REFLECTORIZED FLAGMAN VESTS

MICHIGAN RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF
STATE HIGHWAYS AND TRANSPORTATION

REFLECTORIZED FLAGMAN VESTS

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INTRODUCTION

The use of fluorescent vests by flagmen or traffic regulators on roadway maintenance projects, while greatly increasing the daytime visibility of a flagman wearing the vest, results in little or no enhancement of the nighttime visibility of a flagman. The addition of reflectorized material to the vest would increase nighttime visibility for motorists viewing the vest.

The Federal Manual on Uniform Traffic Control Devices (MUTCD), dated 1971, on page 313, Section 6 E-3, entitled, "Flagman," asserts:

> "The use of an orange vest and/or an orange cap shall be required for flagmen. For night conditions similar outside garments shall be reflectorized."

The Federal Manual went into effect July 1, 1973.

In February 1973 the Engineer of Testing and Research suggested the Department should undertake development of a reflectorized traffic regulator's vest in view of the MUTCD requirement. It was noted that some construction work was being carried out at night and that night construction work was likely to increase in the future.

Although nighttime use of flagmen constitutes perhaps one to five percent of maintenance hours, the Department normally furnishes the vest design to the counties and contractors who may work on 24-hour projects, such as construction of concrete median barriers on Detroit freeways, etc. In addition, in very overcast daytime conditions when drivers must use their headlights, a reflectorized material could become a highly desirable adjunct to the fluorescent vest.

Floodlighting of the traffic regulator station and construction site is recommended as a supplement to reflectorized signs and barriers in Section 6D-2 of the MUTCD. If floodlights are used, great care must be taken to ensure that the floodlighting does not cause glare in the eyes of either the drivers, the workmen, or flagmen.

Blomberg and others (1) in a U. S. Department of Transportation report on a mail survey of the public and their officials (police, judges, traffic engineers, AAA, etc.) concerning a model road work site law received support for a proposed regulation that would require a retro-reflective material to be worn by roadway workers at night. The respondents suggested that the employer should provide and supervise the wearing of retro-reflective fluorescent apparel by night workers. The respondents also felt that the reflectivity and color of the reflectorized material should be standardized.

In February 1973, a preliminary study (Research Project 73 TI-164) was initiated by the Photometry Group of the Research Laboratory to determine requirements for a reflectorized vest culminating in Report No. R-873, "Reflectorization of Fluorescent Flagmen's Vests," (July 1973). This report recommended a reflectorized vest pattern with five arms.

In a memo of June 22, 1973, M. N. Clyde, Engineer of Testing and Research, confirmed observations of the reflectorized vest patterns made by himself and representatives of the Maintenance, Traffic and Safety, Personnel, and Testing and Research Divisions on June 21, 1973, in the course of the Research Project 73 TI-164. He felt that patterns containing diagonal lines rather than vertical or horizontal lines were "attention-getting." Diagonal lines are not as prevalent as vertical or horizontal lines in the field of view of a driver. The silver patterns and the red patterns viewed provided more "punch," but he felt that the color orange should be adhered to, if possible, in view of the MUTCD requirement for orange warning signs and for orange vests.

M. N. Clyde (memo to G. J. McCarthy, N. C. Jones, L. J. Doyle, W. A. Sawyer, and D. F. Haley, August 22, 1973, transmitting copies of Research Report No. R-873) recommended the shape of the pattern be similar to either Figure 3C or Figure 5 in Report No. R-873. Figure 1 portrays these patterns.

In an April 12, 1974 memo to the Engineer of Testing and Research, the Assistant Deputy Director requested that a supplemental specification for vests worn by traffic regulators be prepared. He asked that the specification provide for both the non-reflectorized type utilized for daylight trunkline operations and a reflectorized type for use during hours of darkness. The latter type was to bear a "man-like" five element figure similar to those shapes recommended as shown in Figure 1.

The Engineer of Testing and Research in a May 21, 1974 memo to L. A. Kinney, Manager, Training and Safety, stated that the specification, when prepared, will be presented to the Safety Section for inclusion in the latest revision of the booklet "Instructions for Traffic Regulators."

Subsequently, at a meeting July 17, 1974, attended by members of the Traffic and Safety, and Testing and Research Divisions, it was decided that

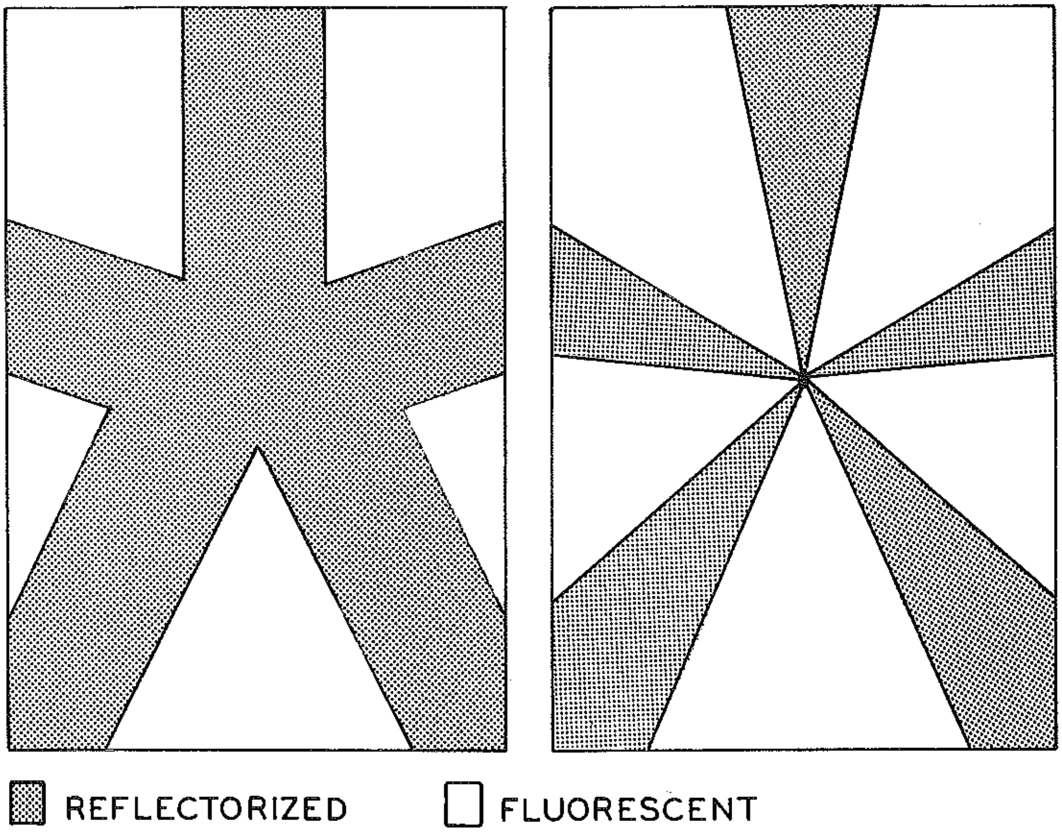


Figure 1. Pattern shapes based on observer preferences as recommended by Research Report No. R-873.

in order to facilitate standardization of reflectorized flagman vest design throughout the country, the Department should send its recommendation for the vest design to the National Advisory Committee to the Federal Manual. The participants in the meeting agreed that a copy of this Research Report on vest reflectorization should accompany the recommendation to the National Advisory Committee.

Since Report No. R-873 recommended only generalized shapes for the reflectorized vest pattern and evaluated a limited selection of available materials, this research study was conducted to finally select the precise shape and to determine an optimum color for the reflectorized patterns, using state-of-the-art reflective materials in various lighting environments. The colors and pattern shapes used in this study were selected as follows.

Color

The MUTCD states that a flagman vest should be orange for daytime use and should be reflectorized for nighttime use. The manual does not recommend a particular nighttime color for the vests. Since orange is now the color for maintenance and construction signs it may be assumed that the nighttime color of the vests should also be orange.

The daytime color of warning flags and traffic regulator vests in use on State of Michigan construction projects has been specified as fluorescent yellow-orange. The Michigan Department of State Highways and Transportation supplemental specification (to Standard Specifications Section 6.31.04e) for color of fluorescent flags reads:

> "The color shall match 'Day-Glo Blaze Orange' of Switzer Brothers, Inc., or 'No. 3483 fluorescent yellow-orange' on Scotchcal of 3M Company."

The fluorescent yellow-orange was chosen in consideration of the following:

1) Hanson and Dickson (2) and Michon, et al, (3) discovered that fluorescent yellow-orange was more visible to the majority of people than other fluorescent or non-fluorescent colors. Fluorescent red-orange was as visible as fluorescent yellow-orange except to those persons deficient in color vision.

2) Fluorescent yellow-orange was the fluorescent color judged closest in appearance to Highway Orange (FHWA color PR No. 6, 1971).

Addition of colors other than orange to the vest for nighttime reflectorization also may not conform to the daytime appearance prescribed by the MUTCD: "... the use of an orange vest and/or an orange cap shall be required for flagmen." This sentence could be construed as requiring only the orange color. Apparently, some states do not agree with this interpretation of the MUTCD. It has been reported that Illinois, Indiana, and Kentucky use a fluorescent orange vest with fluorescent yellow-green striping. The yellow-green striping was dual-purpose (simultaneously fluorescent and reflective) reflecting a silver color at night. It is also known that some states use silver reflectorized chevrons attached to fluorescent orange vests.

It was decided that in addition to the prescribed orange color other colors commercially available in reflective fabric that might be sewn or attached with adhesive to a fluorescent vest would be used in the study.

Subsequently two manufacturer's (Rowland Development Corp. and the 3M Co.) known to be active at the time in production of reflective fabric for vests and other safety devices were contacted.

Rowland claimed that their reflective materials would pass Federal LS 300b specifications for reflective sign materials. Rowland's reflective materials employ the principle of prism or cube corner reflection. However, Rowland prism material may not reflect as much light at large entrance angles as does glass bead reflectorized fabric. Wide angle reflection by a flagman vest might be an advantage in situations where a traffic regulator is inadvertently turned away from traffic.

Rowland reflectorized fabrics were available in the orange, yellow, silver, and red as follows:

1) Construction Orange — The color conformed to the FHWA Highway Orange color. This orange fabric was not fluorescent. Rowland indicated there were technical difficulties in producing a dual-purpose fluorescent yellow-orange and reflective orange fabric.

2) Yellow — This fabric was reflectorized and non-fluorescent.

3) Silver — This fabric also was reflectorized, but not fluorescent.

4) Red — This fabric was dual-purpose fluorescent red and reflectorized red.

3M Company was able to furnish reflectorized vinyl fabrics in either orange, silver, or red. Some of these fabrics were also fluorescent. The 3M materials are as follows:

1) Construction Orange (Highway) reflectorized, encapsulated bead, non-fluorescent. 3M does not produce a dual-purpose fluorescent yellow-orange and reflectorized Construction Orange.

2) Silver reflectorized, exposed bead and fluorescent yellow-green.

3) Red reflectorized, encapsulated bead, and fluorescent red.

4) Silver reflectorized, exposed bead, and fluorescent red.

5) Identical to (4) except fabric was heat-applied to vest. Experimental results for fabric (5) are not reported because they were essentially the same as for fabric (4).

Shape of Reflectorized Pattern

Four patterns which were based on patterns shown in Figure 1 were shown to six observers in a laboratory simulated full size study. Two of these patterns were selected by the observers and are shown in Figure 2. These two pattern shapes, called "X" and "Y," were used in this study. Enough material to make two patterns of each shape and color as listed above was purchased from the above two manufacturers. The material was sewn, or heat applied where required, to fluorescent yellow-orange flagman vests. The exact pattern dimensions are given in Appendix A.

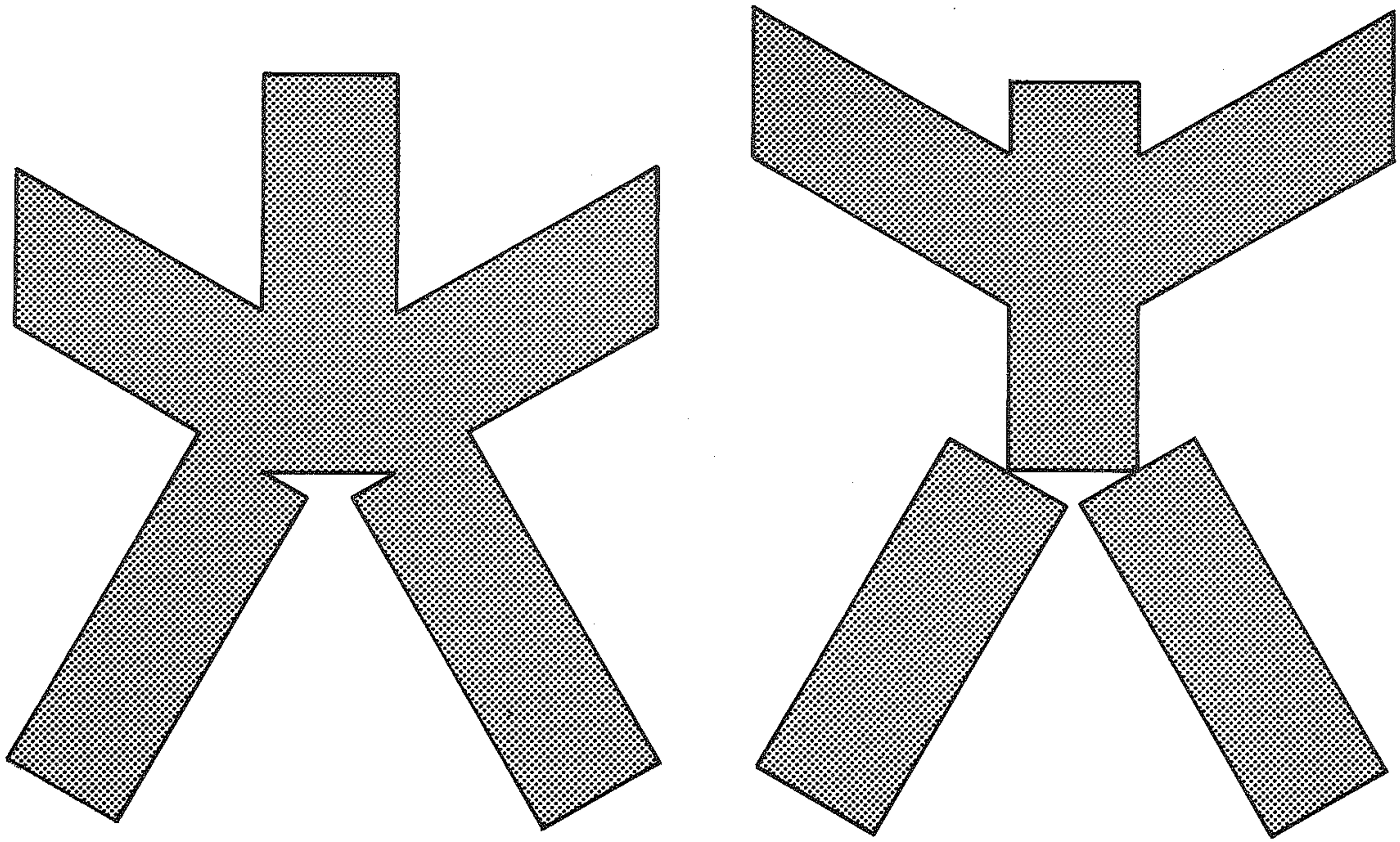
Figure 3 depicts day and night views of the two vest patterns used in this study.

The area of the reflectorized portion of each vest was 210 sq in. Since the frontal area of a flagman vest is about 590 sq in. the reflectorized portion constituted about 1/3 of the total vest area.

It was theorized that less area was necessary at night where the vest is usually seen against a dark background than during the day where vest visibility competes with bright backgrounds. Solomon (4) found 232 sq in. of reflectorized area was adequate, and Michon (3) thought that about 1,200 sq cm (196 sq in.) was sufficient area for adequate attention value.

Procedure

The procedure used in this study to evaluate the vest patterns approximated that described in Research Report R-873. Two flagmen, side by side, but separated about 4 ft with a STOP sign between them displayed a different vest pattern or material affixed to the standard fluorescent yellow-orange vest required by the Michigan Department of State Highways and Transportation (Fig. 4). Observers were instructed to choose within 15 seconds the "better" vest of each pair based on the subjective criteria of attention-getting, conspicuity, recognizability, meaning, and connotations of danger or hazard. The vests were arranged in a cyclic order and presented by varying the beginning of the order for each observer group. The observers were all drivers and Michigan Department of State Highways and



SHAPE "X"

SHAPE "Y"

Figure 2

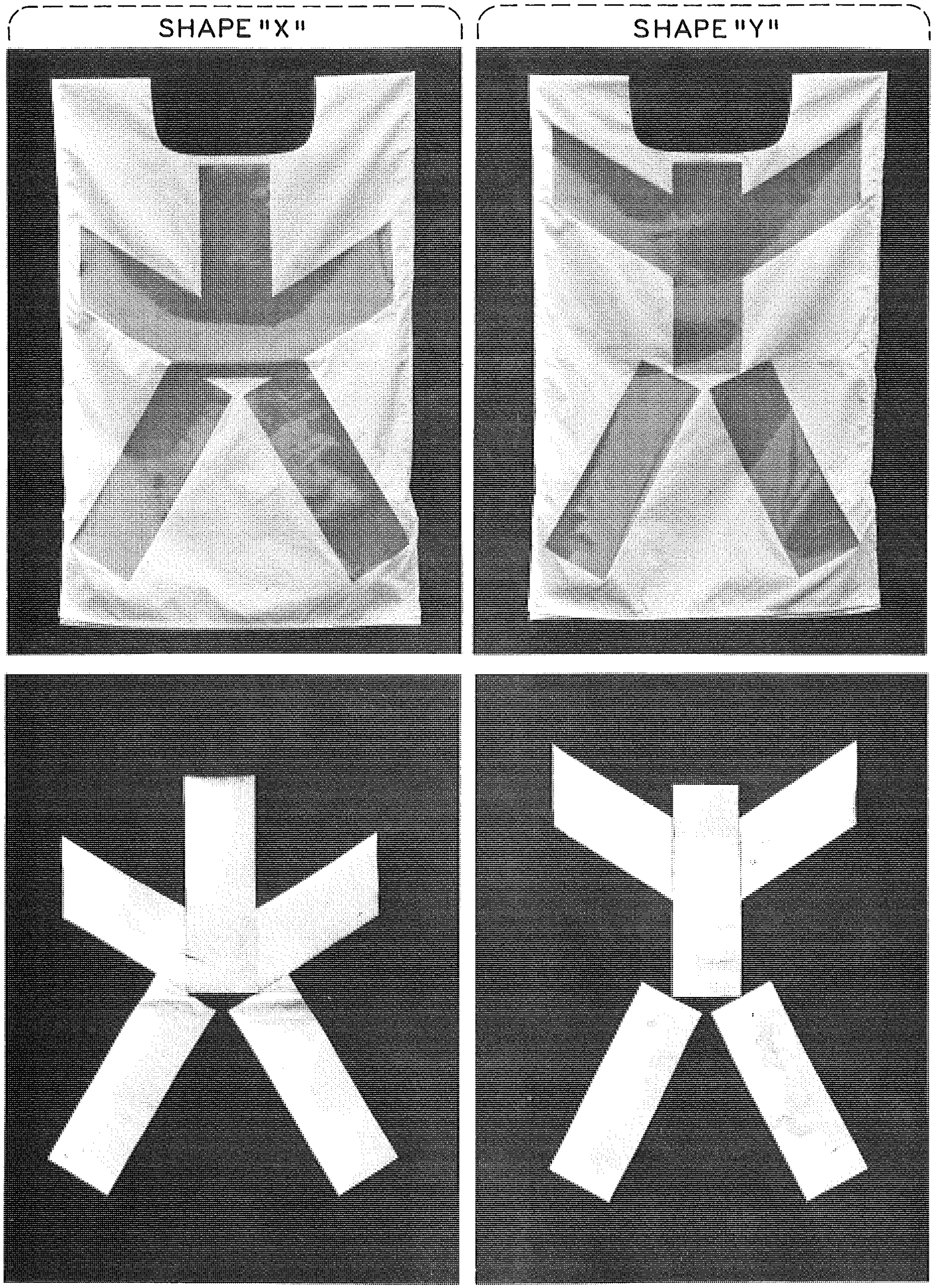


Figure 3. Daytime (top) and nighttime (bottom) appearance of experimental reflectorized vest patterns.

Figure 4. Traffic regulators wearing fluorescent orange vests with reflectorized patterns attached.

Transportation employees representative of the Maintenance, Testing and Research, and Traffic and Safety Divisions. The observers had vision corrected to 20/25 or better with no color blindness.

Observations took place in two lighting environments; urban and rural. The urban lighting environment contained advertising signs, residential and business lighting, as well as lighted objects visible to the observers including streetlights and a vehicle with two rotating beacons next to the flagmen. The rural lighting environment contained very few light sources in the field of view. The test distance for the urban environment was 350 ft; for the rural environment the observation distances were 500 and 1,000 ft. Twenty-three observers viewed the vest comparisons in the urban environment and seven observers viewed the patterns in the rural environment.

The 350 ft viewing distance was chosen for the following reasons:

1) The 6-in. high letters on the STOP sign normally held by the flagman should be read at approximately 300 ft under most lighting conditions. The vest pattern should be recognized a little farther.

2) Most urban sight distances are probably less than 300 to 400 ft.

3) Even at a rate of speed as high as 50 mph a fairly comfortable deceleration rate of 8 ft per sec/sec would allow a vehicle to come to a stop in approximately 340 ft. *

4) The outer limits of the effectiveness of low beam headlights is no more than 500 ft.

5) The last FLAGMAN AHEAD sign the driver normally sees should precede the flagman by 500 ft, it was therefore assumed that the driver should recognize the presence of a flagman soon after passing that sign. In addition, the PREPARE TO STOP sign is normally located 250 ft in front of the traffic regulator.

RESULTS

It must be remembered that the results of this study are based on static rather than dynamic viewing conditions of the actual roadway situation. Rank order of the vests might be altered under the dynamic viewing conditions of a driver in a moving vehicle.

Daytime

Illuminance at the vests was about 2,900 ft-c (clear sky, 3:00 p.m., June). Vest luminances were typically around 3,000 ft-L, the precise value depending upon the daylight color of the reflectorized, and in some instances, fluorescent material attached to the vest. The basic vest color in all cases was fluorescent yellow-orange.

Table 1 shows that the fluorescent yellow-green (3M) vest was chosen nearly unanimously by the observers when compared with all other vest materials in pairs. The other three fluorescent materials, all of them red, were preferred only to orange colored materials. Two non-fluorescent materials, a silver (Rowland) and a yellow (Rowland), were preferred over the fluorescent red materials from both 3M and Rowland. In one previous study a non-fluorescent color has been found to have greater visibility than its fluorescent counterpart color. Michon, Ernst, and Koutstaal, in a 1969 study (3) reported that a non-fluorescent yellow was detected by observers at a greater distance than a fluorescent yellow. They discovered

* Traffic Engineering Handbook (3rd Edition, 1965).

TABLE 1
DAYTIME OBSERVATION
350-ft Distance

Rank	Observer Preference, percent	Color of Reflectorized Vest Pattern		Manufacturer
		Day	Night	
1	98.0	Fluorescent yellow-green	Silver	3M
2	72.9	Silver	Silver	Rowland
3	69.4	Yellow	Yellow	Rowland
4	38.3	Fluorescent red	Red	Rowland
5	35.4	Fluorescent red	Red	3M
6	34.0	Fluorescent red	Silver	3M
7	29.2	Orange	Orange	3M
8	20.8	Orange	Orange	Rowland

that the fluorescent yellow was so bright that its yellow color washed out and acted as a white which has a shorter visibility distance than yellow. In fact, they found the non-fluorescent yellow could be seen farther than most typical fluorescent colors except fluorescent orange.

Several observers remarked that the red patterns, though fluorescent, were nevertheless darker in appearance than the silver or yellow non-fluorescent patterns, and had low contrast against the fluorescent yellow-orange materials of the vests.

Observers remarked that the yellow-green fluorescent material provided more contrast against the standard yellow-orange vest than did the fluorescent red patterns. Contrast with the standard vest color was important in vest visibility and recognition to most observers. They felt that the yellow non-fluorescent pattern also afforded some contrast with the fluorescent yellow-orange vest.

Shortly after sunset the vests were again compared with each other in pairs, and illuminated with low beam headlamps. Table 2 shows the rank order of observer preference.

The fluorescent yellow-green reflectorized pattern vest was still preferred compared with all of the other vests. Observers considered it the superior vest in each pair comparison in two-thirds of the occurrences but it no longer retained the wide margin in preference to the other vests that

TABLE 2
TWILIGHT OBSERVATION
350-ft Distance

Rank	Observer Preference, percent	Color of Reflectorized Vest Pattern		Manufacturer
		Day	Night	
1	66.7	Fluorescent yellow-green	Silver	3M
2	61.9	Yellow	Yellow	Rowland
3	54.0	Fluorescent red	Red	3M
4	52.4	Silver	Silver	Rowland
5	50.0	Fluorescent red	Silver	3M
6	50.0	Fluorescent red	Red	Rowland
7	40.4	Orange	Orange	Rowland
8	23.8	Orange	Orange	3M

it had in the daylight pair comparisons. The yellow non-fluorescent material ranked almost as high as the fluorescent yellow-green (silver reflectorized) material. The fluorescent reds and the reflectorized reds and silvers were grouped in the middle of the rankings with the reflectorized orange materials last in the rankings as they were in the daylight comparisons.

Nighttime (Urban Lighting Environment)

In the urban lighting environment the yellow pattern was chosen by the observers the highest proportion of the time for both upper and lower beams (Tables 3 and 4).

Of the factors contributing to the contrast of the vest with its background such as color, luminance, and shape of the vest pattern, luminance seems to have been weighted more heavily by the observers in making their choices.

For lower beams (Table 4) the order of observer preference is roughly the same as the vest patterns ordered according to decreasing luminance (Table 5).

There were two exceptions to this similarity of rankings: the yellow and silver (Rowland) ranking according to observer preference were interchanged relative to their ranking by luminance alone; the positions of the

TABLE 3
NIGHTTIME - URBAN LIGHTING ENVIRONMENT
(UPPER BEAMS)
350-ft Observation Distance

Rank	Observer Preference, percent	Color of Reflectorized Vest Pattern		Manufacturer
		Day	Night	
1	81.4	Yellow	Yellow	Rowland
2	77.4	Fluorescent red	Red	Rowland
3	68.5	Silver	Silver	Rowland
4	56.2	Orange	Orange	Rowland
5	42.8	Fluorescent yellow-green	Silver	3M
6	40.8	Fluorescent red	Red	3M
7	24.6	Fluorescent red	Silver	3M
8	7.5	Orange	Orange	3M

TABLE 4
NIGHTTIME - URBAN LIGHTING ENVIRONMENT
(LOWER BEAMS)
350-ft Observation Distance

Rank	Observer Preference, percent	Color of Reflectorized Vest Pattern		Manufacturer
		Day	Night	
1	81.0	Yellow	Yellow	Rowland
2	76.2	Silver	Silver	Rowland
3	61.9	Fluorescent yellow-green	Silver	3M
4	61.9	Orange	Orange	Rowland
5	52.4	Fluorescent red	Red	Rowland
6	38.1	Fluorescent red	Silver	3M
7	23.8	Orange	Orange	3M
8	4.8	Fluorescent red	Red	3M

TABLE 5
NIGHTTIME LUMINANCE OF
REFLECTORIZED VEST PATTERNS
350-ft Test Distance

Vest Description Color of Vest Pattern		Average Luminance, in ft-L		Manufacturer
Day	Night	Lower Beams	Upper Beams	
Silver	Silver	44.1	227.0	Rowland
Yellow	Yellow	36.3	197.0	Rowland
Fluorescent yellow-green	Silver	10.6	54.0	3M
Orange	Orange	9.7	52.0	Rowland
Fluorescent red	Silver	7.1	36.0	3M
Fluorescent red	Red	6.2	33.3	Rowland
Orange	Orange	2.4	13.9	3M
Fluorescent red	Red	2.3	11.3	3M

red (Rowland) and the 3M silver (daytime fluorescent red) were also interchanged. Several observers considered other pattern colors, such as yellow and red, superior to silver because they felt that the silver could be mistaken for oncoming headlights or for fixed lighting in the area. The reason that the Rowland red pattern was placed by observers ahead of the 3M silver (daytime fluorescent red) even though the luminance of the red pattern was less than the luminance of the silver may be that the red color contrasts more sharply with its background, has more attention value, or connotes danger to a greater degree than silver.

Austin, Klassen, and Vanstrum in an unpublished 3M study (5) found that a brightness level of nearly 20 ft-L (Fig. 2, p. 17) was required for a 256 sq in. target to be "attention getting,"* and about 1 ft-L minimum to be "easily visible." The area of each reflectorized vest pattern used in this study was 210 sq in. Table 5 contains only two reflectorized vest patterns that for low beams at 350 ft meet the 20 ft-L "attention getting" criterion: the patterns made with Rowland silver and yellow material. All of the remaining materials fall into the "easily visible" range.

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* The authors define "attention getting" as being not only bright enough to be "easily visible" but bright enough to attract one's attention even if not looking at the target.

For upper beams at 350 ft, six of the reflectorized vest materials meet the 20 ft-L requirement. However, low beams can be expected to be used by motorists the majority of the time while passing through a controlled construction or maintenance area.

Thirty-Degree Angle Orientation

Observers also compared flagman vest reflectorized patterns with the flagmen turned 30 degrees with respect to the viewing axis. The test was conducted using lower beams in the urban lighting environment at a distance of 350 ft. Table 6 lists observer preferences and corresponding luminances for each material for the 30-degree orientation. Again, the influence of vest brightness is evident, although red-colored materials are ranked higher than some brighter silver patterns. The Rowland vest materials were selected by the observers in preference to the 3M vest materials. Angles of incidence greater than 30 degrees might show a superiority of the 3M materials since the Rowland materials are based on cube-corner reflectivity, but 30 degrees was judged to be a practical maximum for flagman rotation. Researchers from the 3M Company who participated in the observations as reported in Table 6 concurred in the 30-degree criterion.

TABLE 6
VEST ROTATED 30 DEGREES WITH
RESPECT TO VIEWING AXIS

Rank	Observer Preference, percent	Color of Vest Pattern		Manufacturer	Low-Beam Luminance, ft-L
		Day	Night		
1	90.5	Silver	Silver	Rowland	17.1
2	80.0	Yellow	Yellow	Rowland	12.9
3	65.0	Orange	Orange	Rowland	3.6
4	57.1	Fluorescent red	Red	Rowland	1.5
5	47.6	Fluorescent yellow-green	Silver	3M	2.6
6	38.1	Fluorescent red	Red	3M	1.4
7	14.3	Fluorescent red	Silver	3M	1.5
8	9.5	Orange	Orange	3M	1.4

Luminances of reflectorized vests worn by flagmen turned 90 degrees with respect to the viewer were between 3 and 8 percent of the head-on luminance depending upon the vest material and the stance of the flagmen.

Nighttime (Rural Lighting Environment)

The observations were made on a moonless night at distances of 500 and 1,000 ft on a level plane surface. The vests were not discernible by all observers at 1,000 ft under low beam illumination. The observers had great difficulty in discerning the vests under low beam illumination at 500 ft. Disability veiling glare for the observers was negligible, although there were some extraneous lights and reflecting surfaces in the observers field of view.

Tables 7, 8, and 9 show observer preferences for reflectorized pattern color in the rural lighting environment. Under conditions of high brightness contrast such as the rural lighting environment where there were relatively fewer lights in the field of view competing with the vest brightness, the observers favored the red reflective material by Rowland with the exception of a preference for Rowland silver at 500 ft using low beams. Observers commented that although the silver patterns were the most visible at 1,000 ft, they felt they could have easily interpreted the silver pat-

TABLE 7
NIGHTTIME - RURAL LIGHTING ENVIRONMENT
(LOWER BEAMS)
500-ft Observation Distance

Rank	Observer Preference, percent	Color of Reflectorized Vest Pattern		Manufacturer
		Day	Night	
1	88.6	Silver	Silver	Rowland
2	80.0	Fluorescent red	Red	Rowland
3	80.0	Yellow	Yellow	Rowland
4	51.4	Fluorescent yellow-green	Silver	3M
5	48.6	Orange	Orange	Rowland
6	31.4	Fluorescent red	Silver	3M
7	17.1	Fluorescent red	Red	3M
8	2.9	Orange	Orange	3M

TABLE 8
NIGHTTIME - RURAL LIGHTING ENVIRONMENT
(UPPER BEAMS)
500-ft Observation Distance

Rank	Observer Preference, percent	Color of Reflectorized Vest Pattern		Manufacturer
		Day	Night	
1	85.7	Fluorescent red	Red	Rowland
2	68.6	Yellow	Yellow	Rowland
3	62.8	Fluorescent red	Red	3M
4	57.1	Orange	Orange	Rowland
5	51.4	Silver	Silver	Rowland
6	40.0	Fluorescent yellow-green	Silver	3M
7	25.7	Fluorescent red	Silver	3M
8	8.6	Orange	Orange	3M

TABLE 9
NIGHTTIME - RURAL LIGHTING ENVIRONMENT
(UPPER BEAMS)
1,000-ft Observation Distance

Rank	Observer Preference, percent	Color of Reflectorized Vest Pattern		Manufacturer
		Day	Night	
1	82.8	Fluorescent red	Red	Rowland
2	77.1	Silver	Silver	Rowland
3	60.0	Yellow	Yellow	Rowland
4	51.4	Orange	Orange	Rowland
5	48.6	Fluorescent yellow-green	Silver	3M
6	45.7	Fluorescent red	Red	3M
7	31.4	Fluorescent red	Silver	3M
8	2.9	Orange	Orange	3M

terns as oncoming headlights. Therefore, they selected the red pattern as their preference since in their opinion red had more warning value even though it apparently was less bright than the silver or yellow patterns made from Rowland material.

Many observers remarked that the orange color, Construction Orange, was very drab with little attention-getting value. The color of Construction Orange, as set forth by the FHWA for reflective signs (Highway Orange), and as manufactured by 3M and Rowland for reflective fabric, has low chromatic saturation or purity. It has been established that most colors including orange must have high purity for good visibility.

Shape

There were patterns with two different humanoid shapes presented to the observers dubbed the "X" type and the "Y" type (Fig. 2). Table 10 lists their relative observer preference by viewing condition.

The "Y" pattern shape was preferred to the "X" pattern shape under most viewing conditions. In daylight, dusk, and in nighttime urban viewing conditions observers did not show a strong preference for either shape. In nighttime rural viewing conditions observers strongly preferred the "Y" pattern.

In general, observers preferred the "Y" shape when the patterns were poorly illuminated. Several observers remarked that pattern "X" became a shapeless "blob" under poorer lighting conditions but they thought that the "Y" also tended to become amorphous where the pattern was dim.

A number of observers also felt that for the lower vest luminance levels at the 1,000 ft and at the 500 ft distance achieved with low beams, shape was more important than color or brightness. They felt that the "Y" pattern was more distinctive than the "X" pattern where compared with patterns of other reflective surfaces or lights that could be seen. Additionally, the "Y" shape was considered more indicative of the flagman function by many observers because it vaguely resembled a human figure with upraised arms.

STOP Sign

Many observers remarked that the STOP sign held by the flagman was barely visible under lower beam illumination. Moreover, the STOP sign was invisible at 1,000 ft with upper beam illumination in the rural lighting

TABLE 10
PATTERN SHAPE PREFERENCE
"X" AND "Y" SHAPES

Lighting Environment	Observation Distance, ft	Observer Preference, percent	
		"X" Shape	"Y" Shape
Day	350	47	53
Dusk, urban, lower beams	350	67	33
Night, urban, lower beams	350	48	52
Night, urban, upper beams	350	58	42
Night, urban, lower beams, 30 degree incident angle	350	42	58
Night, rural, lower beams	500	7	93
Night, rural, upper beams	500	32	68
Night, rural, upper beams	1,000	10	90

environment. The STOP sign had enclosed lens reflective sheeting affixed to it. The sheeting may have been five years old. The bottom height of the STOP sign was six feet in conformance with Michigan practice. The purpose of the six foot bottom height is to enable drivers to see the sign over the tops of vehicles.

In addition, when the STOP legend was scrambled at random intervals, none of the observers noticed the changed legend. *

* The scrambled legend was "POTS."

The luminance of the STOP sign was measured. Table 11 shows the luminances for the engineering grade reflective sheeting on the STOP sign used in the test. For comparison purposes luminances for a STOP sign with red silkscreened on high-intensity silver reflective sheeting and for the red (Rowland) flagman vest pattern are also shown. Since the luminance of the silkscreened red on high intensity is comparable to the luminance of the red vest pattern, and because the STOP sign should be at least as conspicuous as the person holding the sign, it is recommended that high-intensity instead of engineering grade reflective sheeting be used on all STOP signs held by traffic regulators wearing reflectorized vests.

TABLE 11
STOP SIGN LUMINANCE
350-ft Test Distance

Description of Reflective Materials on STOP Sign	Luminance, ft-L Upper Beams
Red reflective sheeting, enclosed lens	5.4
Silver legend reflective sheeting, enclosed lens	11.5
Red, silkscreened on silver encapsulated lens, reflective sheeting (6 ft bottom height)	36.0
Red, silkscreened on silver encapsulated lens, reflective sheeting (5 ft bottom height)	40.0
Red reflectorized vest material by Rowland for comparison	33.3

The luminance for a STOP sign with red high-intensity reflective sheeting at a five-foot bottom height (allowed by the Federal MUTCD) shows little more than a 10 percent increase over an identical sign held at the six-foot bottom height. Lowering the STOP sign one foot in height would not then improve significantly the visibility of the sign as much as would the use of high-intensity sheeting.

Additional Reflectorization

Reflectorization of the flagman in the form of reflectorized forearm gauntlets and leggings was shown to a group of six observers in comparison with a flagman wearing only a reflectorized vest. The observers remarked that the additional reflectorization was a great improvement especially when the flagman moved his arms and legs. The movement was very attention-getting.

In a September 7, 1973 letter to M. N. Clyde, Engineer of Traffic and Safety, K. A. Allemeier, Engineer of Testing and Research recommended use of reflectorized flagman vests on an experimental basis by Testing and Research inspectors who were obtaining density measurements at night for an I 75 resurfacing project.

He recommended that reflectorization be used for other than traffic regulator vests since vest reflectorization seemed to be a reasonable safety consideration. Accordingly, the 3M and Rowland vests which had been used in this study were worn on a trial basis for two nights by Testing and Research Division inspectors on the job on I 75. An observer reported that as he drove through the construction site all the reflectorized patterns were visible, but very few of the workers not wearing reflectorized vests, were visible. In fact, one of the workers was nearly struck by a vehicle.

CONCLUSIONS

Shape

Fully reflectorized vests might be seen farther than partially reflectorized patterned vests; however, fully reflectorized vests might not be recognized as a flagman as far away as a suitably shaped pattern. The evidence of the primarily subjective observer responses points to shape "Y" as being the clearly superior of the two humanoid shapes "X" and "Y," considered by this study. The two shapes used for this study were based on observer preference as a result of viewing the several shapes described in Research Report No. R-873, July 1973.

Observers preferred shape "Y" predominantly where the viewing conditions were more difficult. The shape also has the advantage of being associated with the function of the wearer.

Therefore, the man-like shape "Y" is recommended for the reflective pattern for vests worn by traffic regulators at night. Dimensions of shape "Y" are given in Appendix.

Color, Daytime

In an unpublished study (1970) it was found that against green foliage, concrete, asphalt, and other typical roadway backgrounds, a fluorescent orange flagman vest could be seen from 120 to 180 percent as far in daylight as the former Michigan standard flagman vest with yellow and black diamond pattern (see the Michigan Manual of Uniform Traffic Control Devices, 1971); however, against the ubiquitous orange of highway vehicles the fluorescent orange vest could be seen about 95 percent of the maximum sight distance of the yellow and black vest.

Since the Safety Section has indicated an interest in flagman vests which are both conspicuous under all viewing conditions and which also provide sufficient color contrast with orange highway equipment, it would be desirable that the flagman vest display a color other than, and in addition to, the fluorescent yellow-orange color of the vest. This additional color might well be yellow (2, 3, 4). The yellow need not be fluorescent. In the majority of viewing situations non-fluorescent yellow is more conspicuous than fluorescent yellow (3).

However, the Federal Manual on Uniform Traffic Control Devices can be interpreted as forbidding any color other than orange: "... the use of an orange vest and/or an orange cap shall be required for flagmen." This statement can be construed to mean that only the color orange should appear on the vest; hence, no reflectorized color other than orange could be affixed to the orange vest unless it could be removed for daytime use.

Color, Nighttime

Despite the apparent intent of the MUTCD, this study clearly shows that observers did not prefer orange as the color for the reflectorized vest pattern, unless the luminance of the orange fabric was higher than the luminance of the fabrics with which it was compared. The 3M orange fabric with a low luminance (only the 3M red pattern was lower) invariably ranked last or next to last for all viewing conditions. The Rowland orange fabric with a luminance above that of all of the 3M fabrics was preferred over all the 3M fabric colors in some viewing conditions, but the Rowland material patterns of yellow, silver, and red usually ranked higher than the orange.

The orange fabrics from both manufacturers were low saturation colors and hence relatively inconspicuous. An orange fabric with a more saturated or pure color might improve the ranking of the orange fabric.

From this study it appears that luminance or reflectivity is an important design consideration for a flagman vest, especially for lower beam illumination.

The patterns with the greatest reflectivity or brightness, the silver patterns, were highly rated, but some observers complained that the silver patterns had poor color contrast with their surroundings. Several observers confused the silver patterns with headlights.

Patterns made with the red Rowland material also were ranked high by the observers. Observers tended to associate the color red with danger. The color red apparently provided more color contrast than the other colors since the red fabrics had the lowest luminance (Table 5).

For the lighting environments used in this study the pattern made with yellow Rowland material ranked slightly higher overall than the red and silver patterns as shown by Table 12.

Examination of Table 12, which compares the four colors of vests made with Rowland material, shows that with the exception of orange, the colors are extremely close in observer preference over all viewing conditions. The yellow color performs best in the 350 ft viewing distance urban (high glare) lighting environment, perhaps the most frequent situation in which motorists encounter traffic regulators, and also does well in the rural (low glare) lighting environment, as well as in the daylight illumination.

Silver patterns carry the risk of being mistaken for headlamps or other lights, as noted by several observers. Red patterns have the greatest color contrast against most backgrounds, but may compete with the red STOP sign that the flagman controls.

Therefore, yellow is recommended as the color for the reflectorized portion of flagman vests.

Rowland was the only manufacturer of yellow reflectorized fabrics evaluated by this study. Rowland reflectorized fabrics will lose their reflectivity if the clear plastic covering is torn and water is permitted to flood the prism retro-reflective material inside. The 3M fluorescent yellow-green performed very well in daytime comparisons and moderately well in nighttime comparisons. The 3M fabric consists of exposed glass beaded material and may be difficult to keep clean under normal field conditions. Therefore a field trial period on construction projects of both the Rowland and 3M reflectorized fabric on fluorescent yellow-orange flagman vests is recommended. The color of the Rowland fabric should be yellow and the 3M fabric should be the dual-purpose fluorescent yellow-green and reflectorized silver material. The shape of the reflective pattern for the field trial should be the "Y" shape (Appendix A).

TABLE 12
SUMMARY OF RANKINGS OF VESTS (ROWLAND)* BY COLOR

Lighting Environment	Observation Distance, ft	Rank of Color			
		Yellow	Red	Silver	Orange
Day	350	3	4	2	8
Dusk, urban, lower beams	350	2	6	4	7
Night, urban, lower beams	350	1	5	2	4
Night, urban, upper beams	350	1	1	3	4
Night, urban, lower beams, 30 degree incident angle	350	2	4	1	3
Night, rural, lower beams	500	3	2	1	5
Night, rural, upper beams	500	2	1	5	4
Night, rural, upper beams	1,000	3	1	2	4
Average Rank		2.1	3.0	2.5	4.9

* For comparison, the average rank of the 3M dual-purpose fluorescent yellow-green and reflectorized silver fabric was 3.8.

RECOMMENDATIONS

1. The shape of the reflectorized pattern should be as shown for pattern "Y" in Appendix A.

2. The color of the pattern should be FHWA Highway Yellow (Color PR No. 1).

3. The Rowland yellow fabric and the 3M dual-purpose fluorescent yellow-green and reflectorized silver material should undergo field trials of up to one year on construction projects.

4. Fabrication of the vests should be investigated to determine the most economical procurement. Fabrication methods and distribution should also consider the very limited nighttime use of reflectorized vests.

5. If feasible, traffic regulators should wear reflectorized gauntlets and leglets in addition to the reflectorized vest.

6. The STOP sign controlled by the flagman should be silkscreened on silver encapsulated lens or "high-intensity" sheeting rather than on silver enclosed lens sheeting as is now the practice.

7. In considering the above recommendations it is also suggested that the Department be requested to propose MUTCD revisions which would incorporate the following:

   a. For night time conditions a flagman vest shall bear a reflectorized pattern, front and back, as illustrated by pattern "Y" in Appendix A.

   b. The color of the pattern shall be FHWA Highway Yellow (Color PR No. 1).

   c. When flagging traffic at night, reflectorized arm gauntlets and leglets may be used to provide signaling emphasis.

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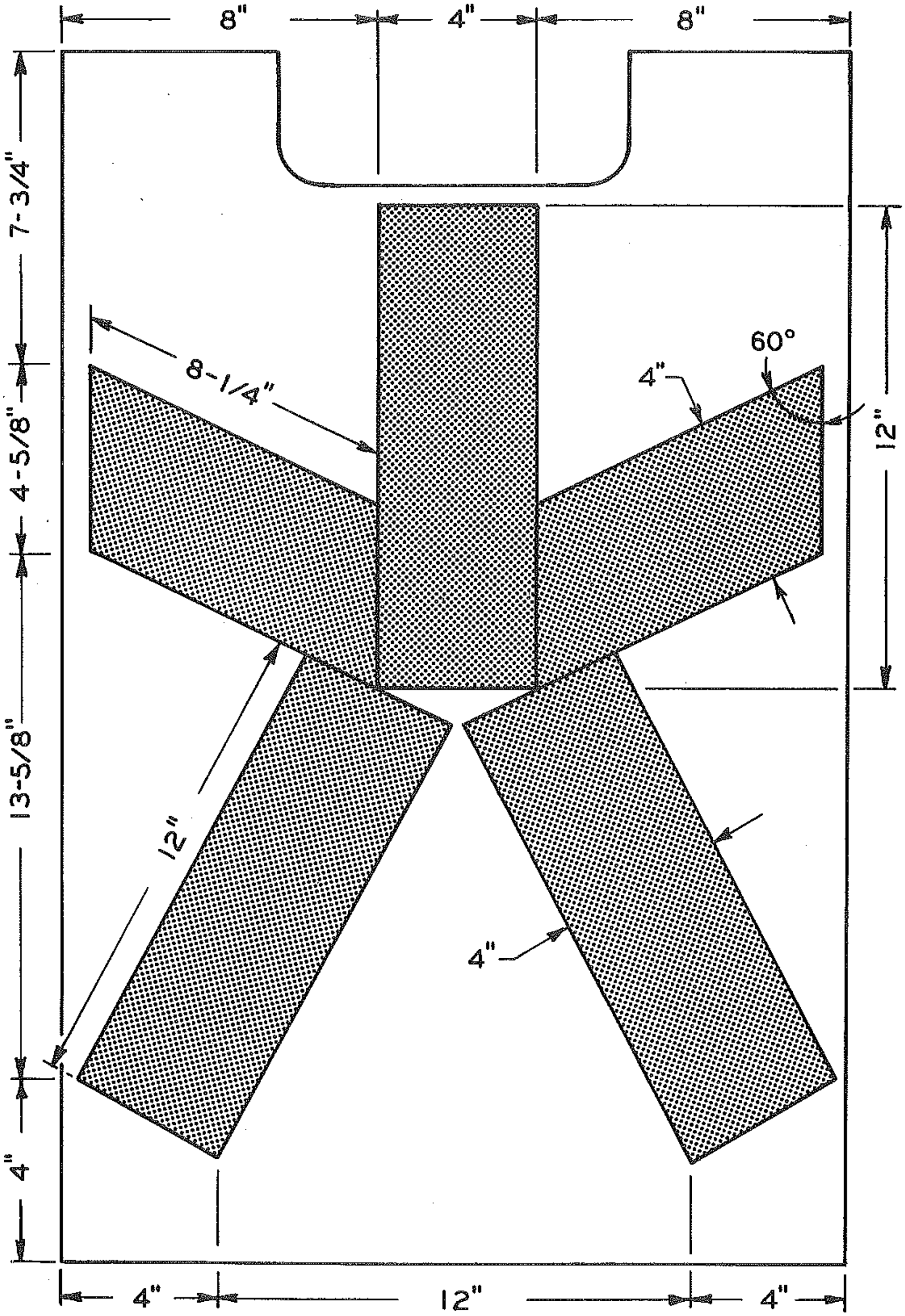
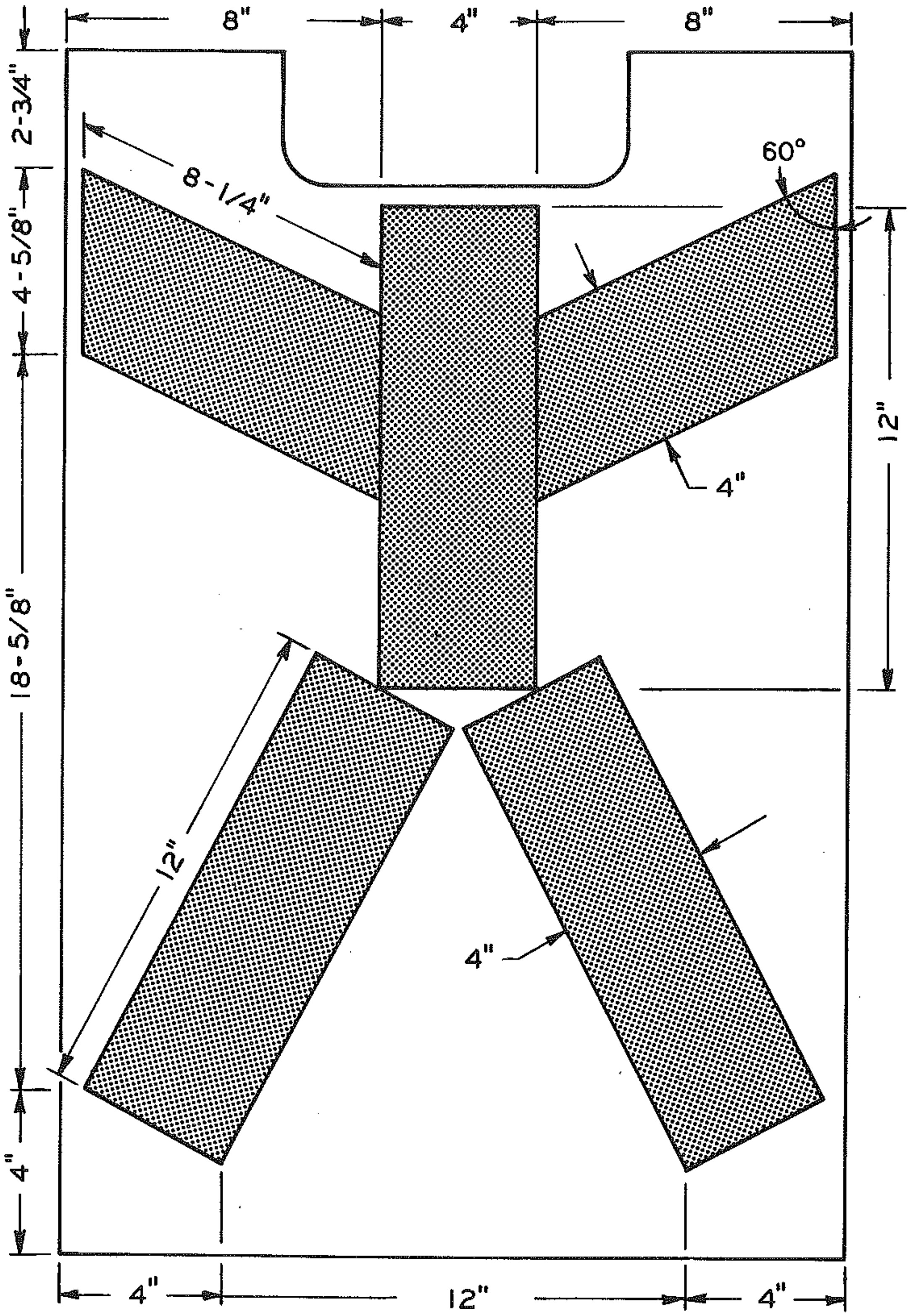
5. Austin, R. L., Klassen, D. J., Vanstrum, R. C., "Pedestrian Conspicuity Under the Standard Headlight System Related to Driver Perception," 3M Company, unpublished.

APPENDIX A



REFLECTIVE PATTERN "X"



REFLECTIVE PATTERN "Y"