

Report of PWM Flickering Light Experiment in Actual Seas

Japan Coast Guard

1. Objective

20 years have passed already since LED lanterns, which have more visibility and conspicuity than existing lanterns, were adopted as lights for aids to navigation. Meanwhile, the illuminating power of light at night has increased in the metropolitan area as a center of activity. And given these background lights, more advanced measures were expected for certainty of visibility of lights for aids to navigation. But simply increasing the illuminating power of light is not an option because the power to be used for aids to navigation is limited.

But an LED light source, with advanced light emission response, can be configured freely with a light emission pattern (the light modulated as to its flashing time, circle and flashing width of pulse emission- PWM flickering light), according to a report about how conspicuity can be improved with lights formed by a group of pulses without consuming more electricity. (“Research and Study of How LED Lamps Look”, 2006 to 2008).

Preparation of this report was based on the evaluation of visibility and troublesomeness of seeing lights for vessels in general navigating in actual seas, and the information was collected through questionnaires and analyzed. In addition, the results of observation by preparatory personnel of this report is reported as well in order to clarify the relationship between aids to navigation, which were used for the experiment, and lights in the background or visual obstacles.

2. Period

Period during which surveys by questionnaire were conducted
Between December 22nd (Tue.) 2009 and February 1st (Mon.) 2010.

3. Subject

Yokohama Daikoku Futo Funadamari Breakwater Light (aids to navigation under jurisdiction of Yokohama Coast Guard Office).
Light characteristics: Fl 4.0 sec, red (see Fig. 1 and Photo 1)

4. Method

The surveys were conducted for vessels, which use Yokohama Daikoku Futo Funadamari Breakwater Light (hereinafter called “Funadamari Breakwater Light”) or which pass the area where the light is visible. 300 or more questionnaire forms were mailed to 29 organizations including government and municipal offices, and 113 responses (108 were valid) from about 20

organizations were received by February 12th either via mail or fax. The contents of the questionnaire included: 1. Date of seeing the light, 2. Evaluation of visibility of the light (discrimination), 3. Unpleasantness of seeing the light, and 4. Evaluation for conspicuity of the light. These were the questions. And the questionnaire also asked for comments and opinions. (see attachment 1)

5. Miscellaneous

Besides the use of the questionnaire survey, the flickering light installed in the Funadamari Breakwater Light, the area surrounding the Funadamari Breakwater Light and the conditions of the various light sources in the background were observed and studied from “Hakuko”, a lighthouse patrol vessel of Yokohama Coast Guard Office, between 16:30 and 18:00 on January 21st (Thur.), 2010

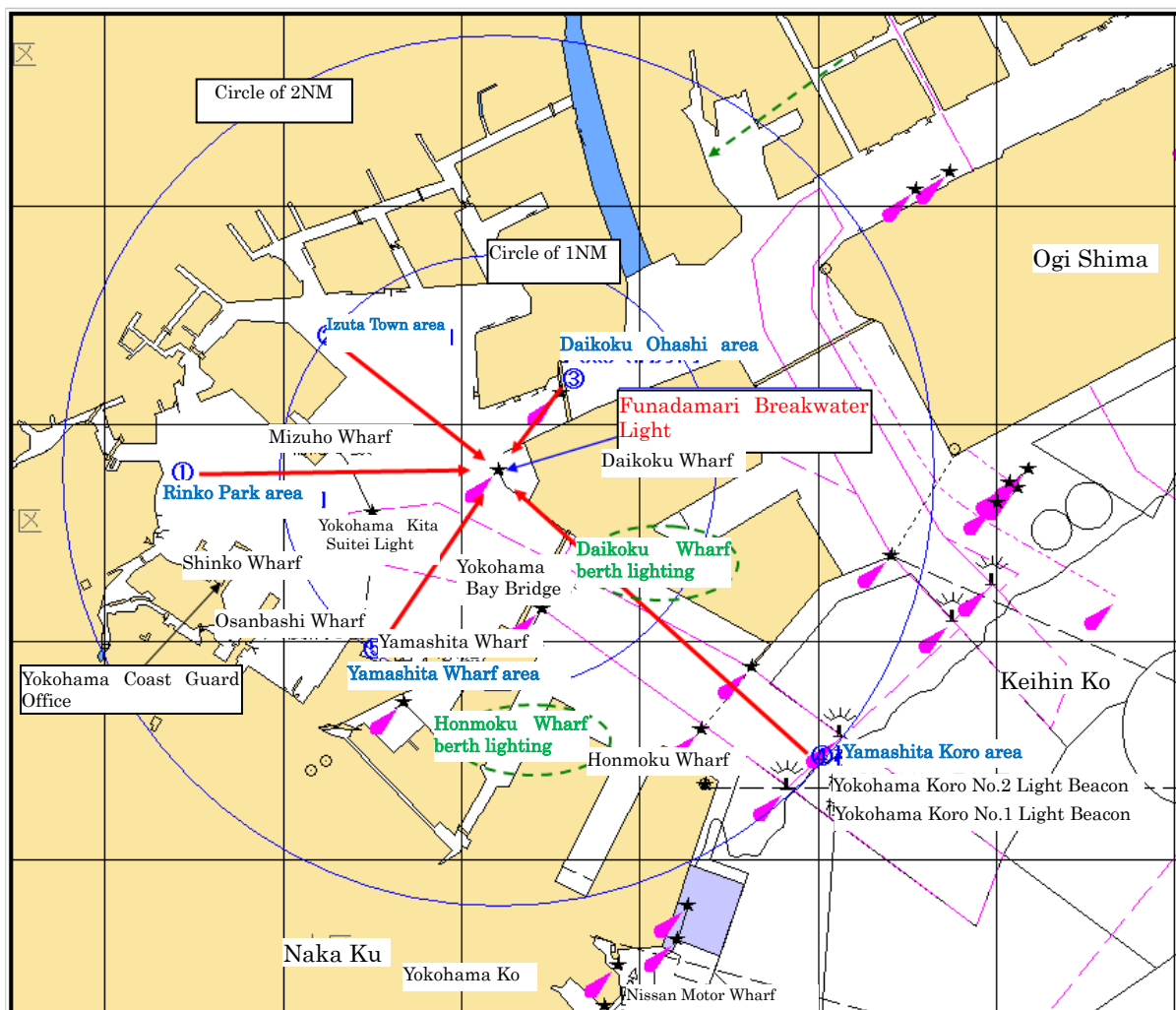


Fig. 1. Lighthouse locations and surrounding areas



Photo 1 (Photo on right is the lantern using flickering light)

Funadamari Breakwater Light
 Color/light: Red
 Light characteristics : Fl 4.0 sec.
 Height: Approx. 9.8 m

6. Results of the questionnaire

(1) Q2: Results on the visibility of the light (discrimination) is shown in Fig 2, 3 and Chart 1.

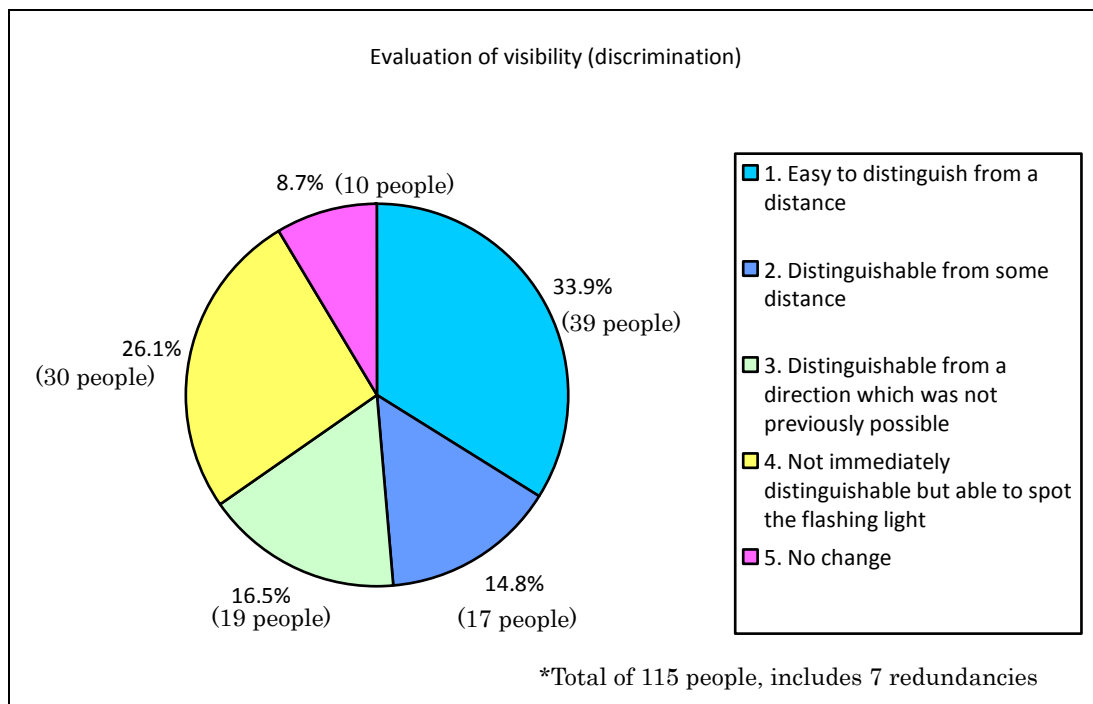


Fig. 2. Evaluation of visibility (discrimination)

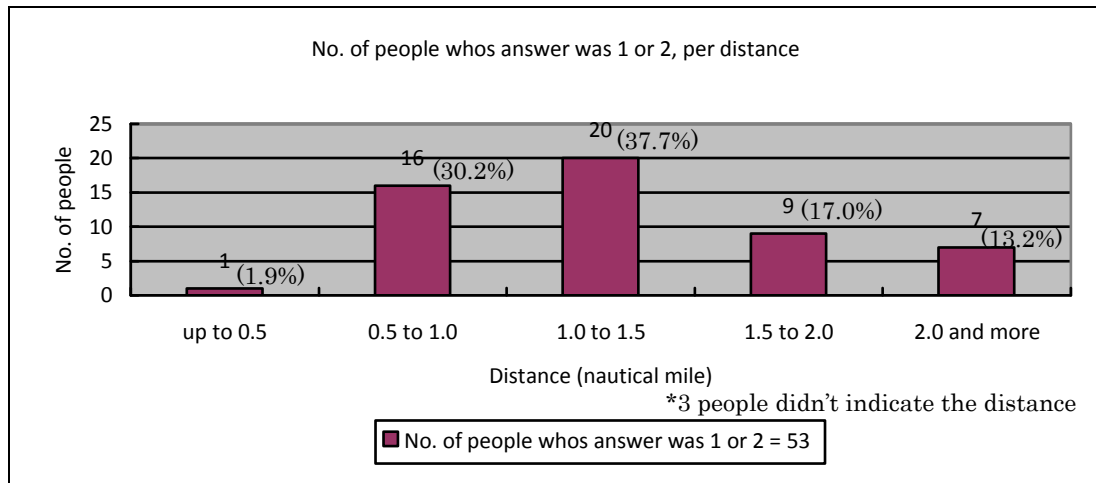


Fig. 3. Visibility (discrimination) per distance

Chart1. Total data on visibility (discrimination)

Q 2 - ②		
Did you spot it sooner than before?		
	No. of people	%
1. Yes	52	92.9
2. No	4	7.1

Positive responses regarding the effectiveness of flickering light are categorized in 1, 2 and 3 in Fig. 2 as 33.9%, 14.8% and 16.5%, respectively. Total is 65.2%. But category 4 is 26.1% who see the effectiveness of the flickering but expressed insufficiency. Category 5 is 8.7% who see no effectiveness of the flickering and expressed no change from existing lantern. People in categories 1 and 2 showed the distance from the light (Fig. 3). The majority of the distance was from 1.0 to 1.5 nautical miles, which is 37.7%, and from 0.5 to 1.0 nautical miles, which is 30.2%. 1.5 nautical miles or more is 30.2% including 2.0 nautical miles or more. Another question was if they could spot it sooner than before at that time, and 92.9% had a positive response (Chart 1).

(2)Q 3: Results on unpleasantness of the light shown in Fig. 4 and Chart 2.

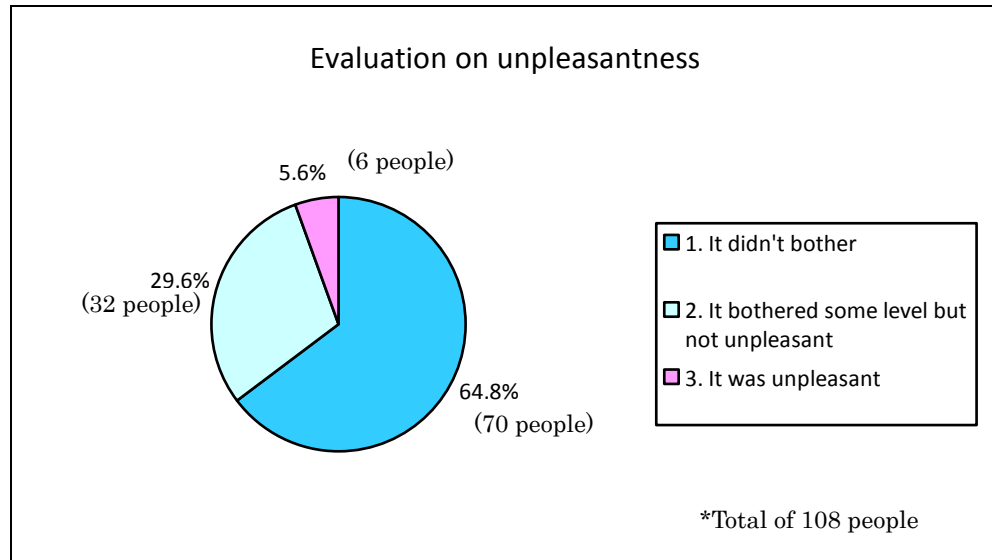


Fig. 4. Evaluation of unpleasantness of the light

Chart 2. Total data on unpleasantness

(a)

Q3 - ① The distance	
Nautical mile	No. of people
Up to 0.5	1
0.5 to 1.0	4

5

(b)

Q3 - ② How unpleasant	
	No. of people
1.Troublesome	1
2.Sick feeling	0
3.Others	4

5

*1 among 6 who expressed unpleasantness had no response to ① and ②

As shown in Fig. 4, 5.6% expressed unpleasantness of the light of the Funa-damari Breakwater Light, and the other 94.4% expressed no unpleasantness. The details for those who expressed unpleasantness are shown in Chart 2. (a) and (b). One of them expressed “troublesome” of the light, and the other 4 expressed strangeness of the new pattern of the light. None expressed sick feeling. The distance was 0.5 nautical miles for those who expressed “troublesome”, and 500 m, 0.5 nautical miles and 1.0 nautical mile for the other 4, which shows no relations between unpleasantness/strangeness and distance.

(3) Q4: Results on conspicuity as shown in Fig. 5, 6.

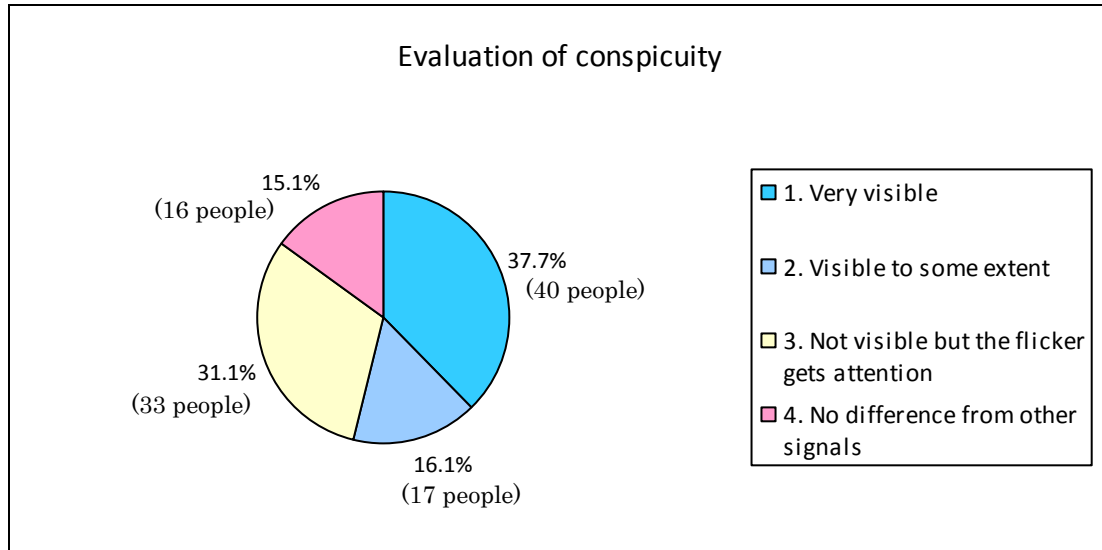


Fig. 5. Evaluation of conspicuity

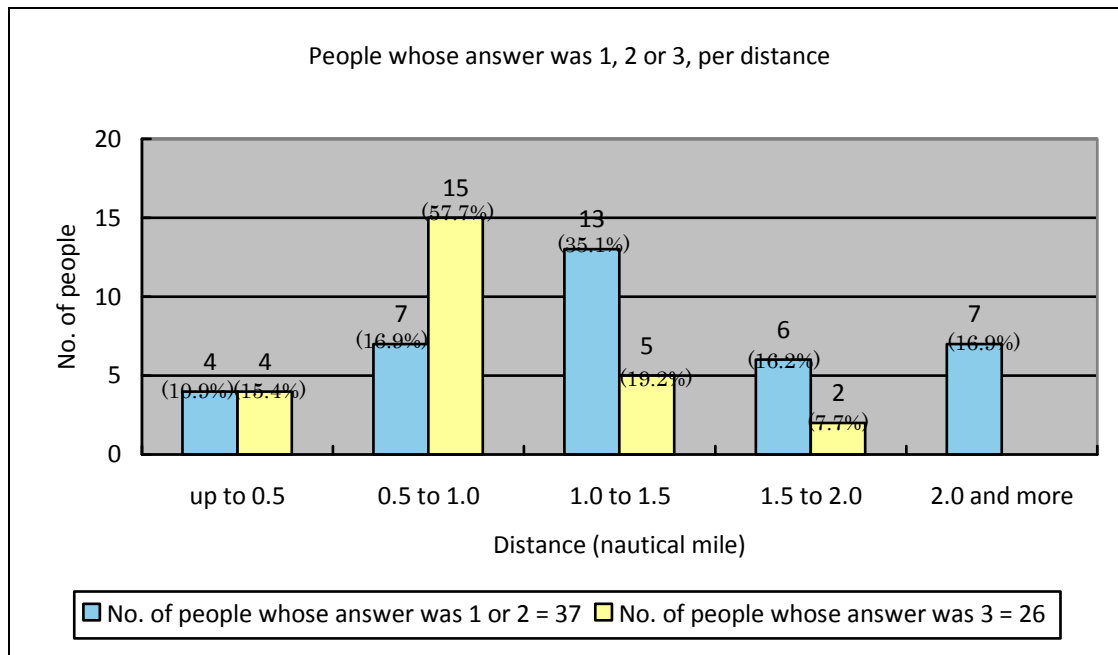


Fig. 6. Conspicuity per distance

Categories 1 and 2 are positive responses to the flickering lights in Fig. 5 as well as Q2. The totals are 53.8%, 37.7% and 16.1%, respectively. But category 3 is 31.1% who see the effectiveness of the flickering but expressed insufficiency. Category 4 is 15.1% who see no effectiveness of the flickering and see no change from the existing nearby lights. Categories 1, 2 and 3 indicated the distance in Q4, and categories 1 and 2 are separated from category 3 (Fig. 6). From 1.0 to 1.5 nautical miles (35.1%) is the majority for categories 1 and 2 as well as Q2 with similarity in the distributions. From 0.5 to 1.0 nautical mile is the majority in category 3. The distance tends to be shorter but response was negative.

(4) Comments as shown in Chart 3 (see attached 2, comments and opinions)

Positive responses and negative responses are mixed in the evaluations and descriptions in category 2 of Chart 3. The overall responses came out positive as 61.5% and negative as 38.5%, if the positive and the negative in category 2 are to be 7.7% and 7.7%, respectively, and calculated.

Chart 3. Results and categories on comments

Comments	No. of people	%	
1. Positive	21	53.8	61.5
2. Mix of positive and negative	6	15.4	
3. Negative	12	30.8	
4. Others	(2)	-	-

[Basis of category]

1. Positive: The answer was 1, 2 or 3 in Q2 or 1 or 2 in Q4 (one way or the other) and had mainly positive comments or requests.
2. Mix of positive and negative: The answer was 1, 2 or 3 in Q2 and 1 or 2 in Q4 but had negative comments. The answer was 4 in Q2 and 3 in Q3 but had no negative comments.
3. Negative: The answer was 5 in Q2. The answer was 4 in Q2 and 3 in Q3 but had negative comments.
4. Others: Comments without evaluations (not included in calculations)

(5) Analysis on results of the questionnaire

- “Visibility (discrimination)” in Q2 and “Conspicuity” in Q4 were asked to determine how much users acknowledge the effectiveness of the flickering. The overall result was that an average of about 60% of users saw the effectiveness and about 30% recognized “blinking” of flickering light but expressed its insufficiency. And about 10% saw no effects.

- Most users recognized the Funa-damari Breakwater Light at a distance of 1.0 to 1.5 nautical miles. This may be because the maximum distance is only about 1.5 nautical miles from the Funa-damari Breakwater Light to vessels on the W side of Bay Bridge in Yokohama port, thus most users may have seen the light within this range and been able to make an evaluation.

- Users who evaluated at 1.5 nautical miles or more may have seen the light from the direction of the entrance to the Yokohama passage on the east side of Bay Bridge.

The light can be seen only between the Bay Bridge piers and the wharf from this direction, and the other lights, such as berth lights, make it difficult to spot the light. But some users saw the light at a distance of 2 or more nautical miles, and that indicates the possibility of long distance recognition.

- The majority of the distance range is from 0.5 to 1.0 nautical mile for users who answered “3” in Q4. This indicates that the brightness of the background lights is different depending on the direction of the view.

- Among those who expressed “unpleasantness” in Q3, one user expressed “troublesome” and four expressed “strangeness”, but few expressed “unpleasantness” on the actual seas.

- 61.5% had positive comments and opinions which show similar results of 65.5% in Q2 and 53.8% in Q4.

7. Results of visibility study at night

Routes of study: Started from Yokohama Coast Guard Office, ①Rin-ko Park offshore (about 1.3 nautical miles of the Dock Light), Yokohama Kita Suitei harbor Light, ②Izuta town offshore (about 1 nautical mile of the Dock Light) North side of Mizuho Warf, ③North side of Daikoku Bridge (about 0.8 nautical miles of the Dock Light), ④East side of Yokohama Bay Bridge (about 1.2 nautical miles of the Dock Light) and back to Yokohama Coast Guard Office (see Fig. 1)

(1) Conditions of visibility of the flickering light

① From Rin-ko Park

Photos 2 and 3 show the view of the Dock Light from around Yokohama Kita Suitei harbor Light. The lights around the warehouses at Daikoku Warf, Daikoku JCT of Metropolitan Expressway and road/bridge lamps of Daikoku Ohashi are conspicuous. The flicker light blinks very differently from others and is easy to spot. The glare of berth lights in the background may cause difficulty in distinguishing the flickering light depending on the direction.



(Dock Light in the red circle. The same shall apply hereinafter. Taken at intervals between flashes)

Road/bridge lamps of Daikoku Ohashi



Photo 3. (Taken at intervals between flashes)

② **Conditions of the view from the direction of Izuta Town**

Photo 4 shows the view of the Dock Light from Izuta Cho offshore. It was relatively easy to spot the Dock Light from the direction where the photo was taken. But there is a large area and a wide range of views, in which the glare of the berth lights is always in view and causes difficulty in distinguishing the light.

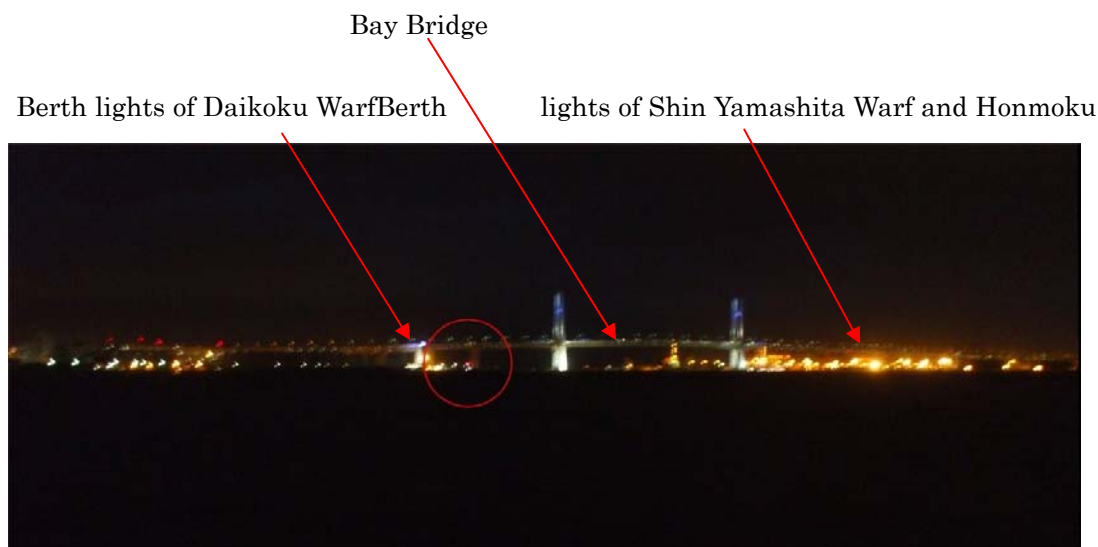


Photo 4 (Taken during flash)

③ **Conditions of the view from the direction of Daikoku Ohashi**

Photo 5 shows the view of the Dock Light from Daikoku Ohashi at a distance of 0.2 nautical miles. It was easy to spot the Dock Light since it was close but also close to the berth lights of Honmoku Warf which may be confused with the Dock Light.

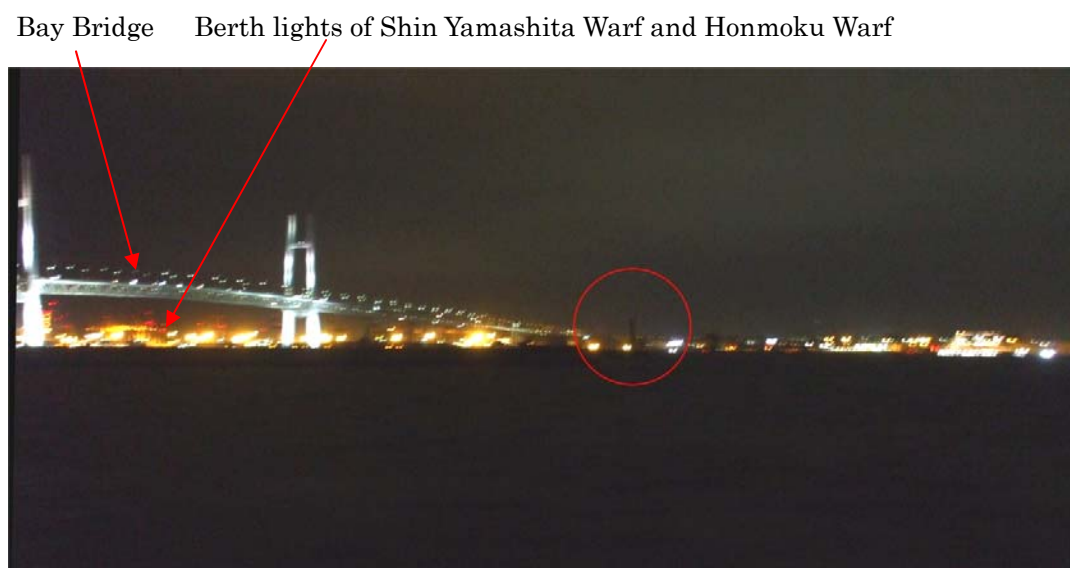


Photo 5 (Taken at intervals between flashes)

Photo 6 shows the view from a distance of 0.4 nautical miles. Berth lights stayed out of sight and the lights of downtown Yokohama became visible in the background. Flickering light was very visible.

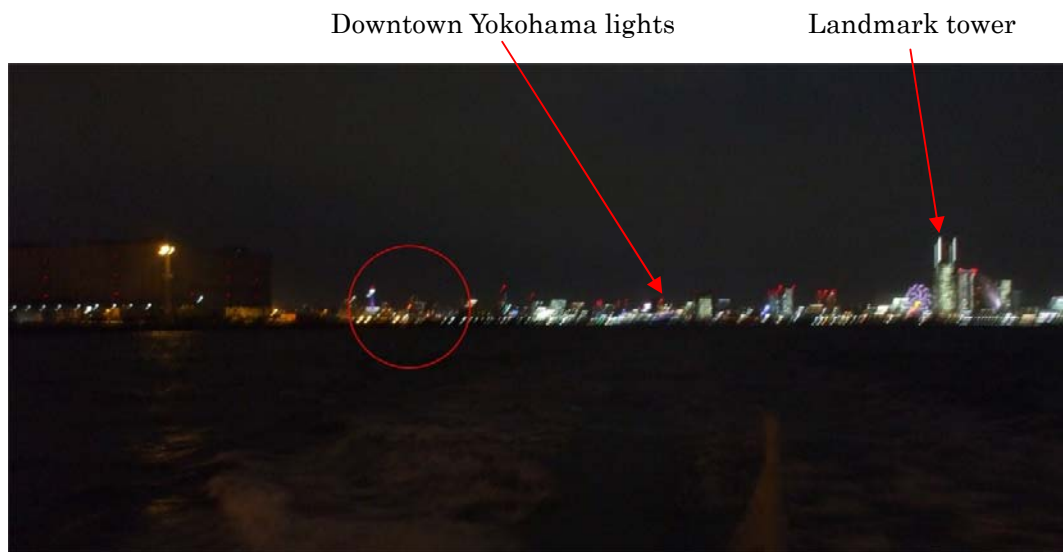


Photo 6. (Taken during flash)

Photo 7 shows the view of the Dock Light from a distance of 0.6 nautical miles at the pier of Daikoku Ohashi after passing through it. Downtown Yokohama lights completely overlapped with the Dock Light. Bridge lamps in front stood out very much, but the flicker light was easy to spot. But the Dock Light moved behind the warehouse from the view about 0.8 nautical miles away.

When entering Yokohama Ko from this direction, the Dock Light, which a relatively short distance away, can be used after passing through.



Photo 7. (Taken at intervals between flashes)

④ **Conditions of the view from the direction of Yokohama Passage**

Photo 8 shows the view of the Dock Light from the direction of 0.5 nautical miles right under the Yokohama Bay Bridge. No other background lights make it possible for the light to be spotted.



Photo 8. (Taken during flash)

Photo 9 shows the view of the Dock Light from a distance of 1.2 nautical miles. Berth lights in front came into view. It is difficult to distinguish the Dock Light without blocking the glare.



Photo 9. (Taken at intervals between flashes)

(2) **Results of visibility study at night**

- The Dock Light lies between the pier of Bay Bridge and Daikoku Warf from the view from the direction of the entrance to Yokohama Passage, and glare caused by bridge lamps and berth lights may interfere with distinguishing the Dock Light.
- Berth lights of Honmoku Warf and Daikoku Warf sometimes overlap the

Dock Light in the view from Izuta Town offshore or around Daikoku Ohashi, and reduce the effectiveness of flickering.

- The berth lights look like a belt of lights without dark spots. It takes some amount of time to distinguish the Dock Light, if it gets lost in the belt of lights. These berth lights could be the big disincentive for discriminating aids to navigation lights in Yokohama Port.

- Road lamps and bridge lamps are strong background lights as well. But the Dock Light can be found in no time even if it gets lost, because these lamps are lined up in order and have some dark spaces in between.

- Downtown lights are mostly white with some red and blue, etc. but they are mostly fixed lights. The flicker light is a totally different object, in a sense among others, and it was relatively easy to distinguish it.

- The Dock Light didn't quite stand out among other nearby aids to navigation lights, but overall it was more noticeable than other lights at a distance of 1.0 to 1.5 nautical miles.

- When passing near the Dock Light (about 300 m), it didn't cause unpleasantness by looking at the flicker light directly.

8. Summary

(1) According to the results of the questionnaire about the flickering light, the ratios of "Effective", "Insufficient" and "Not effective" are about 60%, 30% and 10% respectively.

Many of the users may have evaluated from the light on the W side of Bay Bridge within the port that its distance is about 1.0 to 1.5 nautical miles, according to the answers to the questionnaire. The users who have evaluated the light at a distance of 1.5 or more nautical miles may seem to be on the E side of Bay Bridge. But the Dock Light can be seen between the pier of Bay Bridge and Daikoku Warf from this direction, and there are many existing obstacles such as bridge lamps, berth lights, etc.

Many of the users who concluded as "Insufficient" or "Not effective" are speculated to have evaluated from this direction, and the users who concluded as "Effective, at 1.5 nautical miles or more", remains only 30 to 35%, which is understandable. Considering that it was conducted during operations and within regularly used sea areas, these numbers are not quite negative.

We really appreciate that these users, who conscientiously evaluated from these directions, cannot see the Dock Light well.

(2) From the direction of downtown lights in the background, the flicker light can be seen as a totally different kind of light, and is effective in the visibility study at night. But from the direction of the berth lights in the background, it was confirmed that the glare of the lights could be a factor that decreases the evaluation significantly.

If the main reason the Dock Light does not "stand out" as effectively as expected from the short distance was the glare of other lights, then according to the results of the questionnaire, "Effective, Insufficient, Not effective", which were 60%, 30% and 10%, respectively, were quite reasonable as results of a test using a 2 nautical mile model lamp.

(3) There was no user who felt sick from looking at the flickering light directly. As far as the 2 nautical mile model lamp (Fl 4.0 sec) is concerned, the flicker light is not likely to influence human health, etc., and few users even come close enough to be influenced (the minimum distance was 400 m as reported).

(4) The following should be considered to have been based on the results of the experiment analysis:

- Installing the flicker light in the aids to navigation at the entrance to the passage in order to focus on the direction to see the object and easily spot it from a distance (e.g. Yokohama Passage No. 1 or No. 2 Offshore fixed lights at Yokohama Passage).
- Installing in aids to navigation, which are closer to downtown, in order to make it is easy to see under strong background lights. (e.g. Yokohama Kita Suitei Light, Yokohama Higashi Suitei Lighted Buoy)
- Study the effectiveness of several flickering lights within the same sea area (at the entrance to the passage and in the inner port in the case of the above mentioned aids to navigation).