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# PROGRESS IN AUTOMOBILE LIGHTING

## Laboratory of Lighting Technology
## September 25-26, 2001

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U.S. Patent No. 11,208,029

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**P**rogress in **A**utomobile **L**ighting

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# The Research on the Effectiveness of AFS Bending Lamp in Japanese Road Environment

**Takao Watanabe, Noriyuki Nakamura, Naoki Matsumura:**
**Koito Manufacturing Co. LTD., Japan**

## 1. Introduction

The achievement of good low-beam visibility at low and medium driving speeds is a particularly important task in Japan's general road environment. To examine the effectiveness of AFS bending lamps in achieving this task, we manufactured and tested a prototype AFS (Adaptive Front-lighting System) featuring a modified light distribution below the cutoff line.

## 2. The Road Environment in Japan

### 2.1. Road Environment Features

Japan is an island nation with predominantly mountainous geography, and inhabitable regions account for only about 20% of the nation's total land area. Passenger cars are used most frequently for commuting. The principal characteristics of Japan's road environment can be summarized as follows, in relation to commuting routes at night.

| No. | Home location | Work location | Road environment | Visibility issue |
|---|---|---|---|---|
| (1) | Plain region | Plain region | (1) Mainly straight roads & intersections<br>(2) Fair number of road lamps in cities/suburbs<br>(3) Mainly national & prefectural roads | Pedestrian visibility on roads and at intersections<br>Improved by road lamps |
| (2) | Hilly region | Plain region | (1) Mainly curved roads in hill areas<br>(2) Small number of road lamps in hill areas<br>(3) Mainly prefectural and township roads | Lane visibility on curved roads |
| Note | In plain big-city areas, commuting is primarily by rail. | | | |

*Table 1 Commuting road environment*


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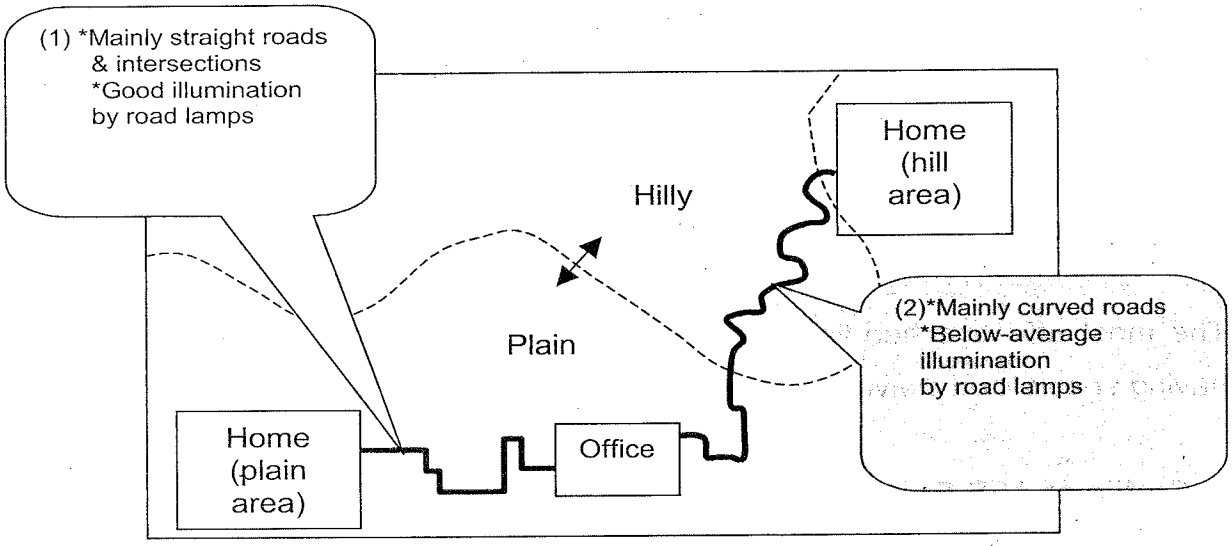


*Fig.1 Typical examples of commuting routes in Japan*

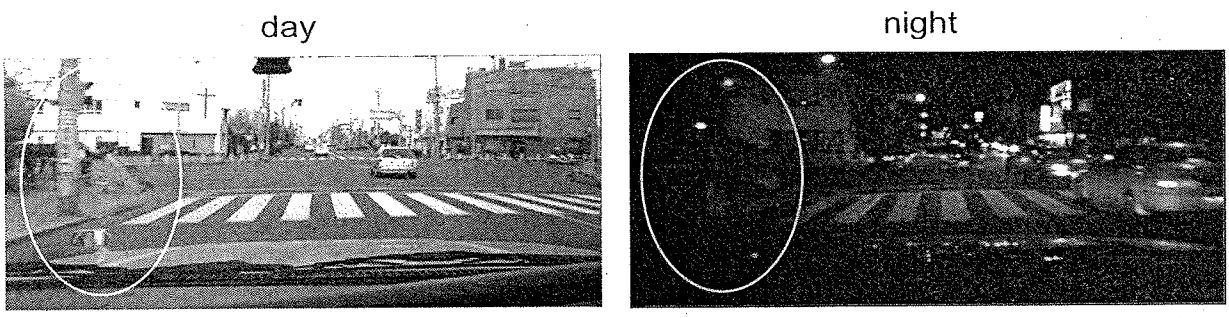


*Fig.2 View of a city intersection*

*Fig.3 Curved prefectural road in suburbs*

2.2. Characteristics of Curved Roads (township, prefectural)

(1) Small curvature (R16-40, driving speed of 20-50 km/h)

(2) No more than two lanes

(3) Minimum road lamp illumination at sight-blocking curves

(4) Heavy traffic even at night (i.e., mostly low-beam driving)

The most effective headlamp system under these road conditions is an AFS having specialized swiveling lamps to cover below the cutoff line.

## 3. Profile of AFS Prototype

3.1. Development Concept

To develop a headlamp system which will provide satisfactory visibility especially for low- to mid-speed cornering.

* "Satisfactory visibility": A sufficiently visible field obtained through light distribution around the driver's eye focus point.

(Photometry for intersections not included as a target of this development.)

3.2. Aim of Light Distribution

3.2.1. Photometric conditions for low/mid-speed cornering

(1) Eye focus on:

a. Center lane marking in case of right cornering

b. Left lane marking in case of left cornering

c. Forward point arriving about 1.5 seconds later

(2) Corner radius and assumed driving speed

| | Speed | Radius |
|---|---|---|
| Low | 20-40 | 15-40 |
| Medium | 40-60<br>60-80 | 40-75<br>75-120 |
| High | 80- | 120- |


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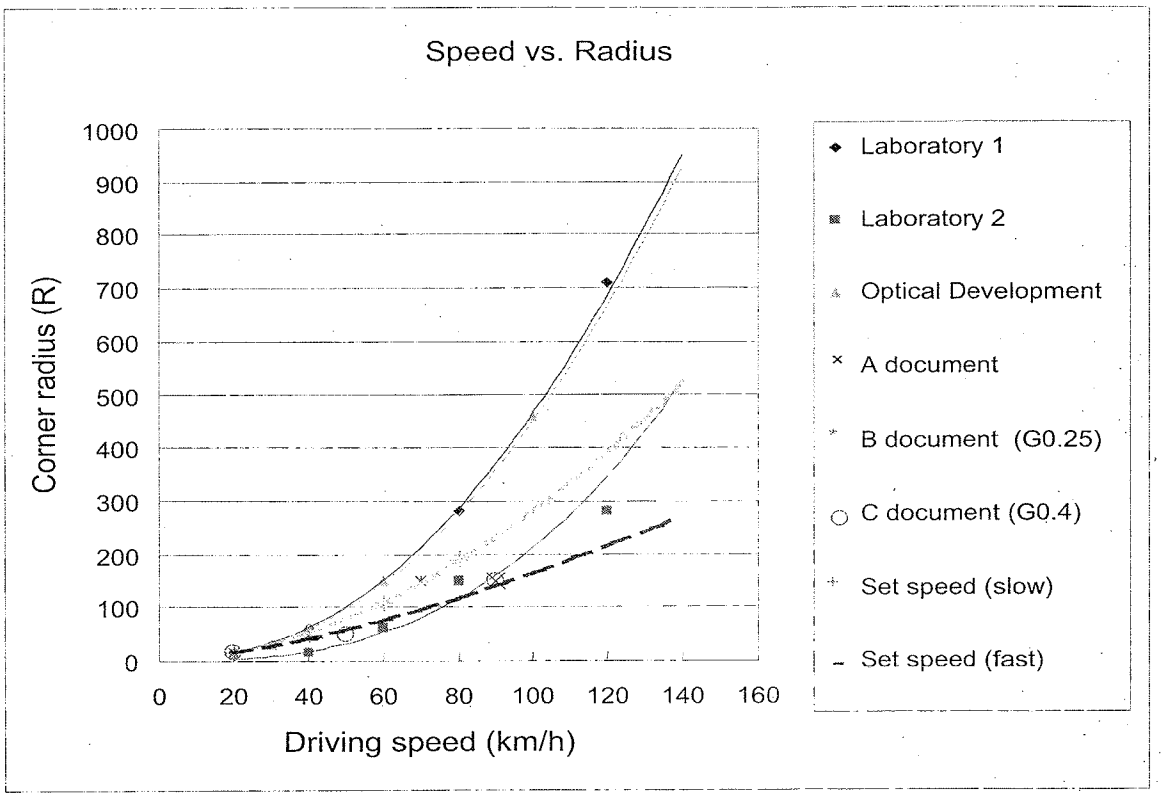
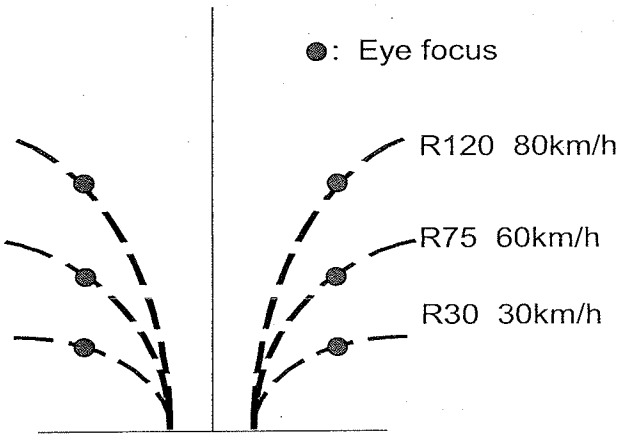



Relation between Radius, Speed, Eye Focus (arriving point 1,5 sec. later)

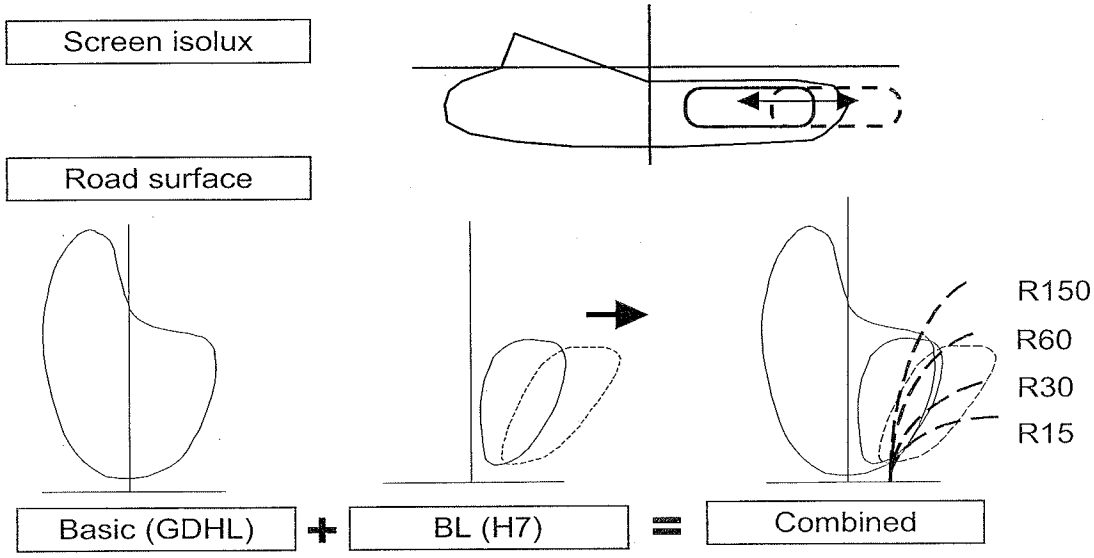


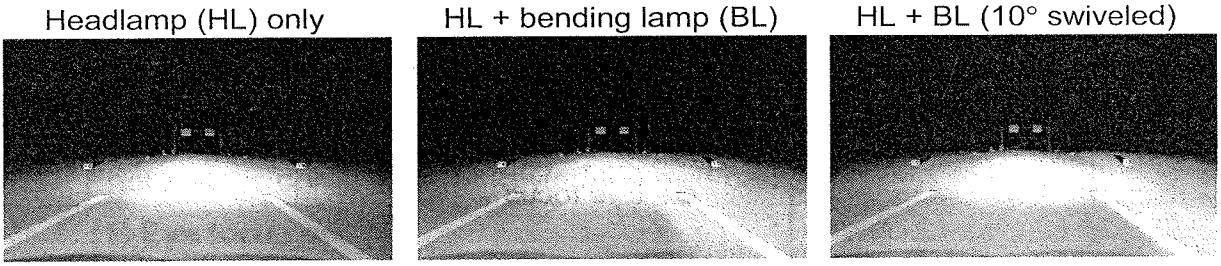

3.2.2. Designed light distribution for low/mid-speed cornering

To ensure an illuminance of 50 lx or more in the eye focus area during low- or mid-speed cornering, we examined the basic light diffusion patterns of gas-discharge headlamps. It was found that, if the diffusion becomes excessive, the far visibility declines and the overall illuminance of the visible field decreases.

To overcome this problem, additional lamps (H7) were introduced to ensure sufficient illuminance by reducing the light diffusion requirement of the

headlamps. Further, by providing a reflector-swiveling capability to the additional lamps, a necessary amount of light was distributed to the eye focus area during cornering.




3.2.3. Construction and control

In our AFS prototype, the ECU functions to turn on/off the bending lamp and to adjust the reflector swivel angle during cornering in response to the input of steering angle and vehicle speed data. Thus the AFS prototype automatically optimizes the light distribution in the eye focus area.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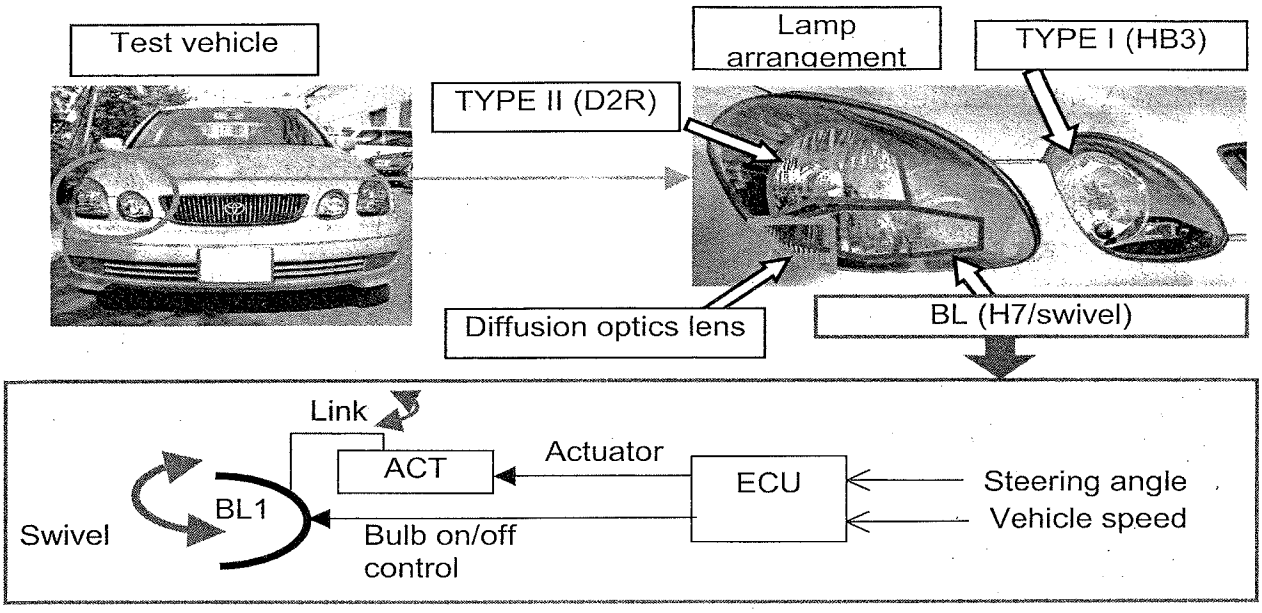


## 4. Verification of Effectiveness

### 4.1. Selection of a Test Course

In view of Japan's typical road conditions reported in section 2 and the AFS prototype concept introduced in section 3, possible test courses were investigated around the Koito Shizuoka plant. A section of Prefectural Road 75 located in the Takayama district of Shimizu City was selected for testing.

| | No. of lanes | Road width | Curvatures | Road lamps |
|---|---|---|---|---|
| Typical prefectural roads | 2 | 7-9m | R 20-60 | In sight-blocking corners |
| Takayama section of Pref. Road 75 | 2 | 7m | R 16-85 | In each corner |

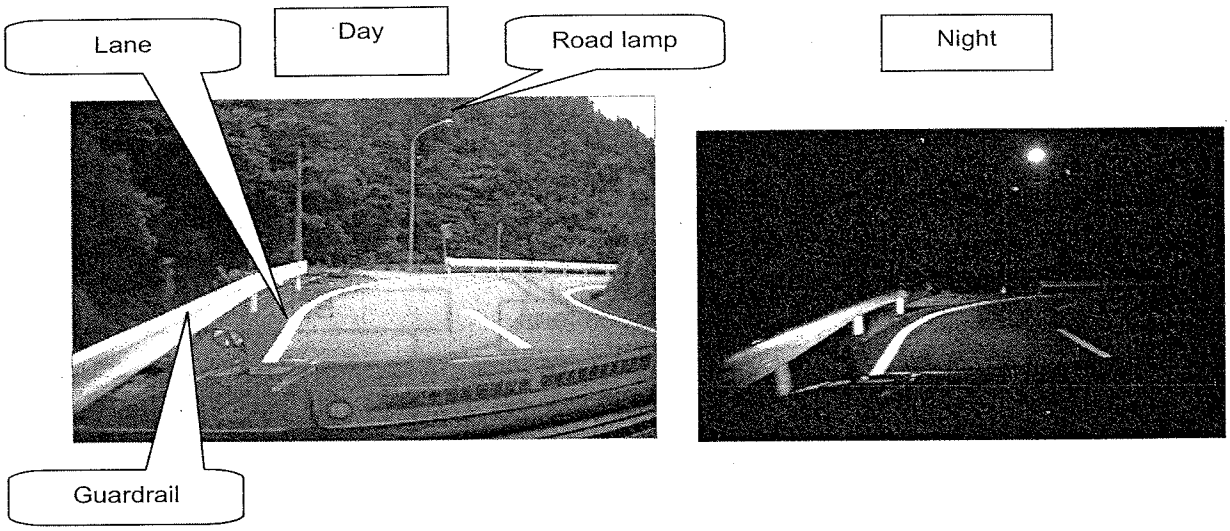


*Fig.4 Approach to R16 right corner on test course*

4.2. Visibility Rating Method

4.2.1. Perceptual rating by human subjects

(1) Subjects

Five subjects were selected among those having a driving experience of at least five years, normal eyesight, and aged between 20 to 59.

(2) Rating procedures

a. The subjects were conditioned to the test course by driving a conventional (non-AFS) car three round trips along the test course.

b. Five rating targets were set in the test course, where the subject was asked to rate the visibility of those targets during driving operation according to a five-point rating:

5 points: Very good visibility

to

1 point: No visibility at all.

The rating by the subject was recorded by an instructor in the adjacent passenger's seat.

c. Each subject underwent the above rating test two times, using a conventional car and an AFS-equipped car.

d. The rating results were analyzed.


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| Rating target | | Curvature R (m) | Spped (km/h) | Rated target |
|---|---|---|---|---|
| 1 | Mid-speed corner 1 (right) | 85 | 70 | center lane marking (long.) |
| 2 | Mid-speed corner 2 (left) | 85 | 70 | left lane marking (long.) |
| 3 | Mid-speed corner 3 (right) | 55 | 60 | center lane marking (long.+lat.) |
| 4 | Mid-speed corner 4 (left) | 55 | 60 | left lane marking (long.+lat.) |
| 5 | Low-speed corner 1 (right) | 16 | 35 | center lane marking (lat.) |
| 6 | Low-speed corner 2 (left) | 16 | 35 | left lane marking (lat.) |

Note: Long. means "emphasis on longitudinal extension" and lat. means "emphasis on lateral diffusion."

*Table 2 Targets in the Visibility Rating Test*

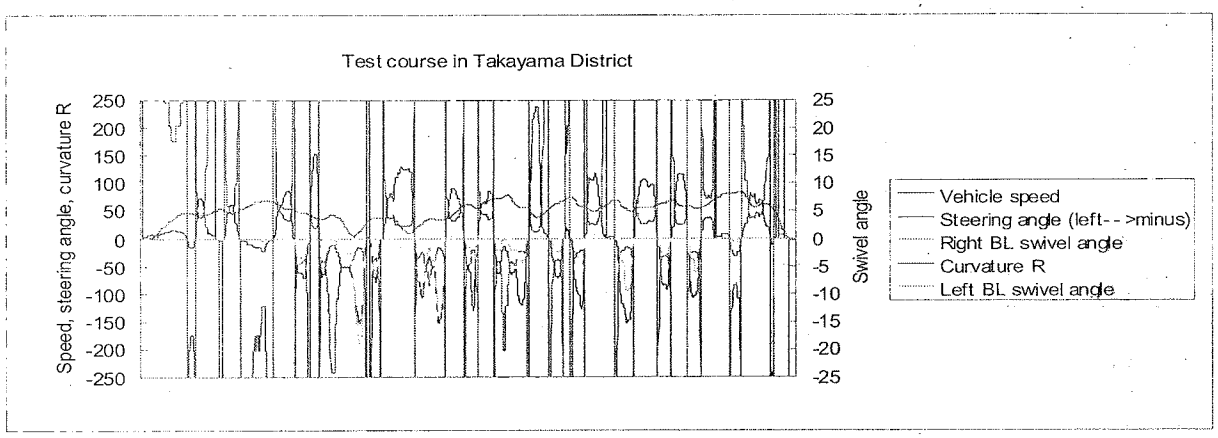



*Fig.5 Measurements of curvature R, driving speed, swivel*

4.2.2. Quantitative evaluation of eye focus area visibility

(1) Investigation of eye focus position

It was assumed that, during driving, drivers fixate their eyes at a point where the vehicle will arrive in 1.5 seconds later and which varies slightly according to corner curvature and driving speed.

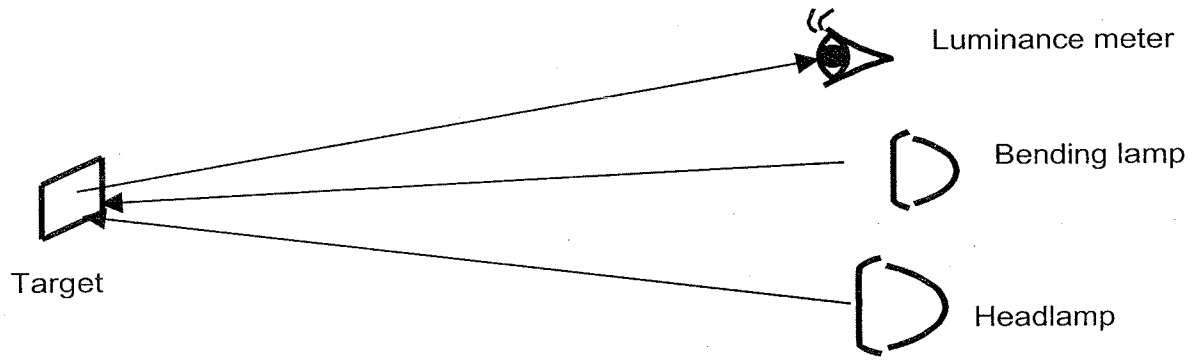
a. Subjects were asked to drive an AFS car both in the day and night and a conventional car in the night. During each driving test, the subject was questioned at the above-mentioned five target locations as to the position of their eye focus.

b. Of the responses from the subjects, the most frequent response was taken as indicating the eye focus position at each of the target locations.

(2) Quantitative data in eye focus areas

a. Measurement of target luminance, background luminance and their contrast

Since it is extremely difficult to measure the luminance of visibility rating targets on a real road for traffic reasons, the measurement was performed in a secluded visibility test ground offering various road curvature conditions. As illustrated below, a target was placed in a setting simulating the positions of the eye, bending lamp and headlamp. Then the luminance values of the target and its background were measured with a luminance meter placed at the eye position.




b. Reflectivity of Target

The target plate, measuring 20 cm by 20 cm and colored gray mat, had a reflectivity of 5%.

## 4.3. Evaluation Results

### 4.3.1. Perceptual rating by subjects

The results of visibility rating by the five subjects clearly indicate that the cornering visibility improved by changing from a conventional car to an AFS-equipped car.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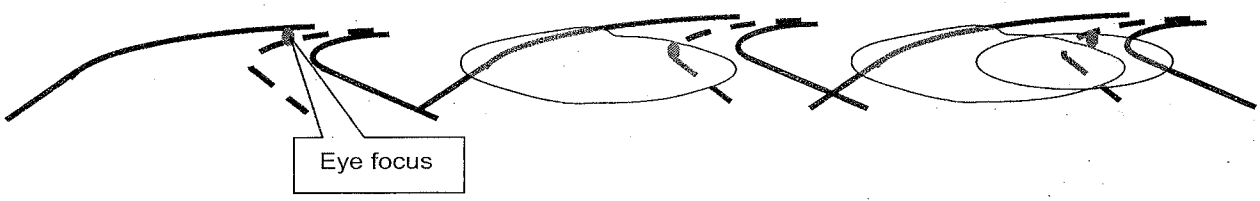
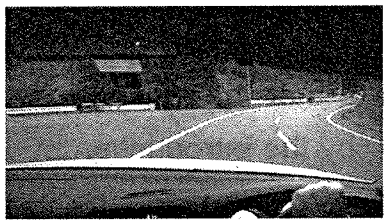
## Results of Perceptual Rating

| | Rating target | Curvature R (m) | Spped (km/h) | Rating point Conventional car | AFS-equipped car |
|---|---|---|---|---|---|
| 1 | Mid-speed corner 1 (right) | 85 | 70 | 3 | 4 |
| 2 | Mid-speed corner 2 (left) | 85 | 70 | 3 | 4 |
| 3 | Mid-speed corner 3 (right) | 55 | 60 | 2 | 3 |
| 4 | Mid-speed corner 4 (left) | 55 | 60 | 2 | 3 |
| 5 | Low-speed corner 1 (right) | 16 | 35 | 1 | 2 |
| 6 | Low-speed corner 2 (left) | 16 | 35 | 1 | 2 |

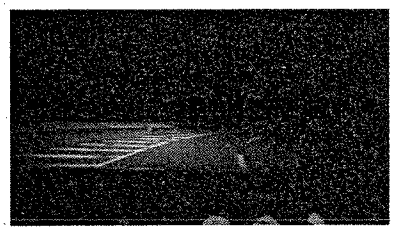
Mid-speed corner 1 image (day) Conventional lighting (night) AFS-lighting (night)

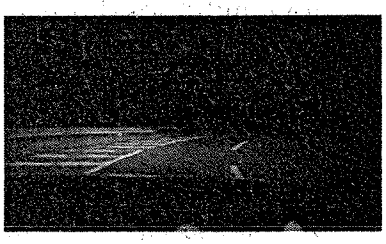



mid-speed corner 1 right

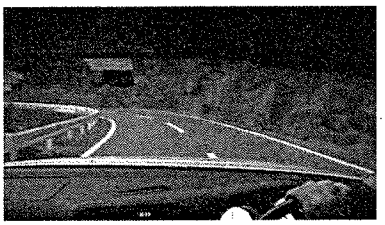


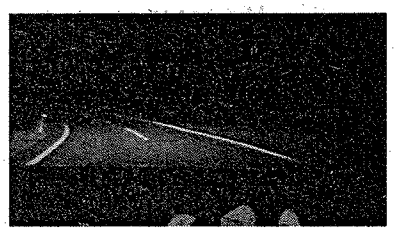
mid-speed corner 3 right





low speed corner 2 left

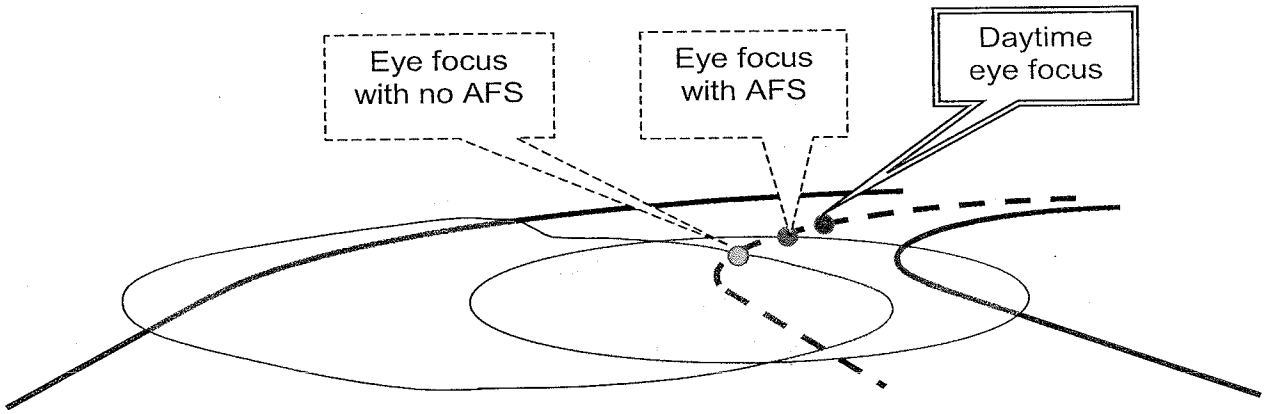




day non-AFS (night) AFS (night)

4.3.2. Quantitative evaluation by luminance contrast

The contrast between the luminance of the target and that of the background was compared between AFS and conventional headlamp systems. The results indicate that the luminance contrast increased in most of the target sites by replacing the conventional headlamp system with our AFS prototype.




4.3.2.1. Luminance contrast at eye focus

As shown in the table below, the results indicate that the luminance contrast value increased 1.5 times to stand at around 1.0 by the introduction of an AFS. Thus we confirmed that the AFS markedly improved the nighttime visibility in low/mid-speed driving.

| Rating target | | Curvature R (m) | Spped (km/h) | Contrast Non AFS (A) | Contrast AFS (B) | (B)/(A) |
|---|---|---|---|---|---|---|
| 1 | Mid-speed corner 1 (right) | 85 | 70 | 0.630 | 0.933 | 1.48 |
| 2 | Mid-speed corner 2 (left) | 85 | 70 | 0.630 | 0.962 | 1.53 |
| 3 | Mid-speed corner 3 (right) | 55 | 60 | 0.630 | 1.005 | 1.60 |
| 4 | Mid-speed corner 4 (left) | 55 | 60 | 0.631 | 1.027 | 1.63 |
| 5 | Low-speed corner 1 (right) | 16 | 35 | 0.630 | 0.989 | 1.57 |
| 6 | Low-speed corner 2 (left) | 16 | 35 | 0.630 | 1.073 | 1.70 |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## 5. Conclusion

5.1. Perceptual rating by subjects

Visibility improved with an AFS.

As the visible field expanded farther and sideways, the road curve lines became more easily recognizable.

The eye focus moved closer to the daytime eye focus position.

5.2. Quantitative evaluation by luminance measurement

The luminance contrast and road surface illuminance in the eye focus area increased with an AFS

According to the above

Perceptual rating and quantitative evaluation in agreement

5.3. Overall

Under the Japanese traffic environment, Introduction of bending lamps into AFS beneficial for low/mid-speed driving