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# LED APPLICATION IN HELICOPTER COCKPIT LIGHTING

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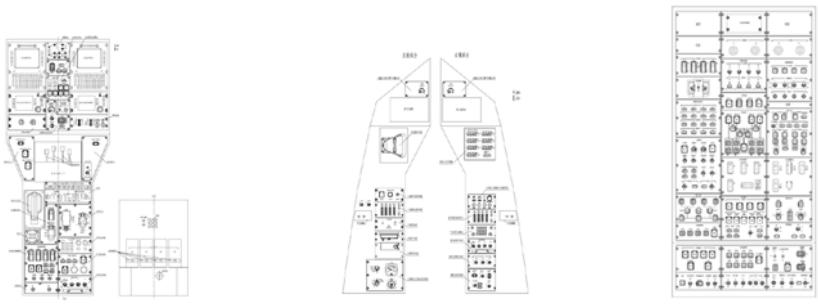
## Abstract

LED has been widely used in indoor and outdoor spaces of buildings. But for the internal space of the vehicle, which is also an important space for modern people, there is a lack of theoretical research and corresponding data bases for LED applications. Helicopter as a special vehicle, putting higher demands on the quality of the lighting environment required to meet visual tasks. Also, the external light environment of the helicopter's cockpit is variable and the self-luminous equipment in the helicopter's cockpit is sophisticated and varied. Therefore, Increased the difficulty of basic research in LED applications. This paper is a basic data study of the application of LEDs in helicopter cockpit lighting systems, obtained the lighting environment parameters of the in-service helicopter cockpit and the subjective feeling evaluation data of the corresponding driver. Based on subjective and objective data, The research and development needs of LEDs for use in helicopter cockpit lighting environments have been clarified.First, Improve the recognition of self-illuminating equipment under sunny and night conditions: to obtain the luminance range and luminance self-adjusting control curve that meet the requirements of the recognition of self-illuminating equipment under sunny and night conditions; Then, improve the ambient lighting comfort at night: to obtain the Illuminance and illuminance uniformity of the ambient lighting under the night conditions that meet the visual comfort and visual efficacy requirements.

*Keywords*: LED、Helicopter cockpit、Lighting environment

## 1 Introduction

The cockpit space of the helicopter is limited, and the equipment is sophisticated. Inevitably, as shown in Figure 1, the equipment layout is highly integrated. This results in a particularly heavy visual load on the driver. Therefore, the efficient and comfortable cockpit lighting environment is the necessary condition to relieve the visual fatigue of pilots, ensure the long-term safe flight of the helicopter, and is the fundamental task of the cockpit light environment design.



**（a）Central console　（b）Left and right console　（c）Top console**

**Figure 1 – The equipment layout on the console of one helicopter cockpit**[1]

That is to say, helicopter as a special vehicle, putting higher demands on the quality of the lighting environment required to meet visual tasks. Also, the external light environment of the helicopter's cockpit is variable and the self-luminous equipment in the helicopter's cockpit is

sophisticated and varied. Therefore, Increased the difficulty of basic research in lighting applications.

LED uses cold-lighting technology, so it has less heat dissipation. It is energy efficient, has a long service life, with small size, so it can be highly integrated. LED has been widely used in indoor and outdoor spaces of buildings. The above advantages of LED offer extremely high possibilities for its applications in helicopter equipment and lighting systems, which need a more rigorous integration because of the limited space and the harsh physical environment in the cockpit. Currently, there are technical recommendations for the application of LEDs to aircraft lighting systems[2]. However, there is still a lack of theoretical research and corresponding data foundation for several problems, such as the glare problem caused by high brightness of LED, night vision compatibility problem of LED spectrum, and the lack of the brightness self-adjusting reference curve that based on driver's visual recognition and visual comfort requirements.

This paper is a basic data study of the application of LEDs in helicopter cockpit lighting systems, obtained the lighting environment parameters of the in-service helicopter cockpit and the subjective feeling evaluation data of the corresponding driver. Based on subjective and objective data, The research and development needs of LEDs for use in helicopter cockpit lighting environments have been clarified.

## 2 The Lighting Investigation Of the Helicopter Cockpit

The investigation included an on-board investigation measurement of the light environment of the in-service helicopter cockpit, and conducted a questionnaire survey and subjective interview with drivers.

### 2.1 Lighting Measurement

Generally, there are two types of helicopter cockpits: “Side-by-side” and “Tandem”. About the first type, chief driver and cooperative driver are in the same cabin. And the second has two cabins for the driver. The two types of cockpits differ in their layout of the instrument panels, seats, consoles, controls, etc., but the basic design of the In-cabin lighting system of the helicopter cockpit are the same(Figure 2). In-cabin lighting system of the helicopter cockpit includes LCD screens, meters, light guides(console) and signal lights, which can be called self-illuminating display device, also includes floodlights for ambient lighting and spotlights (reading light) for local illumination. The corresponding factors affecting the driver's recognition ability and visual comfort can be divided into two categories: brightness factor and chrominance factor:

1, brightness factor include :

1) The luminance of the text, characters, scale;
2) The luminance ratio of the text, characters, scale to their background;
3) The luminance ratio of the device display interface to their background;
4) Illumination and uniformity of illumination of the working surface of the device display interface.

2, chrominance factor include :

1) The chromaticity of the text, characters, scale;
2) Background chromaticity;
3) colour rendering, colour temperature, spectral distribution (night vision compatibility requirements) of the ambient lighting.

**Figure 2 – The two types of helicopter cockpits: “Side-by-side” and “Tandem” (Front cabin)**

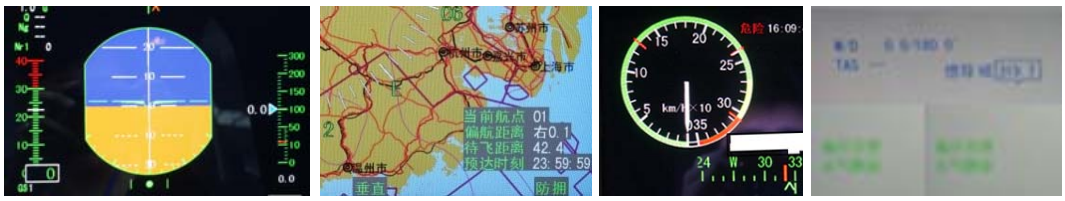
Based on the above influencing factors, this paper carried out an on-board investigation under the two conditions of day/night for the light environment of the in-service helicopter cockpit. Measured the brightness and chromaticity of the main display device, also the quality of lighting provided by ambient lighting. Aims to provide an objective data foundation for the application of LED in helicopter cockpit lighting systems that based on visual ergonomics and visual comfort requirements.

There are two helicopter in the measurement. Helicopter A has a tandem cockpit and Helicopter B has a side-by-side cockpit. Since the text, characters and scales on the device can be clearly identified when the cockpit ambient illuminance is greater than 200lx, there is no need to turn on the lighting system. Therefore, the measuring conditions are cloudy in daytime (environmental illuminance is less than 200lx) and night time.

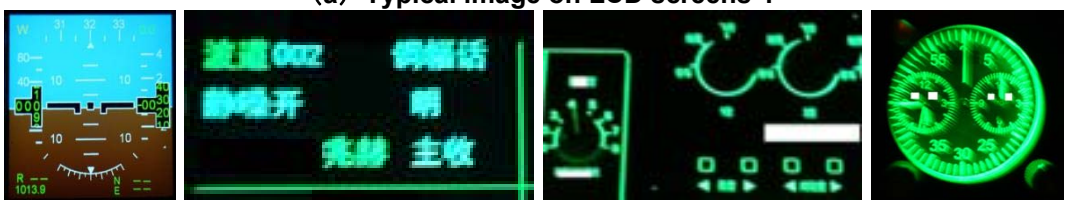
Small-sized text, characters and scales are the main test objects, so the measurement accuracy, image resolution, and minimum measurable area of the measuring instrument needs to be screened. This measurement selects the following measuring instrument (Figure 3) to meet the test requirements.

**Figure 3 – CL-500A Illuminance Spectrophotometer and LumiCam 1300 Color**

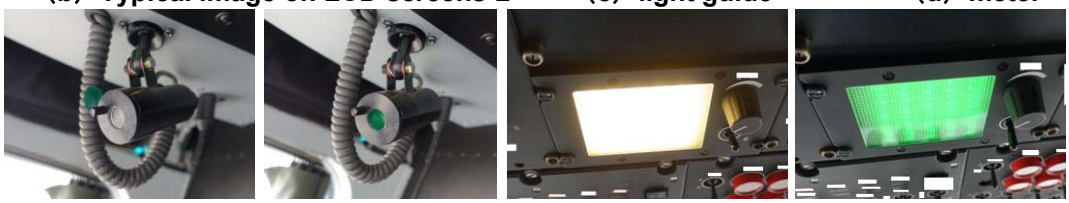
The measuring object is shown in Figure 4, we obtained luminance and colorimetric measured parameters (including Colour coordinates x, y and Dominant wavelength) for LCD screens, meters, light guides and signal lights, also work plane illuminance , colour rendering index, colour temperature and spectral distribution of floodlights and spotlights(reading light).



**（a）Typical image on LCD screens-1**



**（b）Typical image on LCD screens-2** **（c）light guide** **（d）meter**



**（e）spotlight** **（f）floodlight**

**Figure 4 – The details of the measuring object**

Table 1 is part of the data. A total of 16 typical colours were measured. Except for the individual reddish colours, the dominant wavelength of most colours is close to the green wavelength.

And the positions of the measured colour coordinate are concentrated, the colour difference is small.

**Table 1 – Part of the data**

| Equipment | Object | colour | luminance（cd/m²） | | dominant wavelength（nm） |
|---|---|---|---|---|---|
| | | | Night time | Daytime | |
| LCD screen | text, characters, scale | 01blue | 0.6 | 110~160;210~240 | 567；440~490 |
| | | 02cyan | 10~25 | 200~300;350~400 | 500 |
| | | 03green | ＜10 | 100~300 | 500~580 |
| | | 04red | - | 40~60;90~95 | 590 |
| | Background | 05purple | - | 370~450 | 500；570 |
| | | 06earth | 3 | 30;55;100 | 570~620 |
| | | 07cyan | 7 | 300~500 | 495；560 |
| | | 08blue | 3~4 | 30;50 | 460~ 480 |
| | | 09black | 0.25;0.1 | 10;30;62 | 450~ 550 |
| light guide | characters | 10green | 1~3 | 100~300 | 530;570 |
| | background | 11black | 0.02;0.5 | 15~25 | 550~600 |
| Meter | scale | 12green | 0.5~1 | 100~200;300~400 | 500~540 |
| | | 13cyan | - | 250~600 | 500~520 |
| | background | 14black | 0.05 | 5~30 | 480~620 |
| signal light | characters, | 15orange | - | 100~700 | 580~610 |
| | background | 16black | - | 5~12 | 495 |

In the case of night-time, the colour of the light guide and meter are just green and black, that because of the need to meet night vision compatibility requirements. The luminance of the green colour is mostly below 1cd/m², The average luminance of the black background is 0.03 cd/m², so the luminance ratio is about 20. The maximum luminance of the LCD screen in night-time is up to 25cd/m2, which colour is cyan, but the luminance ratio of the LCD screen is below 10.

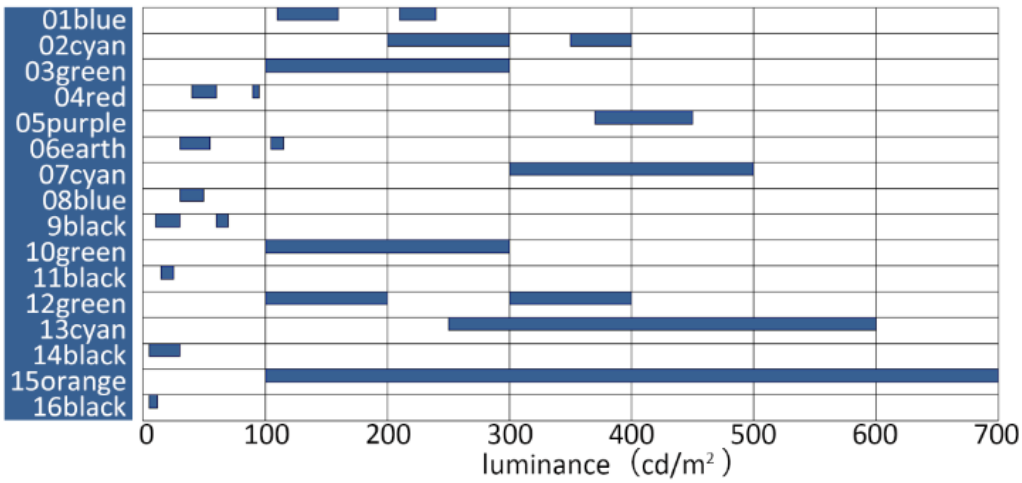



**Figure 5 – The statistics of luminance of the 16 colours in the self-emitting devices**

In the case of daytime, the luminance of the 16 colours in the self-emitting devices have a large distribution range (Figure 5). The luminance of the colour of the text、characters、scale is from 100 cd/m$^2$ to 700 cd/m2 , and the luminance of the colour of the background is mostly below 50 cd/m2 . After calculation, the maximum luminance ratio of the LCD screens is 25.3, and the light guide is 45.6, the meter is 44, and the indicator is 43.3.

Both the floodlight which provide lighting to the overal environment and the spotlight (reading light) which provide lighting to the specific work surface have two lighting modes: normal white light and green light for night vision compatibility. About the white light, the CCT of the light source is between 2429K and 2999K, Ra is between 97 and 99, the spectral distribution is in an oblique line (incandescent spectrum),and the illuminance of the working face is up to 30lx. About the green light, CCT、Ra and spectral distribution maps are unmeasurable, the dominant wavelength is between 540.5 nm and 542.2 nm, and the illuminance of the working face is between 5 lx and 10lx.

## 2.2 Helicopter Pilot Survey

The survey object is the in-service driver of the 3 helicopters(A/B mentioned above and new C ). A total of 36 male drivers (12 *3 models) were surveyed, and 6 of them participated in the interview. All drivers have good eyesight. The driver and age of the helicopter B are older than those of the A and C . The first flight of those drivers is similar(Table 2).

**Table 2 – Driver information statistics**

| helicopter | No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | **Average** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Driving age | 8 | 5 | 5 | 6 | 3 | 3 | 3 | 3 | 5 | 5 | 9 | 10 | **5.42** |
| A | Age | 30 | 31 | 26 | 27 | 25 | 25 | 25 | 25 | 30 | 31 | 30 | 33 | **28.17** |
| | First flight age | 22 | 26 | 21 | 21 | 22 | 22 | 22 | 22 | 25 | 26 | 21 | 23 | **22.75** |
| | Driving age | 11 | 8 | 15 | 8 | 6 | 5 | 15 | 6 | 6 | 3 | 18 | 7 | **9.00** |
| B | Age | 33 | 28 | 38 | 33 | 31 | 30 | 38 | 28 | 32 | 28 | 39 | 29 | **32.25** |
| | First flight age | 22 | 20 | 23 | 25 | 25 | 25 | 23 | 22 | 26 | 25 | 21 | 22 | **23.25** |
| | Driving age | 5 | 5 | 3 | 2 | 6 | 5 | 7 | 6 | 7 | 5 | 5 | 10 | **5.50** |
| C | Age | 26 | 25 | 27 | 25 | 30 | 28 | 30 | 29 | 31 | 28 | 29 | 33 | **28.42** |
| | First flight age | 21 | 20 | 24 | 23 | 24 | 23 | 23 | 23 | 24 | 23 | 24 | 23 | **22.92** |

Topics include:Satisfaction with the cockpit light environment; Satisfaction of the interior lighting environment and the recognition of self-illuminating equipment of the cockpit under four conditions of sunny, cloudy, dusk and night; The degree of glare on sunny days; Satisfaction with interior surfaces, control surfaces and luminaire forms. The existing problems in the lighting environment of the in-service helicopter cockpit are sorted out, and the first-hand data from the user is provided for the LED application to the helicopter cockpit lighting system.

Table 3 and 4 is the result of the survey : -3 is very dissatisfied, -2 is less satisfied, -1 is generally unsatisfied, 0 is not sensed, 1 is generally satisfactory, 2 is more satisfactory, and 3 is very satisfied. The following are the results:

1、Helicopter A

A total of 7 items with a satisfaction rating below 2 points ( more satisfactory).

1) 6 drivers think that sunny daylight glare often occurs (score -2), accounting for 50% ; 1 driver thinks that sunny daylight glare is unbearable (score ≤-3), accounting for 8.3%; although half of the drivers think that daylight glare often occurs, most drivers think it can be tolerated.
2) The main reason for the lower overall satisfaction of the cockpit light environment is that the driver thinks that the cockpit light is too dark and there is occlusion, and the button itself has no illumination, so the button position cannot be seen/cannot be found; in addition, there is still glare and nighttime reflection problems.

3) The main reason for the low satisfaction of night meter identification is that the driver thinks that “too dark” and “color is not easy to identify”
4) The main reason for the low satisfaction of the indicator light recognition at dusk, rainy day and night is that the driver thinks that it is “too bright”
5) The main reason for the lower satisfaction of interior finish color is also because of “too dark”
6) The main reason for the lower satisfaction of the lighting control interface is that the driver thinks that the button position is not clear/cannot be found because the cabin light is too dark and there is occlusion, and the button itself is not illuminated. It is recommended to add button lighting.

2、Helicopter B

A total of 5 items with a satisfaction rating below 2 points ( more satisfactory).

1) 7 drivers think that sunny daylight glare often occurs (score -2), accounting for 58.3% ; 4 drivers think that sunny daylight glare is unbearable (score ≤-3), accounting for 33.3% ; the impact of daylight glare is more serious.
2) The main reason for the lower overall satisfaction of the cockpit light environment is that the driver believes that there is day glare and nighttime reflection problems. In addition, “over-dark” and “brightness adjustment” are also influencing factors.
3) The main reason for the lower satisfaction of night screen display recognition is that the driver thinks “too bright” and “glass reflective”.
4) The main reason for the lower satisfaction of interior finish color is also because of “too dark”.
5) The main reason for the low satisfaction of the lighting control interface is that the driver thinks that the handling convenience and sensitivity are poor.
6) The main reason for the low satisfaction of the form of the luminaire is that the driver thinks that the cockpit light is not soft and there is occlusion.

3、Helicopter C

A total of 3 items with a satisfaction rating below 2 points ( more satisfactory).

1) The main reason for the lower satisfaction of the instrument and indicator light on sunny days is that the driver thinks that it is “too dark”, and the glare problem occurs due to the high brightness of the sunlight or sky outside the sunny cabin, thus causing the recognition to be affected; The glare of the daylight is consistent with the survey results, and one-third of the drivers think that the glare of the daylight often occurs and cannot be tolerated.
2) The main reason for the low satisfaction of the lighting control interface is that the control is inconvenient, and there is no separate and integral linkage adjustment switch, and the brightness adjustment is inconsistent and insensitive.

In summary, based on the questionnaire data and interview conclusions, this survey has the following conclusions:

1.Regarding the sun glare, although the driver has the adaptability, it causes the problem that the identification of the equipment in the cabin is not satisfactory.

2.The cockpit lamp has insufficient illumination and occlusion problems. The side-by-side cockpit is more obvious because its larger opening , which leads to the problem of unsatisfactory recognition of non-lighting equipment.

3.There are direct glare (such as over-illuminated warning lights) and indirect glare (glass reflective) at night interfered with equipment identification.

4.The brightness adjustment of some device is inconvenient and insensitive.

5.The cockpit color recognition problem is mainly caused by insufficient illumination, and has nothing to do with the chroma itself.

**Table 3 – Result of the glare of the cockpit in sunny daylight**

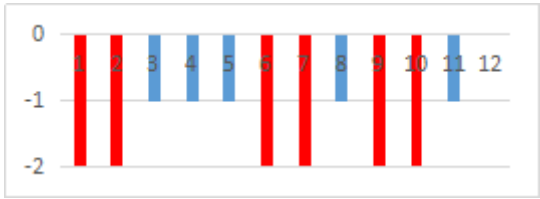
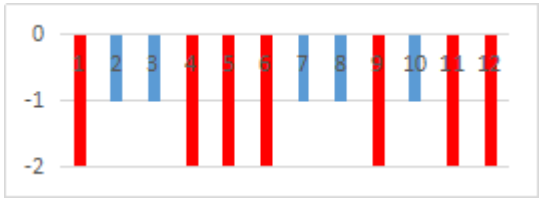
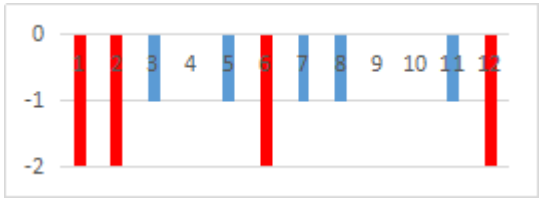
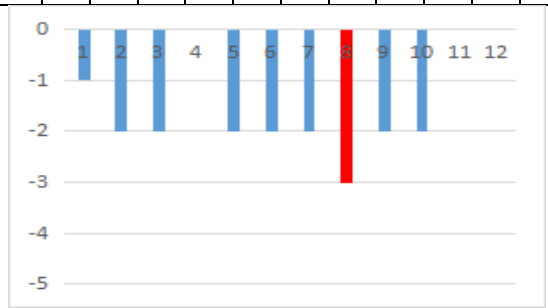
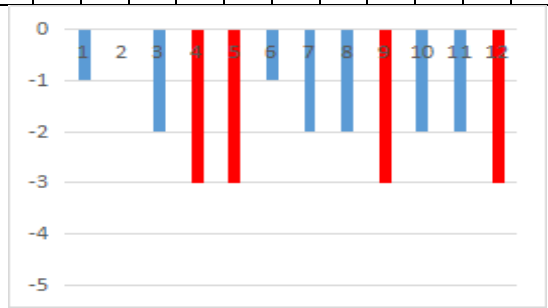
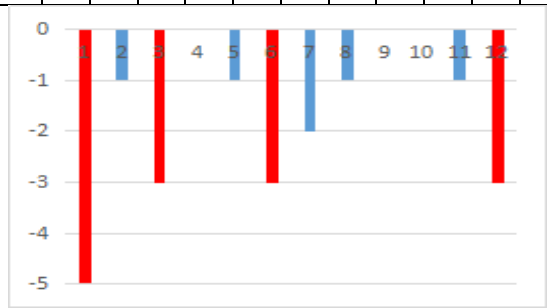
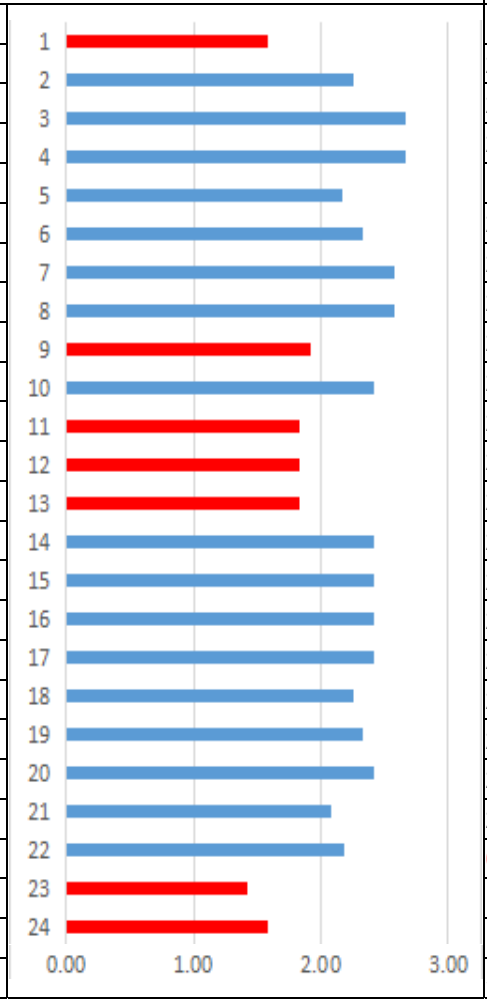
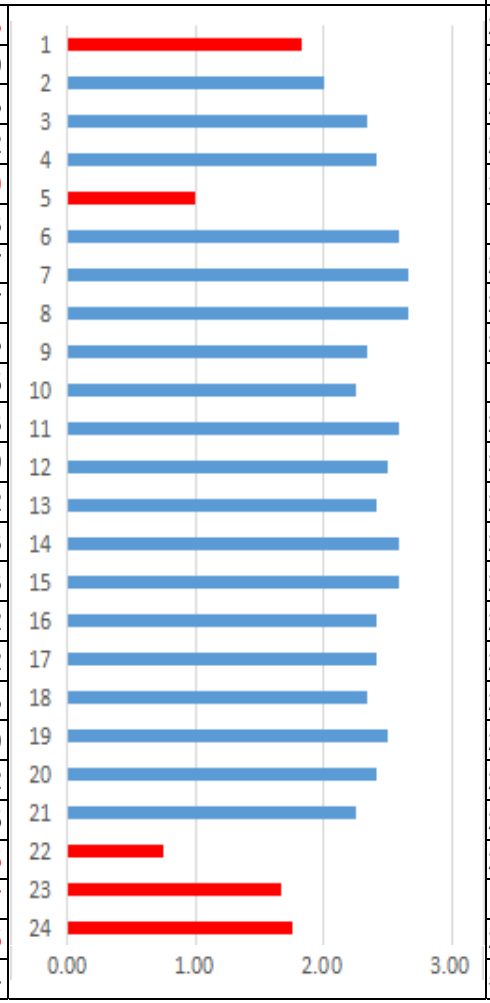
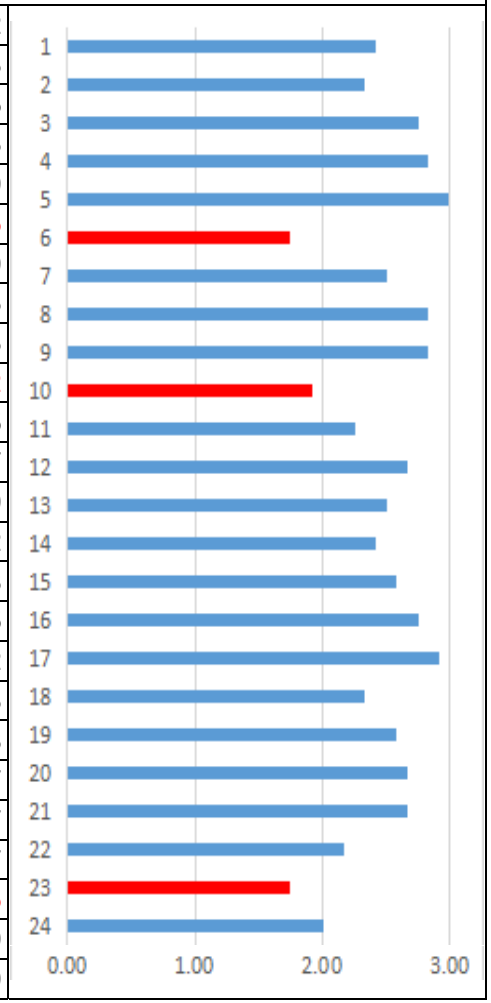
| | | Helicopter A | | | | | | | | | | | | Helicopter B | | | | | | | | | | | | Helicopter C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ⅰ | Average | -2 | -2 | -1 | -1 | -1 | -2 | -2 | -1 | -2 | -2 | -1 | 0 | -2 | -1 | -1 | -2 | -2 | -2 | -1 | -1 | -2 | -1 | -2 | -2 | -2 | -2 | -1 | 0 | -1 | -2 | -1 | -1 | 0 | 0 | -1 | -2 |
| | Map |  | | | | | | | | | | | |  | | | | | | | | | | | |  | | | | | | | | | | | |
| Ⅱ | Average | -1 | -2 | -2 | 0 | -2 | -2 | -2 | -3 | -2 | -2 | 0 | 0 | -1 | 0 | -2 | -3 | -3 | -1 | -2 | -2 | -3 | -2 | -2 | -3 | -5 | -1 | -3 | 0 | -1 | -3 | -2 | -1 | 0 | 0 | -1 | -3 |
| | Map |  | | | | | | | | | | | |  | | | | | | | | | | | |  | | | | | | | | | | | |
| Remarks | | Ⅰ：Occurrence probability of glare: 0 no ；-1 happens by chance； -2 occurs frequently ；(if there is no glare, the degree of glare is ignored)<br>Ⅱ：The degree of glare: unbearable -5 □ -4 □ -3 □ -2 □ -1 □ 0 □ can endure | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Table 4 – The questionnaire statistics**

| n | topic | | Helicopter A | | Helicopter B | | Helicopter C | |
|---|---|---|---|---|---|---|---|---|
| 1 | Total | | 1.58 |  | 1.83 |  | 2.42 |  |
| 2 | Display recognition | sunny | 2.25 | | 2.00 | | 2.33 | |
| 3 | | dusk | 2.67 | | 2.33 | | 2.75 | |
| 4 | | rainy | 2.67 | | 2.42 | | 2.83 | |
| 5 | | night | 2.17 | | 1.00 | | 3.00 | |
| 6 | Instrument identification | sunny | 2.33 | | 2.58 | | 1.75 | |
| 7 | | dusk | 2.58 | | 2.67 | | 2.50 | |
| 8 | | rainy | 2.58 | | 2.67 | | 2.83 | |
| 9 | | night | 1.92 | | 2.33 | | 2.83 | |
| 1 | Indicator identification | sunny | 2.42 | | 2.25 | | 1.92 | |
| 1 | | dusk | 1.83 | | 2.58 | | 2.25 | |
| 1 | | rainy | 1.83 | | 2.50 | | 2.67 | |
| 1 | | night | 1.83 | | 2.42 | | 2.50 | |
| 1 | Guide plate recognition | sunny | 2.42 | | 2.58 | | 2.42 | |
| 1 | | dusk | 2.42 | | 2.58 | | 2.58 | |
| 1 | | rainy | 2.42 | | 2.42 | | 2.75 | |
| 1 | | night | 2.42 | | 2.42 | | 2.92 | |
| 1 | Bright and identification | sunny | 2.25 | | 2.33 | | 2.33 | |
| 1 | | dusk | 2.33 | | 2.50 | | 2.58 | |
| 2 | | rainy | 2.42 | | 2.42 | | 2.67 | |
| 2 | | night | 2.08 | | 2.25 | | 2.67 | |
| 2 | Finish color | | 2.18 | | 0.75 | | 2.17 | |
| 2 | Control | | 1.42 | | 1.67 | | 1.75 | |
| 2 | Lamp form | | 1.58 | | 1.75 | | 2.00 | |
| 2-24Total score | | | 51.0 | | 51.4 | | 57.0 | |

## 3 The Research And Development Needs Of LEDs Used In Helicopter

According to the different factors considered in the previous experimental setup, the experimental results are analyzed in seven aspects: illuminance, colour temperature, reflectance of reading background, lighting style, luminance of reading background,and the influence of different reading tools on reading comfort. The experimental results are shown in Figures 2-7.

As talked above, unlike conventional lighting space, the study of the cockpit lighting environment should consist of 3 parts:The first is the outdoor light environment, and the sunny and night cabin light environment is the key research condition ; followed by is the luminance and chrominance of the self-illuminating device ; the last is the ambient lighting in the cabin.

Therefore, the research and development needs of LEDs for use in helicopter cockpit lighting environments are as follows:

1. Improve the recognition of self-illuminating equipment under sunny and night conditions: to obtain the luminance range and luminance self-adjusting control curve that meet the requirements of the recognition of self-illuminating equipment under sunny and night conditions;

2. Improve the ambient lighting comfort at night: to obtain the Illuminance and illuminance uniformity of the ambient lighting under the night conditions that meet the visual comfort and visual efficacy requirements.

## 4 Conclusion

In the modern life, the interior space of the vehicle is also an important daily use space. The wide application of LEDs in indoor and outdoor spaces of buildings is sufficient to illustrate that : There is an urgent need to develop basic research on the application of LEDs to interior lighting of vehicles. Based on the above data foundation, we will continue to conduct in-depth research.

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