lights on a sign can be of importance.

The Troxler phenomenon concerns the fact that stationary objects in the periphery of the visual field cause the retinal photo receptors to adapt and therefore are ignored. Therefore a moving object, such as the alternatively flashing lights on the lighted traffic control sign, would be much more likely to be noticed as compared to a sign with no flashing lights. This phenomenon is more important and especially pronounced in older individuals as the ability to process much visual information has declined.

Yours truly,

Louis Pecora

J. Louis Pecora, M.D.

JLP/msj

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TELEPHONE (607) 785-3043

J. LOUIS PECORA, M.D.

OPHTHALMOLOGIST

December 28, 2000

Ref. My letter dated November 15, 2000, 'Traffic Safety Alert' Lighted Traffic Control Sign Advantec Development Inc.

Ref.: Stiles-Crawford phenomenon, Troxler phenomenon, National Library of Medicine.

To Whom It May Concern:

The above referenced traffic control sign comprises the three major factors in getting the visual attention of drivers more effectively than standard non-lighted signs or signs with only white lights.

It is well known that light, color and motion are the three main ingredients for attracting human visual attention. This is seen in all forms of television advertising, computer graphics and illuminated commercial advertising signs.

It is universally accepted by all motorists that red lights signify Stop and that yellow lights indicate Caution. The red and yellow lights convey information to the viewer, whereas, a white light does not have any specific meaning to a motorist.

The effectiveness of these colors is proven in the fact that world wide, all traffic control signal lights use red for stop and yellow for caution. Also, all automobiles produced in the world utilize red brake lights. If white light was superior, then we would have white brake lights and white stop lights at intersections.

Visual light falls in the range of approximately 400nm to 700nm with peak eye sensitivity in the 500nm to 600nm range. The spectrum is indicated by a bell shaped curve. Yellow light is approximately 590nm with red light approximately 625nm. The yellow and red light fall in the sensitive range of the curve and are easily detected by the human eye.

The actual attention getting effects that are produced by colored lights and motion are a combination of the physiology of the human eye and the way the human brain processes this information. The color red has been a signal for warning since man first saw the color of blood. The human brain attaches certain significance to different colors and produces a specific responses. Ref.: The Psychology of Color by Deiter.

While white light is generally used for illumination, it does not signify any specific message, nor does it produce the eye/brain response that is generated by colored lighting.
White light is essentially the same color as daylight and therefore the effect as an attention getting flashing light, on a work zone traffic control sign, results in low contrast to the existing daylight and a diluted effect. Conversely, red flashing lights on the same sign have a dramatic contrast to the white daylight, convey a message and produce an enhanced psychophysical response. This increased stimulation is especially valuable to older drivers with diminished visual capabilities and generalized slower response times.

Ref. : Stiles-Crawford phenomenon.

The red alternately flashing lights on the stop face of the referenced traffic control sign and the yellow alternately flashing lights on the slow face of the sign provide the `motion` factor in attention getting properties. This effect is very important and especially pronounced in older individuals as the ability to process much visual information has declined. This effect is extremely valuable in regard to peripheral vision response.

Reference: The Troxler phenomenon.

Reference: United States National Library of Medicine, PubMed.

Yours truly,

J. Louis Pecora, M.D.

JLP/msj