Experimental Study on Effect of Escape Guidance in Fire Smoke by Travelling Flashing of Light Sources

TADAHISA JIN
Matsushita Electric Works, Ltd.
4-8-2, Shiba, Minato-ku,
Tokyo 108, Japan
(*Formerly at Fire Research Institute)

TOKIYOSHI YAMADA
Fire Research Institute,
14-1, Nakahara 3 chome, Mitaka,
Tokyo 181, Japan

ABSTRACT

A new escape guidance system is now developing for safety evacuation. This system indicates appropriate escape directions by making flashing of row of light sources successively away from hazardous area such as fire room. An experimental study is conducted to evaluate effectiveness of the escape guidance system under smoke and non smoke condition by changing the flashing light conditions i.e., spacing length between flashing lights and traveling speed. Effects of flashing light conditions and smoke on effectiveness of guidance are examined. The result shows that the escape guidance system can be expected as a powerful tool for safety evacuation even under smoke filled condition, when the spacing length is less than 1.0 m.

KEY WORDS: Emergency Exit Sign, Traveling Flashing Sign, Evacuation, Escape Guidance, Fire Smoke

INTRODUCTION

Interior spaces in many buildings up-to-date tend to be more spacious and multiple use oriented as shown in big shopping malls, high rise buildings and underground constructions. It is, however, our concern that people in those buildings will be more upset psychologically than in conventional buildings in emergency such as fire. One of the reason is due to difficulty to recognize their own whereabouts and escape route correctly in such buildings. Therefore, it is obvious that a powerful escape guidance system utilizing dynamic light and/or sound will be required for guiding evacuees to the escape route swiftly and appropriately in those buildings.

One of ideas for the new system came from utilization of travelling flashing lights like a light stream on runway for airplane landing. An original type of the new escape guidance system was developed by an adhoc groupe of Illuminating Engineering Institute of Japan. This system is designed for giving effective escape guidance to evacuees by allowing them walk along a row of green light sources embedded on floor surface, while the flashing of the light sources was travelled in the direction of escape route. Some results of the effectiveness of this system have been reported in the past [1]. However, it is not known that the system works appropriately under more realistic condition i.e., in fire smoke. We conducted a series of experiments by using the same system and evaluated the escape guidance effectiveness of the system.

PREVIOUS STUDY ON ESCAPE GUIDANCE SYSTEM BY TRAVELLING FLASHING LIGHT SOURCES

An original escape guidance system was developed and basic experimental study was carried out [1]. For the first step of development, conditions of traveling flashing light including size, luminance, travelling speed and spacing, were examined to get effective guidance. In the experiments, the green light sources are distributed at an interval of 25 to 325 cm on the floor passageway.

The experimental results are summarized as follows;

1) The smaller the spacing length between light souses, the larger the effect of escape guidance. (see Figure 1)

2) Luminance of 2000 cd/m^2 (when green filter was removed) and the travelling speed of flashing light sources of 2 m/s were fixed. The larger the size of light source, the effectiveness of escape guidance is improved, however, light source size larger than 5 cm x 5 cm is not so influential. (see Figure 1)

3) Light source size of 5 cm x 5 cm and the travelling speed of flashing light source of 2 m/s were fixed. The higher the luminance, the effect of escape guidance is improved, but luminance larger than 2000 cd/m^2 is not almost influential. (see Figure 2)

4) Light source size of 5 cm x 5 cm and luminance of 2000 cd/m^2 were fixed. It is found that the travelling speed of flashing of 2 m/s or more is preferable for improving the guidance effectiveness. (see Figure 3)

EXPERIMENT

A series of experiments are conducted to evaluate the effectiveness of the escape guidance system under smoke and non smoke condition with subjects. The travelling speed and the spacing length of flashing light sources are changed to examine the effects on the evaluation of guidance effectiveness.

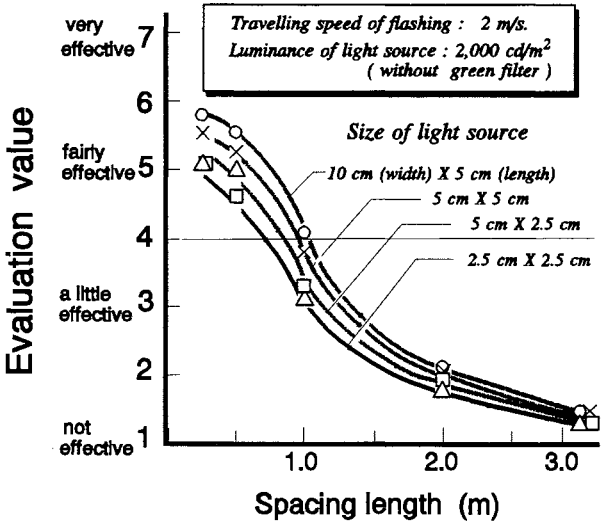


FIGURE 1: Relation between the spacing length of flashing light sources and the effectiveness of escape guidance depending on the size of light source. [1]

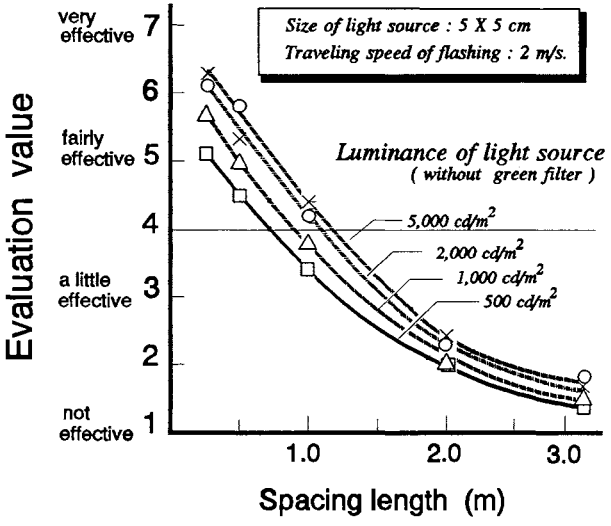


FIGURE 2: Relation between the spacing length of flashing light sources and the effectiveness of escape guidance depending on the luminance of light source. [1]

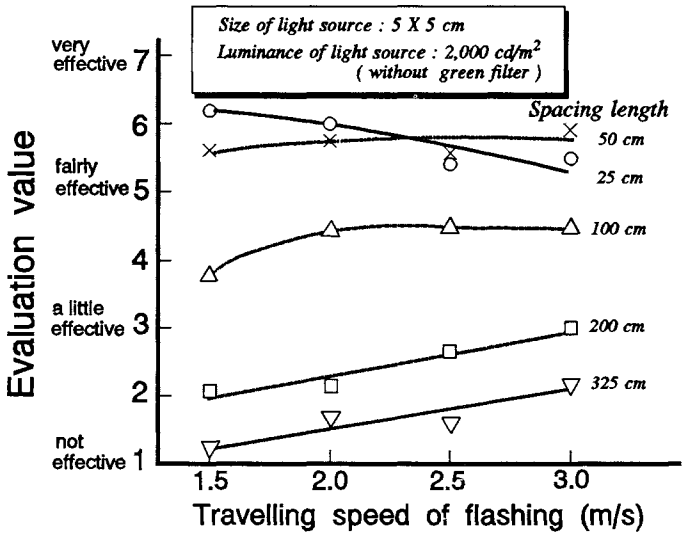


FIGURE 3: Relation between the travelling speed of flashing light sources and the effectiveness of escape guidance. [1]

Experimental Installation and Evaluation Method

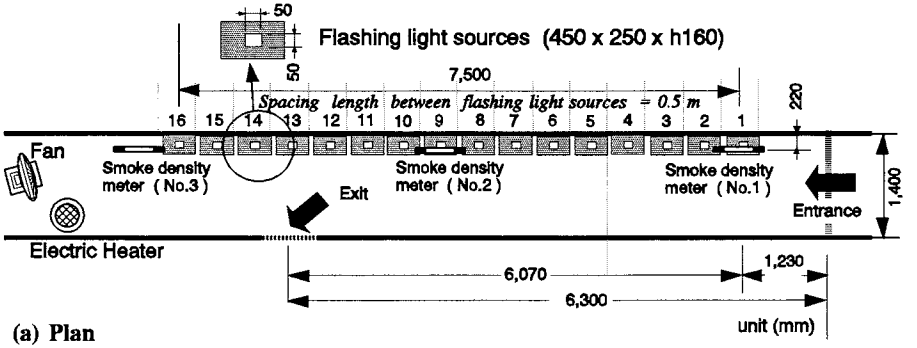
A portion of passage way (1.4 m width , 6.3 m long and 2.5 m height) filled with smoke is used for this experiment as shown in Figure 4. As lighting for the experimental passageway, four units of fluorescent (40 W x 2) lamps are equipped under ceiling, which give about 200 lx at the center of the passage under non smoke condition. 16 flashing light unit boxes as mentioned later are set on the floor along the right hand side wall at a pitch of 0.5 m as a test guidance system.

The effectiveness of the escape guidance is evaluated by 12 subjects, who walk in a line at a side of a row of flash-travelling green light sources located on the floor under various conditions i.e. the spacing and the travelling speed of flashing lights and smoke concentration. Under each condition, subjects walk along the system successively, however, there are only two or three people inside the passage way at a time for keep free walking speed.

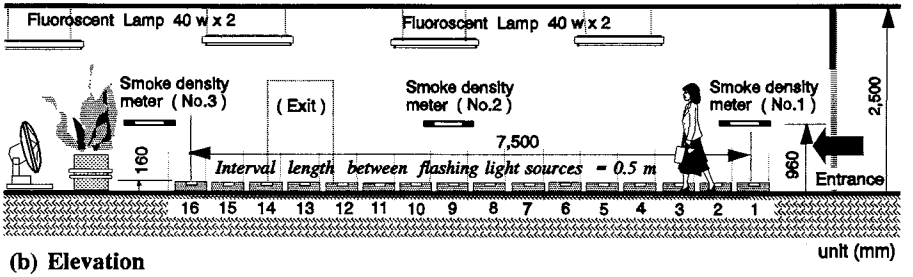
The degree of effectiveness of escape guidance is classified into seven steps as follows, and the evaluations are made by filling one score from seven points into an observation sheet directly after each test run. These categories are adopted as semantic differential scale for escape guidance.

Score: 7 point --- very effective for escape guiding
5 point --- fairly effective
3 point --- a little effective
1 point --- not effective

(2,4 and 6 point correspond middle point between 1 and 3, 3 and 5, 5 and 7 respectively.)*



(a) Plan



(b) Elevation

FIGURE 4: Schematic of experiment.

Specification of Guidance System

The experimental conditions are changed at random under various smoke concentration for eliminating personal intended evaluation. The escape guidance system used in this experiment is almost the same as was used in the past.[1] As lamps for light sources of escape guidance, 18 W compact fluorescent lamp is installed inside unit wooden box (45 cm x 25 cm x height 16 cm) colored in grey. On upper surface, a square shaped window (5cm x 5cm) is fixed as a flashing light source. As a light diffuser, milk white acrylic resin plate (2 mm thick) having green silk screened surface was used at the part, wherein the chromaticity was x = 0.217, y = 0.481 at the operation of compact fluorescent lamp. The luminance of the light source is adjusted to 270 cd/m^2.

The experimental parameters concerned with the flashing light are travelling speed and the spacing as mentioned above. In this experiment, traveling speed is set to be 2 m/s, 4 m/s and 8 m/s. Also, under each speed condition, the spacing length is set to be 0.5 m, 1 m and 2 m. The interval length between lights flashing simultaneously is five times as long as the spacing length. The traveling speed is controlled by changing an on-off frequency of inverter power supply with a function generator and an electrical relay circuit. 16 light sources are placed on the floor at an interval of 0.5 m. The spacing from one to next one is adjusted by changing combination of lights flashing at the same time. For instance, the

lamps at the N + 5*(i-1) th (" i" is a spacing interval increment and N is a time step increment; i=1 to 3 and N repeats from 1 to 5) flash simultaneously, then the lights following flash successively just after the flashing lamps go off.

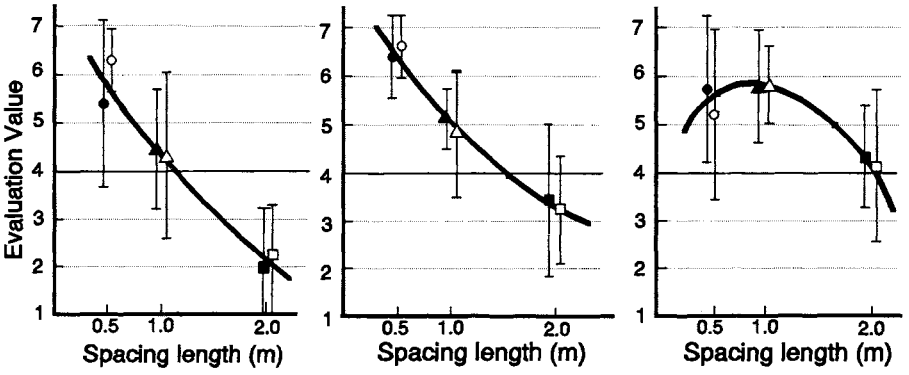
Smoke Condition

Prior to test runs, the passage way is filled with smoke. The smoke is generated by smoldering Japanese ceder with an electric heater. Smoke density as expressed by extinction coefficient is set to be about 1 m^{-1} at the beginning, then the smoke concentration decreased gradually as time goes by. We conducted the experiment under this quasi-steady conditions. However, during one test run of two or three minutes, the smoke concentration is almost constant. The smoke concentration is measure with three smoke concentration meter and the mean value was used as reference smoke concentration. Variance between those three is negligible. The smoke concentration is set to be about 0.8, 0.6, 0.4, 0.2 m^{-1} and test runs are conducted once for each flashing light and smoke conditions.

RESULT AND CONSIDERATION

Effectiveness of Escape Guidance under non Smoke Condition

Two test runs for each flashing condition under none smoke condition are conducted before and after smoke filled test runs. Figure 5 and 6 illustrate mean evaluation values as effectiveness of escape guidance and standard deviations (expressed with $\dot{\phi}$) under various flashing conditions. Three figures in Figure 5 express relations between evaluation value and



(a) Travelling speed is 2m/s. (b) Travelling speed is 4m/s. (c) Travelling speed is 8m/s.

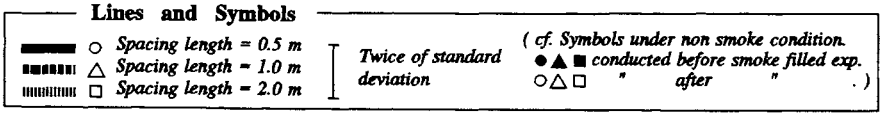


FIGURE 5: Relation between effectiveness of escape guidance and spacing of lights under non smoke condition

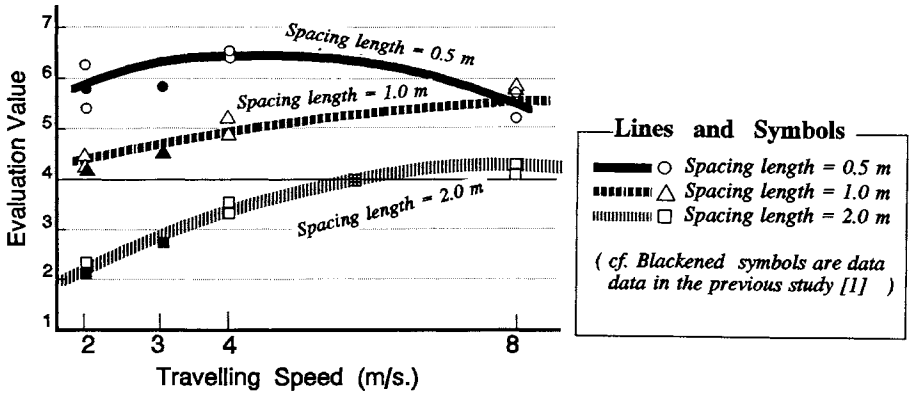


FIGURE 6: Relation between effectiveness of escape guidance and traveling speed of lights under non smoke condition

spacing of lights under same traveling speed. And another relation between evaluation value and traveling speed are presented in Figure 6.

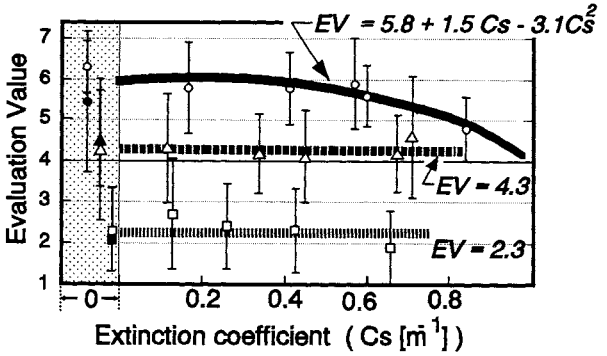
The result indicates that the spacing length of light is more sensitive to the effectiveness than the travelling speed. The effectiveness increases with decreasing the spacing length, however the variance becomes smaller with increasing the traveling speed. And the effectiveness increases with travelling speed, when the spacing is wider than 1m. However contrary tendency is found under narrow spacing condition of 0.5 m. From our observation, this seems to be caused by a hallucination. Under condition of fast travelling speed with narrow spacing, the system is looked like indicating an opposite direction.

It is found in another supplemental experiment conducted under non smoke condition that this hallucination can be avoided by setting a short blank period between two successive flashing, and also extending the interval length between lights flashing simultaneously twice as long as the interval length adopted in this experiment.

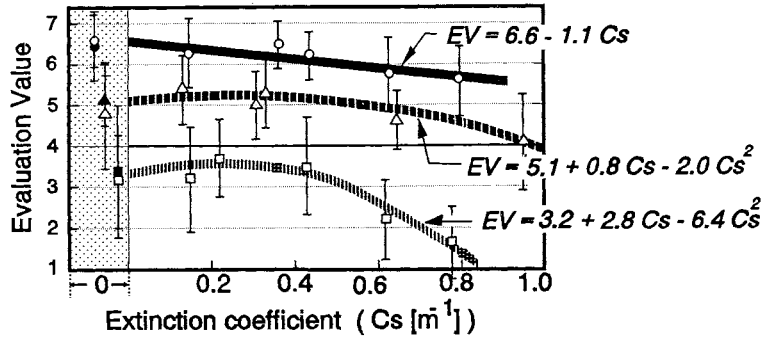
The previous experiment data under 2 m/s and 3 m/s travelling speed condition are also plotted in the figure with blackening symbols in Figure 6. The result obtained in this experiment consist fairly well with the previous results.

Effectiveness of Escape Guidance under Smoke Condition

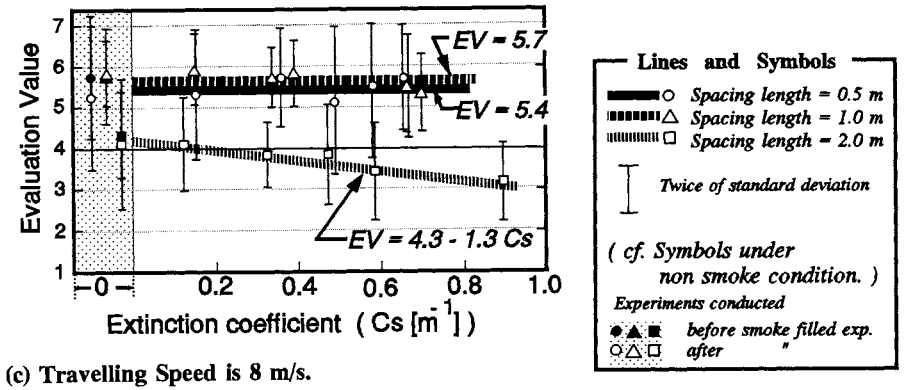
Figure 7 shows the relation between evaluation value and smoke concentration expressed by extinction coefficient under various flashing light conditions. Each of equations indicated in the figure is an experimental regression equation obtained by statistic method called AIC (Akaike Information Criterion).[2] There are three types of equations giving the evaluation value with the smoke concentration, i.e. constant in the four cases, simple equation in the two cases and quadratic equation in the three cases.



(a) Travelling Speed is 2 m/s.



(b) Travelling speed is 4 m/s.



(c) Travelling Speed is 8 m/s.

FIGURE 7: Relation between smoke concentration and the effect of escape guidance with variation of flashing light sources under smoke condition.

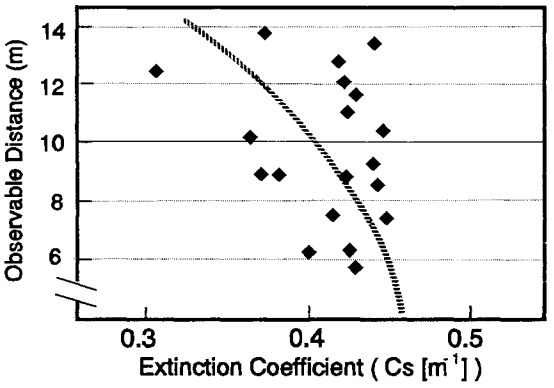


FIGURE 8: Relation between smoke concentration and visibility of exit sign.

In general, the effectiveness decreases with increasing smoke. However, except a few cases having relatively low evaluation value under non smoke condition, the evaluation values are over "4 point" in the smoke concentration of 0.4 m^{-1}. The evaluation value of "4 point" stands for less effective than "fairly effective" and more than "a little effective", so we consider that the value is a threshold where practical effectiveness of escape guidance is secured. This result is very important for evaluating the escape guidance system from the view point of safe evacuation. Because visibility (observable distance) of normal exit sign drops rapidly from over 10 m to 5 m and then lose the guidance effectiveness in that range of smoke concentration.[3] This relation between the visibility of exit sign and the smoke concentration is expressed in Figure 8.

Comparing with the visibility drop of normal exit sign, decreasing rate of the effectiveness of the guidance system seems to be small, so the new system is expected for maintaining high and stable effectiveness of escape guidance even in relatively high smoke concentration. It is known that threshold of smoke concentration required for safety evacuation in a building without indication emergency signs is almost under 0.5 m^{-1} for evacuees who are familiar with the building, and 0.15 m^{-1} for strangers.[4]

Many evaluation values at 0.2 m^{-1} smoke concentration give higher values than those under non smoke condition. It is considered that surrounding light noises are weakened with the smoke, then evacuees can more concentrate to the flashing light. Therefore also in thinner smoke at the very beginning of fire, this type of the guidance system can be expected for having high effectiveness for safety evacuation as well as in thick smoke.

CONCLUSION

The effectiveness of escape guidance by travelling flashing of light sources is examined with 12 subjects under smoke and non smoke conditions. The result shows that relatively high guidance effectiveness can be expected in both thick and thin smoke. And the spacing length

between flashing light sources is very important factor to keep appropriate guiding effectiveness. Especially, high effectiveness is expected, when the spacing is set to be less than 1 m. The relation between effectiveness and flashing light conditions under smoke are found to be almost the same obtained under non smoke condition in the past.

REFERENCE

[1] Illuminating Engineering Institute of Japan, The Interim Report of Basic Research on Escape Guidance System by Travelling Flashing Light Sources,1990.3.

[2] Sakamoto et al., Information Statistics, pp.127, Kyoritu Publ. Inc.,1980.

[3] T. Jin, "Visibility through Fire Smoke", J. of Fire and Flammability, Vol.9, pp.135,1978.

[4] T. Jin, "Studies of Emotional Instability in Smoke from Fires", J. of Fire and Flammability, Vol.12, pp.130,1981.