

# Image Quality Improvement Technologies for Energy-Saving LCD TVs

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## Introduction

We have developed an energy-saving, easy-to-view brightness control technology: the luminance of the liquid crystal display (LCD) TV screen is controlled to match the visual characteristics of the viewer. This technology has been adopted for the REAL MZW and REAL MXW series LCD TVs in the application of the Katei Gashitsu mode and energy-saving Katei Gashitsu mode.

## 1. Brightness Control under Household Conditions

In the 2006 REAL MX60 series LCD TVs, Mitsubishi Electric has introduced a brightness control function, "Katei Gashitsu mode", which eliminates dazzle. This function is the result of research on actual viewing environments, studying the visual characteristics of viewers, and surveying the performance of display devices. The function automatically adjusts the luminance and hue based on the viewer's age, viewing distance and characteristics of images displayed on the screen. Energy is also saved because the function controls brightness and reduces wasted energy.

### 1.1 Viewing environment

In 2004, we conducted a survey on lighting conditions in general households and found the average screen illuminance was 108 lx, while Nakata et al. in 1994 reported<sup>(1)</sup> a value of 93 lx, thus the screen illuminance in an average lighting environment is approximately 100 lx. The Katei Gashitsu mode was set based on a subjective evaluation under these lighting

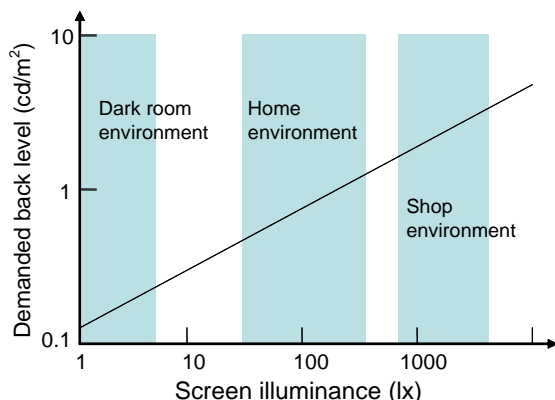


Fig. 1 Relation between screen illuminance and preferred black level

conditions.

### 1.2 Black image on LCD panel

Even if an LCD TV displays a black screen, the backlight is glowing, so a very black scene may appear gray due to light leaking from the backlight. Therefore, we evaluated the relationship between the screen illuminance and the required black level (Fig. 1), and using the results, control the brightness to match the black level in the Katei Gashitsu mode.

In a bright environment, surface-reflected light will degrade the reproducibility of black. Therefore, since the MZW series LCD TVs released in October 2007, we have applied an anti-glare coating to LCD panels, which suppresses surface reflection and internal diffuse light to enhance the reproducibility of black.

### 1.3 Dazzling luminance

On LCD TVs without brightness control, the maximum brightness is constant regardless of the displayed image. Therefore, an image with higher average brightness level will seem more dazzling than an image with a lower level.

We conducted an experiment to evaluate the dazzling luminance for both elderly (60 to 70s) and young persons (20s). The evaluation method used circular patterns of different display sizes to determine the luminance at which the subjects started to sense dazzling. The evaluation showed that dazzling was sensed at lower brightness when the area of the displayed pattern was larger, and under dimmer lighting dazzling was also sensed at lower brightness (Fig. 2).

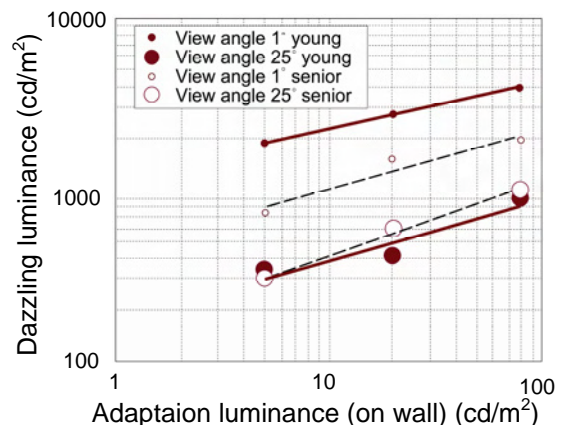


Fig. 2 Adaptation luminance and dazzling luminance

### 1.4 Viewing angle and brightness

Figure 3 shows the relationship between the viewing distances at screen illuminances of 30, 100 and 300 lx, and the preferred luminance. The shorter the viewing distance, the larger the viewing angle and the lower the preferred luminance. The survey results<sup>(2)</sup> of viewing distances of adults and children revealed that children in their teens watched TV at a distance of 0.8 times that of adults. Therefore, since the MX60 series LCD TVs, the luminance is set for the viewing distance according to the setting of the illuminance sensor provided with 3-step intensity differences.

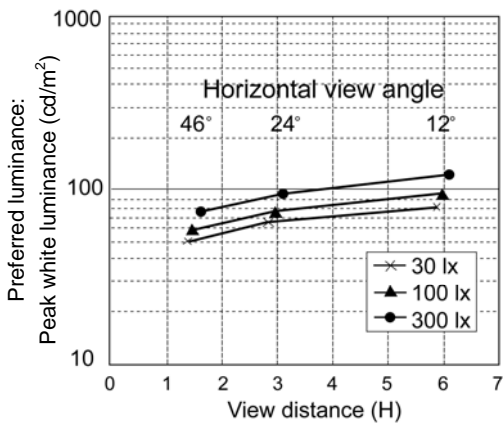


Fig. 3 Viewing distance and preferred luminance

### 1.5 Color temperature and feeling of brightness

The setting of color temperature of household TVs varies greatly, ranging from 7,000 to 20,000 K. The preferred color temperature of TV images depends on the age of the viewer and the preferred luminance. Figure 4 shows the relationship between the preferred luminance and color temperature of 20 elderly subjects. The figure shows that the higher the value, the stronger the preference. Elderly people generally tend to like images with higher color temperature because the spectral transmittance of crystalline lenses changes with age, but these results showed that subjects who liked higher luminance tended to like higher color temperature, and vice versa. The results are reflected in the Katei Gashitsu mode of the 2008 MXW200 series LCD TVs.

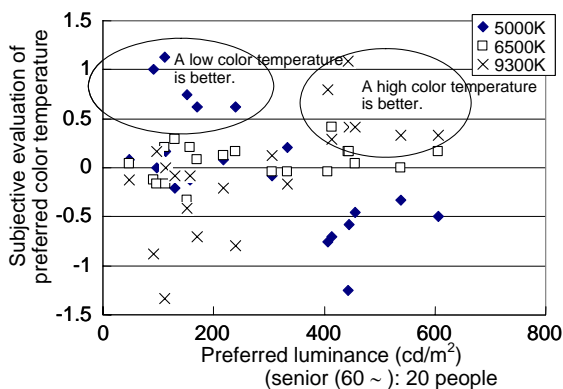


Fig. 4 Relation between preferred luminance and subjective evaluation of preferred color temperature

## 2. Brightness Control for Energy Saving and Image Quality

Figure 5 shows the relationship between brightness feeling and display luminance. The Katei Gashitsu mode controls luminance in the "bright" area where dazzling is not felt. The energy-saving Katei Gashitsu mode installed in the 2008 MZW200 series LCD TVs evaluates the brightness when viewers do not feel that a household environment is dark, and controls luminance in this area.

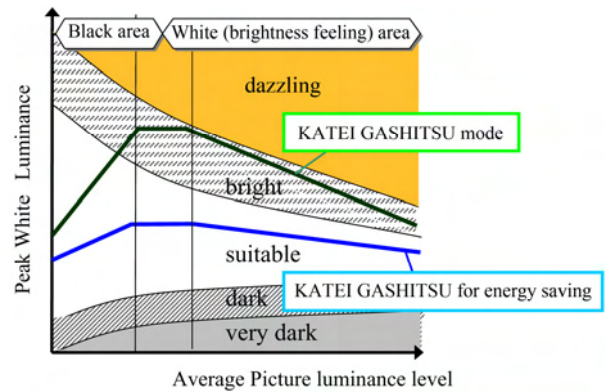


Fig. 5 Peak white luminance and brightness feeling

### 2.1 Permissible lower bound and preferred luminance evaluation

To evaluate the appropriate luminance area, a reference value is determined using the following two evaluation indices:

- (1) Preferred luminance: Brightness at which viewers do not feel eye fatigue, even when viewing for a long time, and can continue to watch the high-quality images
- (2) Permissible lower luminance: Brightness that is permissible when energy saving is taken into consideration

The evaluation was performed using a 46-inch type LCD TV in a household environment, and with 20 subjects aged 20 or older. Figure 6 shows the results: The preferred luminance was between 50 cd/m<sup>2</sup> and 500 cd/m<sup>2</sup>, and the permissible lower luminance was between 20 cd/m<sup>2</sup> and 250 cd/m<sup>2</sup>.

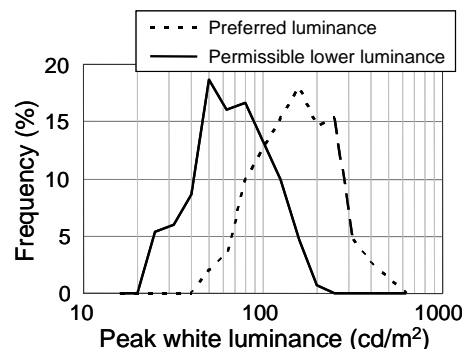


Fig. 6 Distribution of preferred luminance and permissible lower luminance

Considering these results, we chose a luminance that 90% or more of the subjects did not think was dark, and a display luminance that 50% or more of subjects preferred, for the setting values. With these settings, the annual electricity consumption of the MZW200 series LCD TVs was 168 kWh/year for the 40-inch type and 185 kWh/year for the 46-inch type, among the most energy-efficient in the industry.

## 2.2 Settings for image quality and energy saving

Viewers generally prefer higher luminance, so the key when choosing an appropriate luminance setting is to maintain high quality image at an appropriate display luminance. This luminance level for high quality images was obtained from experimental data and theoretical analysis.

## 2.3 Ordered Stimuli Multi-dimensional Image Quality Optimization (OSMIQO)

People's preference for image quality is based on fixed regularity, which is common to many of them<sup>(3)</sup>. Therefore, to achieve an image with an appropriate luminance area, the regularity of image quality was obtained by a subjective evaluation. People other than TV engineers were selected as subjects, and the Ordered Stimuli Multi-dimensional Image Quality Optimization (OSMIQO) method was developed and used, in which subjects watched multiple images of different quality and evaluated them. The following two approaches were selected in this method in order to compare many combinations of image quality parameters within a small number of evaluations:

- (1) Two or more images were compared in an evaluation.
- (2) To simplify the evaluation, only one parameter of image quality varied among the shown images; the other image quality parameters remained fixed. The images to be compared were lined up in order of the varying parameter's value and presented to the subjects.

## 2.4 Experimental method

For this experiment, black level, gamma and color temperature were selected as the image quality parameters to be adjusted. Figure 7 shows the correspondence between the experimental scene and image quality parameter space. The images used for the experiment included sports, news, a variety show, and a movie.

The subjects selected their most preferred image quality of those presented, and then were asked to rank the remaining inferior image qualities according to five grades, comparing them with the most preferred one.

## 2.5 Theory of analysis

We should compute the entire potential distribution

of preference in the image quality parameter space, based on the experimental data that covers the relation between some of the image qualities.

A new algorithm was needed to compute this potential distribution, since experimental data was limited. To construct this algorithm, the following three points must be considered:

- (1) The optimum image quality may not be just one—there may be two or more optimal points within the space.
- (2) Generally, there are multiple paths from an arbitrary point to the optimal point within the space.
- (3) A contradiction may occur in human evaluation, and there is a possibility of returning to the original image quality when better quality is tracked.

Consequently, the OSMIQO method was developed as this algorithm.

## 2.6 Analysis results

Figure 8 shows the potential distribution of preference during a variety show program—the three subfigures show the evaluation function of the preference vs. color temperature and gamma when the black level is fixed. As can be seen from these subfigures, the lower black level setting was preferred. The same result holds true for other contents, which revealed that people truly demand deep black, even during a low-luminance setting.

In addition, the gamma and color temperature affect each other, showing a strongly non-linear potential distribution when the black level is low. These results are the tacit rules for the preference of image quality.

Based on these results, the image quality of the MZW200 series LCD TVs was specified. Thus, the series achieves industry-leading energy saving while offering an image quality that a majority of people prefer.

## 3. Conclusion

The luminance level must be set to an appropriate brightness to reduce the power consumption of LCD TVs. However, people must still like the image quality, so we will use the energy-saving Katei Gashitsu and OSMIQO developed in this study to improve image

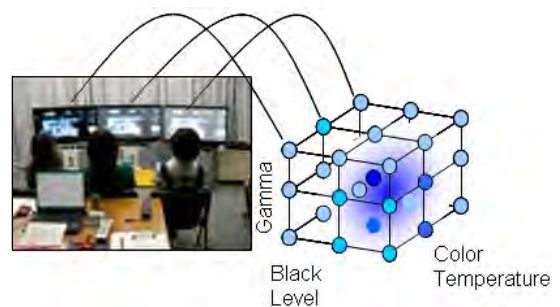


Fig. 7 Experimental scenes and image quality parameter spaces

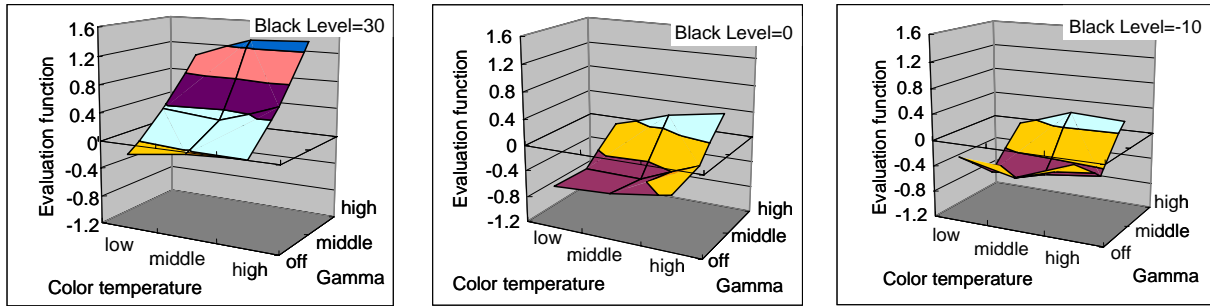


Fig. 8 Correspondence of evaluation image and image quality parameter space (case of variety show program)

quality and save energy, all at the same time, in various ways in the future.

### References

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