REFLECTORIZATION OF FLUORESCENT FLAGMAN VESTS

MATERIALS and TECHNOLOGY DIVISION

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M. H. Janson
G. M. Smith

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E. V. Erickson, Chairman; Charles H. Hewitt,
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As a result of a meeting held January 31, 1973 between L. J. Doyle, D. F. Haley and Max Clyde, colors and patterns of reflectorized and fluorescent flagman vests have been evaluated. The Federal "Manual of Uniform Traffic Control Devices" states that flagman vests must be orange in the daylight, and that they must be reflectorized at night. The Manual does not specifically require orange at night. MDSH has specified a fluorescent yellow-orange for flagman vests, but the color is not known to be available on a material which is both fluorescent and reflective. Therefore, a reflective material must be used either in conjunction with or attached to the fluorescent vest at night.

Initially, eight vests of various patterns as shown in Figure 1 A-H were furnished by the Safety Section for evaluation. The vests were fabricated at Michigan State Industries by sewing red-orange, orange, and silver reflectorized vinyl material (manufactured by the 3M Co.) to fluorescent yellow-orange (Blaze Orange*) color vests. In addition to these, the Photometric Group constructed three more patterns as shown in Figure 1 (I, J, K). Construction Orange reflective sheeting was attached to fluorescent yellow-orange vests.

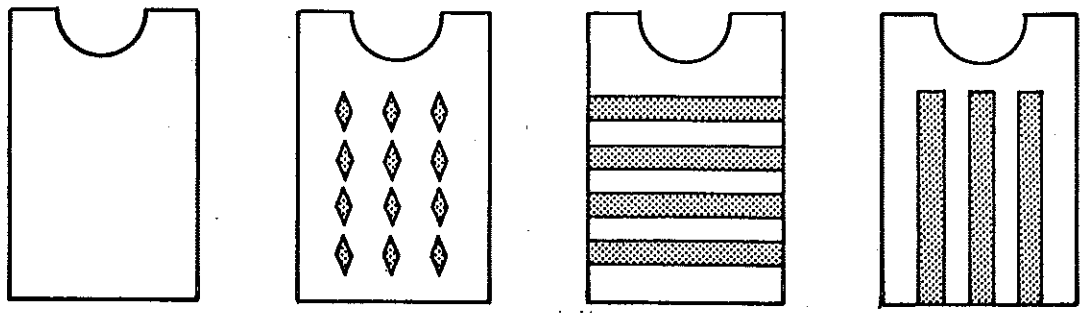
The reflective materials were photometered and the vests were viewed by observers under daytime and nighttime lighting conditions.

The photometric results are listed in Tables 1 and 2. Both tables display photometric factors which apply regardless of the size of the reflective portion of a vest.

Table 1 gives the specific luminance in terms of candela per unit area. The intensities were determined at a 100-ft distance according to the Research Laboratory's standard method of test for reflectorized materials, Research Report No. R-785. Note that the 3M orange vinyl reflective material has approximately the same specific luminance as the 3M Highway Construction Orange (Engineering Grade) sheeting used on signs.

Table 2 lists luminance or brightness values in foot-Lamberts, of the reflective materials for each color. The values were measured by means of a Pritchard telephotometer placed at the average driver's eye position. A set of upper beam headlamps, conforming to Society of Automotive Engineers recommendations and spaced according to a typical 1970 model automobile, provided the illumination at a distance of 100 ft from the vests.

*Dayglo Corp., Cleveland, O., trademark.

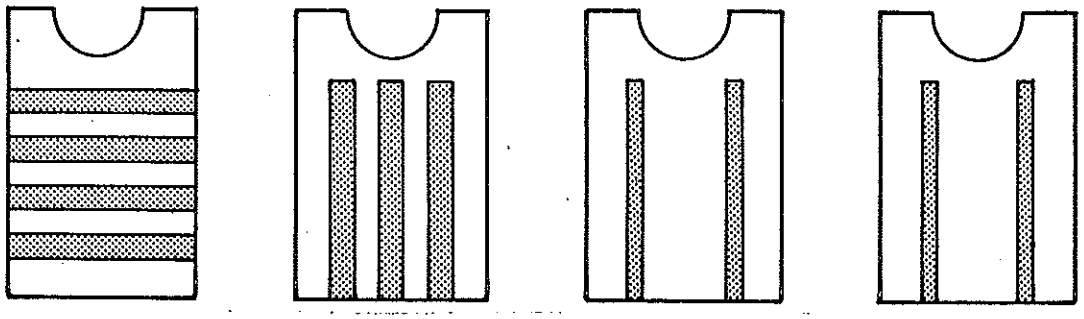


A
Control

B
3 In. Diamonds
Red-Orange

C
3 In. Stripes
Construction
Orange

D
3 In. Stripes
Construction
Orange

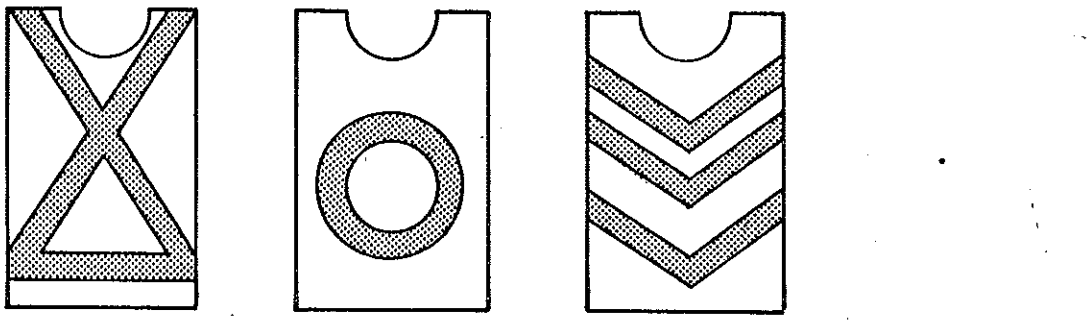


E
3 In. Stripes
Red-Orange

F
3 In. Stripes
Red-Orange

G
2 In. Stripes
Red-Orange

H
2 In. Stripes
Silver



I
3 In. Stripes
Construction
Orange

J
3 In. Ring
Construction
Orange

K
3 In. Stripes
Silver

Figure 1. Fluorescent orange flagman vest. Shaded areas reflectorized. Pattern dimension and color as noted.

TABLE 1
SPECIFIC INTENSITY OF REFLECTIVE MATERIAL
(Specific Luminance in cd/ft-c/sq ft)

Divergence Angle, degrees	Entrance Angle, degrees	Color				
		Red-Orange[1]	Orange[1]	Silver[1]	Construction Orange[2]	Stop Sign Red[3]
1/5	-4	15.6	32.5	102	35	12.5
	30	9.0	17.5	61.1	18	7.5
1/2	-4	8.9	16.5	42.4	19	5.3
	30	5.9	11.6	35.0	12	4.5

[1] vinyl
[2] reflective sheeting
[3] silk screened on silver reflective sheeting

TABLE 2
LUMINANCE WITH HEADLIGHTS AT 100 ft

Color	Luminance, in ft-L
Red-Orange (vinyl)	20.5
Orange (vinyl)	32.2
Silver (vinyl)	105
Construction Orange (reflective sheeting)	34.4

When these values at 100 ft were applied according to the inverse square law at 500 ft and then compared with the results from a legibility study conducted by the Laboratory using illuminated signs (see "Luminance Requirements for Illuminated Signs," Highway Research Record No. 179), it was found that the reduced luminance values were adequate for target recognition.

The daylight luminance of the vests in bright sunlight (clear sky, 3:00 p.m.) averaged 3,000 ft-L and ranged from a low of about 2,500 ft-L (vest with "O" pattern, Fig. 1 J) to around 3,500 ft-L (vest with two vertical silver stripes, Fig. 1 H). On a cloudy day the vest luminances averaged 2,400 ft-L and ranged from 2,100 ft-L ("O" pattern, Fig. 1 J) to 2,900 ft-L (vest with two silver stripes, Fig. 1 H).

The blank vest (Fig. 1 A) had a luminance of around 3,500 ft-L on a clear day and 3,100 ft-L on a cloudy day.

The vests with patterns using the most reflective material exhibited the least daylight luminance and the vests with smaller area patterns had the higher daylight luminances. For example, the luminance of the vest with the two silver vertical stripes (a small area pattern, Fig. 1 H) was approximately the same as the blank vest luminance.

On June 21, 1973, eight observers viewed the eleven vests under day and night conditions at 500 ft (Fig. 2).

This 500-ft viewing distance was chosen for the following reasons:

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

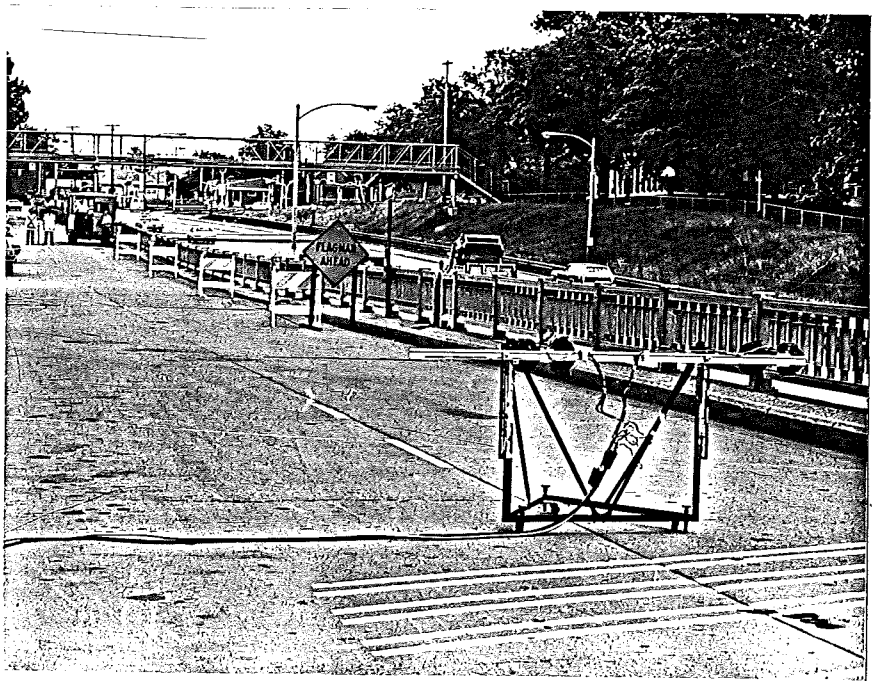
2. The outer limits of the effectiveness of lower beam headlights is about 500 ft (upper beams were used for the nighttime observations, because only pair comparisons were made and it was intended that the patterns be distinct).

3. The last "Flagman Ahead" sign the driver normally sees should precede the flagman by 500 ft at which point the driver should also recognize the presence of a flagman.

The vests were presented a pair at a time. The instructions to observers read "If you were a flagman, which vest of each pair would you prefer to wear? Mark the box signifying the preferred vest." Observers were also asked to base their choice on the more conspicuous or more visible of the two vests. Additionally, they were asked to take into account other factors connoting safety, caution, or ease of recognition as they saw fit.

The daytime results showed little preference for any particular vest. It had been expected that the area of the reflective material which covered the vest would adversely affect the daytime visibility of the vests because luminance was affected (see above). This effect was noted but not considered significant. Consideration was also given to condition of the vests. The yellow-orange or Blaze Orange material was new and clean. A weathered and soiled vest may have enhanced the effect.

Rotating beacons on van were operating during night-time comparisons.



Headlamp apparatus and observer view of test area.

Figure 2. Experimental set-up for day and night flagman vest comparisons.

The nighttime results, however, showed significant differences. The rank order of observer preference was:

Rank		Percent of Observer Choices
1	Four horizontal red-orange stripes (Fig. 1 E)	97
2	"X" over bar, Orange (1 I)	90
3	Three vertical red-orange stripes (1 F)	70
4	Three vertical Orange stripes (1 D)	55
5	Chevron, Silver (1 K)	54
6	Four horizontal Orange stripes (1 C)	54
7	Two vertical Silver stripes (1 H)	28
8	Two vertical red-orange stripes (1 G)	28
9	Diamonds, red-orange (1 B)	12
10	Annular ring, Orange (1 J)	12
11	Blank vest with no reflectorization (1 A)	0

Where striped patterns with different colors were compared, the ranking for color was:

1	Red	75
2	Silver	28
3	Orange	25

The only silver striped pattern consisted of just two vertical stripes. Where the two-stripe silver was compared with the two stripe red only, six of eight observers preferred the silver pattern.

Among orange patterns the X-over-bar (1 I, 93 percent) and the four horizontal stripes (1 C, 63 percent) were ranked first and second, respectively, over vertical stripes (1 D, 46 percent) and the "O" pattern (1 J, 13 percent).

Where only red patterns were compared the horizontal stripes (100 percent) were preferred to vertical stripes (67 percent).

In summary, the observers had clear preferences for the X-over-bar pattern and horizontal stripe patterns, and for the color red-orange.

Following the outdoor tests it was noted that the diamond pattern may have performed poorly because the diamonds were only 3 in. and should have been 4-1/2 in. It was noted too that color preferences could not be separated from pattern preferences. Therefore, it was decided that another test should be conducted under nighttime conditions. On June 28, 1973, a 500-ft viewing condition was simulated in the photometric laboratory by presenting 1/5 normal size vests to observers at a 100-ft distance. Illumination on the vests was equivalent to the illumination which would be provided at 500 ft by a standard set of headlamps but adjusted to approximate an average of upper and lower beam illumination.

The reflectorized patterns employed for this test were variations on the theme of the favored patterns from the outdoor test, viz., the "X" design and the horizontal striped pattern (Fig. 3). The chevron pattern was also retained since it was a pattern containing diagonal striping, and because some other states are using chevron patterns on flagman's vests. A fluorescent red-orange vest with reflectorized silver chevrons is being marketed under the trademark, "Skilcraft," by the Columbia Lighthouse for the Blind, Inc., Washington, D. C.

All the patterns were made from Highway Construction Orange reflective sheeting because we have interpreted the Federal "Manual of Uniform Traffic Control Devices" to mean that the nighttime as well as the daytime appearance should be orange. Twenty observers chose the better vest, again, basing their decision primarily on personal preference with emphasis on conspicuousness, recognizability, and connotations of safety. The same instructions as in the outdoor test were printed on the observer's data sheet.

Each pattern was compared with each one of the other six patterns. The patterns were psychologically scaled according to the pair comparison method and the results are shown in Figure 4. The scaling shows not only rank order of pattern preference, but also strength of preference as shown by the spacing between the preference values. The values are dimensionless and have no meaning other than to denote size of intervals between preferences. The results as depicted by Figure 4 indicate very strong preferences for four of the seven patterns. The intervals between the top three are significant yet small. The observer results indicate preference for a red color, triangular shapes, and rectangular shapes.

The nighttime specific luminance and luminance of the reflectorized portion of the miniature vests was the same as the specific luminance and luminance of the construction orange reflective sheeting listed in Tables 1 and 2.

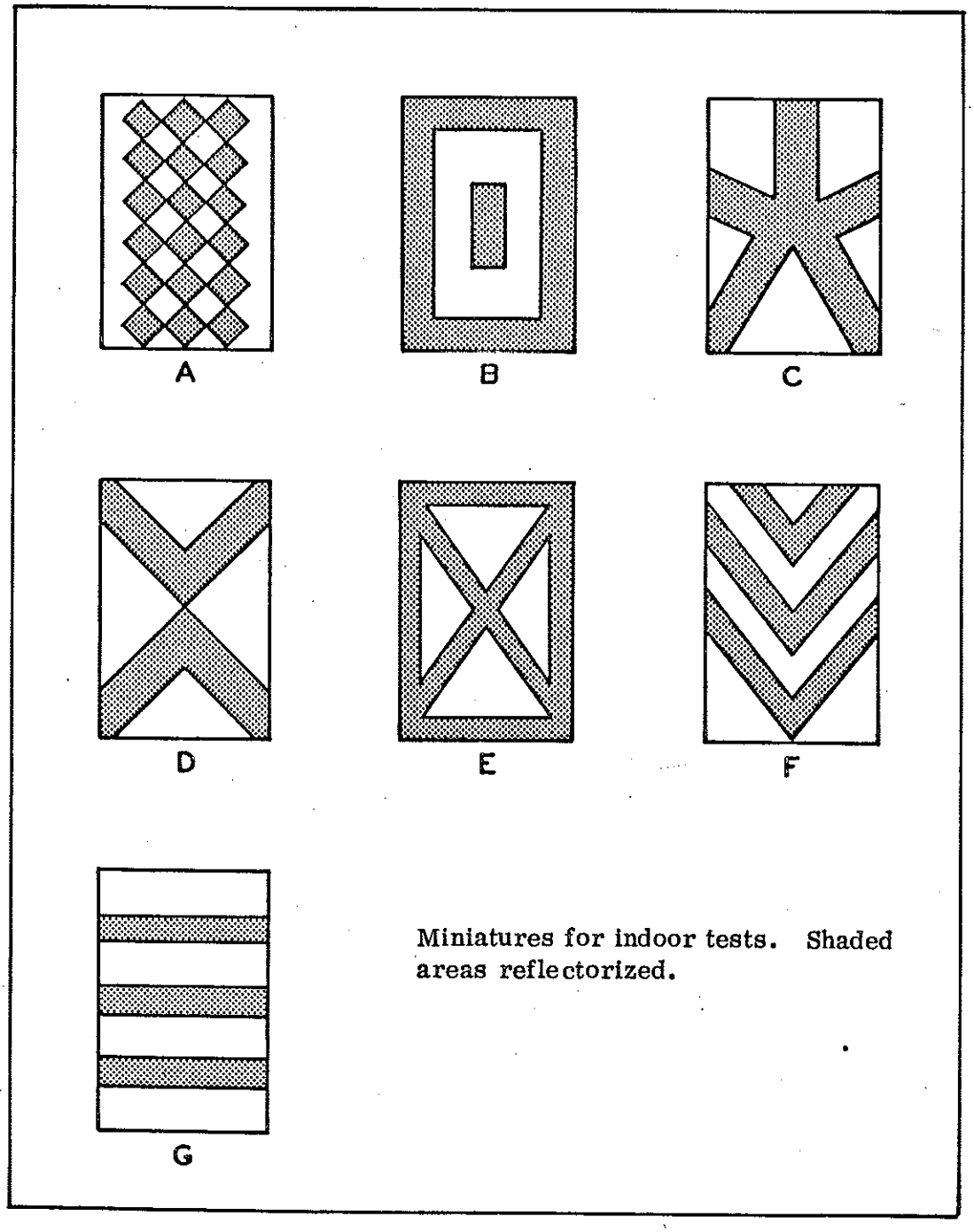


Figure 3. Fluorescent orange flagman vests.

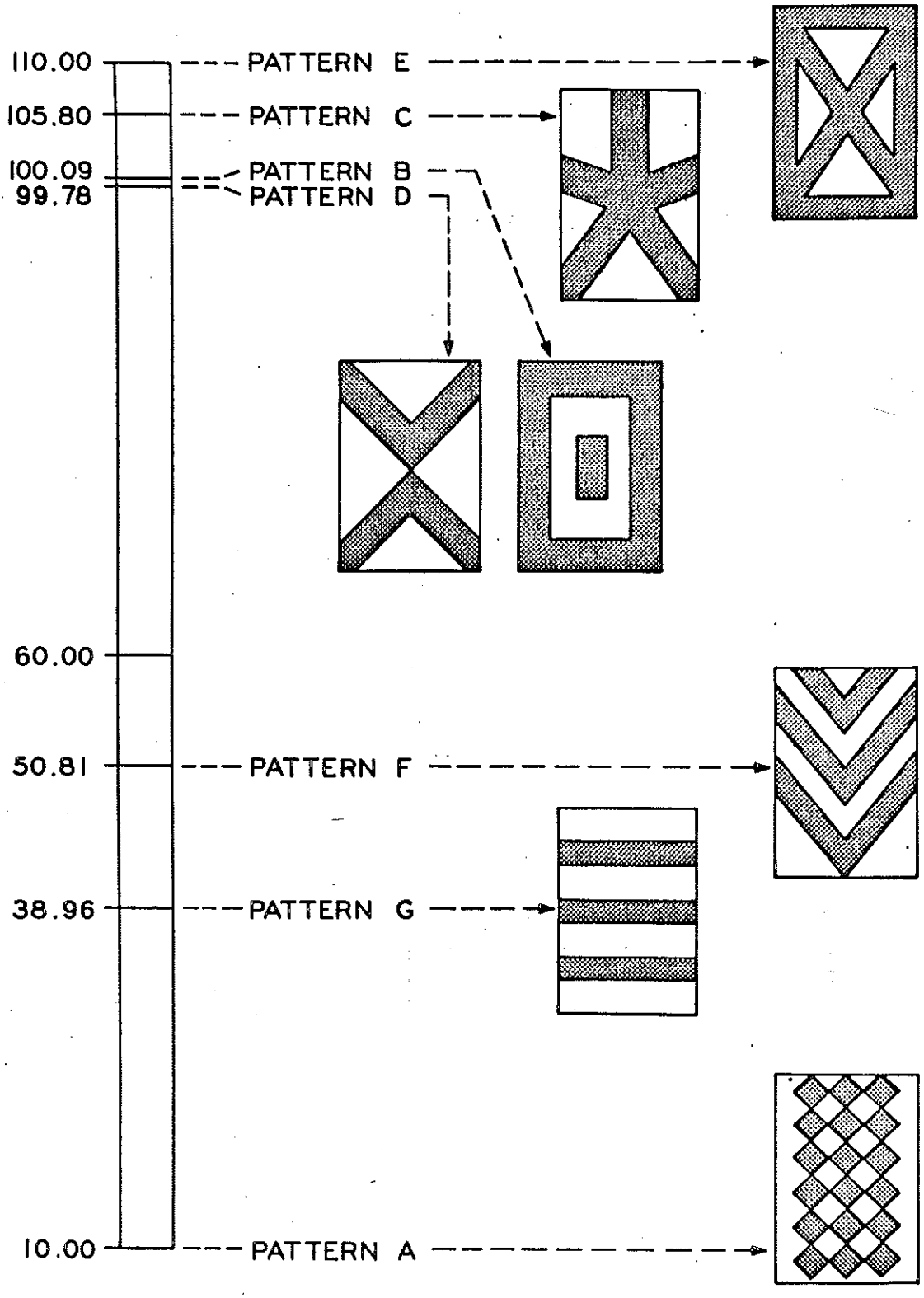


Figure 4. Scaling of pair comparison test results.

The daytime luminance of the miniature vests averaged 2,400 ft-L for bright sunlight and 1,900 ft-L for a partly cloudy day. The vest luminances on a clear day ranged from about 2,300 ft-L (for the patterns, Fig. 3 E and C) to 2,600 ft-L (for the Fig. 3 G pattern), and on a cloudy day from approximately 1,700 ft-L (Fig. 3 E and C patterns) to about 2,000 ft-L (Fig. 3 G and D patterns).

Again, as with the full-sized vests, the area of the reflective material on the vest was inversely related to the daytime luminance of the vests.

The three vests with the greatest reflective area were preferred to the other four vests by observers. It might be concluded that a fully reflectorized vest would be most preferred. Nevertheless, while fully reflectorized vests could be seen farther than the patterned vests, it may not necessarily be recognized as a flagman as far away as a suitably patterned vest.

A red color preference was expected because it provided the most color contrast in the field of view. However, since the driving population has been trained to associate red colors with signs and signals meaning "stop" or "forbidden" it appears doubtful that red colors should be used to provide nighttime conspicuousness for traffic regulators or flagmen.

A study by the Institute for Perception, Sosterberg, Netherlands (J. A. Michon, et al., "Safety Clothing for Human Traffic Obstacles," Ergonomics, 1969, Vol. 12, No. 1, 61-70) has shown that fluorescent orange is more conspicuous against most backgrounds than most other fluorescent or non-fluorescent colors. Fluorescent red-orange was almost as effective, but caused some trouble for color vision deficient persons.

As mentioned above, the "Manual of Uniform Traffic Control Devices," states that a flagman vest should be orange for daytime use and should be reflectorized for nighttime use. Reflectorized color is not specifically established, but in reviewing other parts of the manual intent can be assumed. For example, it is doubtful that yellow (highway sign yellow) should be used because it is the color replaced by orange in maintenance and construction zones. The Manual also dictates that yellow and orange signs should not be intermixed. Silver or white is used on other devices but if such colors are permanently attached to the vest then daytime appearance of the vest may not conform with the manual. Therefore if the daytime orange color of a flagman's vest were a non-fluorescent construction orange then a reflectorized construction orange color could be added or used in conjunction with the vest for nighttime use.

If the daytime color is a fluorescent "blaze-orange" or "yellow-orange," as adopted by the Department, then reflectorization presents a slight problem because the existence of a reflectorized fluorescent orange color is not known. However, adding a non-fluorescent reflectorized construction orange in pattern form may be acceptable even though the pattern could appear relatively dark on a bright background in the daytime and would only show the orange pattern at night.

The use of an orange or silver reflectorized color instead of red would also avoid competition with the STOP sign or the red flags a flagman can use. In many of the tests, viewing comparisons, especially at night, the vest was more conspicuous than the STOP sign because the red-orange vest color was a brighter color than the STOP sign red and because the STOP sign at a 6-ft bottom height was above the main beam of the headlights.

The observer preference for the patterns shown in Figure 3 E, 3 C, 3 B, and 3 D is considered a general preference for triangular and rectangular shapes. Since other patterns similar to the 4 top ranked patterns can be designed it appears that other factors may be considered if it is assumed that a distinctive shape is necessary. For example the "X" patterns are similar to railroad crossing signs, cross road signs, and other non-highway symbols. The Figure 3 B pattern may resemble other construction signs. Some observers associated the Figure 3 D and 3 C patterns with the shape of a human figure. This concept appears to have merit and could be logically extended by distinctively outlining a flagman with reflectorized material added to his helmet, forearm and lower leg. The pattern in Figure 5 may be a suitable variation of the Figure 3 D and 3 C patterns. It was designed to provide reflectorization on approximately 50 percent of the vest area.

Dr. T. M. Allen, psychologist, MSU felt that the design of a reflectorized vest should include the factors of luminance and pattern recognition. The vest should have the highest luminance possible for visibility at a great distance, and the vest should have a recognizable pattern both for identification of the flagman and for attracting attention. A shapeless blob has little attention value.

Dr. Allen felt that a five-armed figure vest pattern (e.g. Figs. 4 C and G) might be desirable in order to convey the notion of the presence of a human figure. It would also be distinguishable from other sign symbols now in use. He suggested that the figure might even take the form of a workman holding a shovel, and furthermore the same symbol should be employed on the "Flagman Ahead" signs.

From his observation of the effectiveness of the new federally required disabled vehicle triangle marker, which is an open triangle, he believes that an open pattern outline is superior for recognition distance to a solid pattern which can become shapeless at a distance.

Dr. Allen volunteered to ask for suggestions for flagman vest pattern designs at the September 1973 meeting of the C.I.E. Committee on Sign Signals and Traffic Markings, and transmit these to the Laboratory.

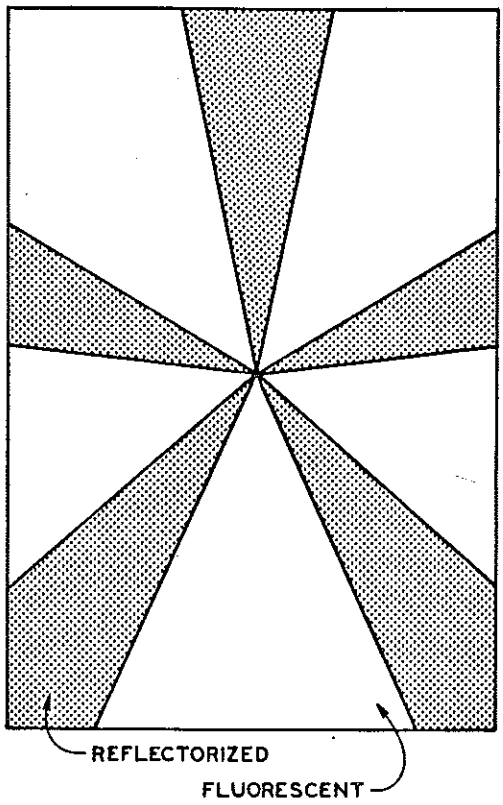


Figure 5. Possible vest pattern based on observer preference for patterns of Figure 3 C and 3 D.

This study has not shown that a distinctive reflectorized vest pattern is preferred over a completely reflectorized vest for nighttime use. Patterns were necessarily used in this study because a reflectorized blaze orange or yellow orange material is not known. We understand that some states are using a chevron pattern. However, since a chevron pattern was not preferred it appears that the Department can specify a distinctive reflectorized pattern for a flagman's vest which might gain National acceptance.

One other detail which should be considered in using the distinctive pattern for nighttime is the method of adding the pattern to the vest. The pattern could be attached permanently to the outside of all vests, it could be attached with various fasteners for night use only, or it could be an accessory such as an additional jacket or belt which would be worn only at night.

Rowland Development Corporation manufactures a "dual purpose" material to meet the requirements of Fed. Std. No. 125, Warning Devices. The dual purpose material is both fluorescent and reflective. The warning marker meeting the requirements of this standard must be fluorescent orange for daytime use and reflectorized red for nighttime. The standard permits the marker to be made of two materials, one fluorescent orange and the

other reflectorized; or, alternatively, the standard allows the marker to employ the dual purpose material. Rowland's dual purpose material is red-orange day and night. Therefore, it does not meet the apparent intent of the Federal "Manual of Uniform Traffic Control Devices" which requires orange by day and by inference, orange at night. Rowland says that there are technical difficulties in developing a dual purpose construction orange colored fabric.

Rowland claims that their reflective materials pass the Federal LS300a specification for reflective materials. Rowland's reflective materials employ the principle of prism reflection in a manner similar to the cube corner technique used in reflector buttons. The prism reflection is not quite as efficient as reflector button reflectivity, but the prism material reflects more light at wide angles.

Rowland has furnished the Laboratory with examples of two different flagman bibs or short vests:

1. A dual purpose material, fluorescent red-orange under daylight illumination and a somewhat redder red-orange under incandescent illumination. The fluorescent red-orange color is similar to a swatch of Fire Orange fluorescent color furnished by Dayglo Corp. Rowland uses Dayglo pigments. The dual purpose vest sells for around $20.

2. Construction Orange color reflectorized material, non-fluorescent. The frontal size of each vest is approximately 17 by 14 in. The nighttime specific luminance of each vest is as follows:

SPECIFIC LUMINANCE
(cd/ft-c/sq ft)

Divergence Angle, degrees	Entrance Angle, degrees	Color	
		Red-Orange	Construction Orange
1/5	-4	32.8	70.5
	30	7.9	13.4
1/2	-4	22.7	41.8
	30	5.6	8.7

A 3M representative, in a discussion of June 20, 1973, said that the 3M Co. is currently making a fluorescent red-orange reflectorized material and a non-fluorescent Construction Orange reflectorized material. 3M management favors the red-orange fluorescent color (equivalent to Dayglo's Fire Orange fluorescent color), and is not interested in developing a fluorescent yellow-orange (Dayglo's Blaze Orange) reflectorized material.

The representative said he was not aware of committee action on the Federal level concerning flagman vests. He gave the name of the manufacturer of vests using 3M materials (Columbia Lighthouse for the Blind) and has sent us their brochure.