Industry Standards

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1 Introduction

The ISO/TC22/SC17 (Visibility) technical committee (TC) handles the regulations for devices that supplement a driver's field of view, excluding headlights, turn signals, and window glass. This committee also regularly reviews ISO and other standards relevant to driving visibility as a regular committee activity to confirm their consistency with UN regulations. In Japan, the Driving Visibility Subcommittee within the Active Safety Group of the Society of Automotive Engineers of Japan (JSAE) handles these issues. Up until recently, rear view mirrors and windshield wipers were the main vehicle components cared by the committee as devices for supplementing a driver's field of view. Currently, due to a request by UN WP29, ISO/TC22/SC17, the committee is working to create a standardized evaluation and test method in conjunction with the revision of UN Regulation No. 46 (Devices for indirect vision). The following sections provide an outline of this evaluation test method standard.

1. 1. Regulations concerning rear view mirrors

The driver uses rear view mirrors mounted both inside and outside the vehicle to check areas that cannot be seen directly. Examples include indirect vision to the rearward oblique sides and directly behind vehicles to visually identify conditions around the vehicle. Therefore, the rules that govern areas viewable via rear view mirrors are extremely important for ensuring the safety of the vehicle and its surroundings. Consequently, legal requirements have been established in every country concerning features such as the curvature of mirror surfaces, the range of visibility reflected via the mirror surfaces, and the like (Table 1 and Fig. 1).

These regulations not only apply to passenger vehicles, but also to trucks and other large vehicles. However, one special characteristic for large vehicle regulation is that they are also required to have close proximity mirrors to cover additional blind spots, such as areas directly in front of the vehicle and near the door on the front passenger side.

1. 2. Regulatory trends

Rear view monitors combining onboard cameras and an inside monitor have been developed for both passenger and large vehicles, mainly to assist with parking, and were first introduced to the market approximately 20 years ago. These rear view monitor systems have proven extremely useful to drivers who are uncomfortable with parking and are especially useful for large vehicles like trucks that tend to have large blind spots all around the vehicle. As a result, such systems have gradually started to become commonly adopted on more and more vehicles, creating a growing need to establish regulations covering the use of cameras in place of conventional mirrors. After the year 2000, the Working Party on Gen-

Table 1 Examples of national regulations concerning rear view mirrors.

Name of regulation	Relevant country	Outline
UN Regulation No. 46	Ratifying countries (European countries, etc.)	Curvature of mirror surface and range of visibility, camera requirements
MVSS 101	U.S and Canada	Curvature of mirror surface and range of visibility
Japanese Safety Regulations for Road Vehicles, Article 44	Japan	Curvature of mirror surface, range of direct and indirect visibility

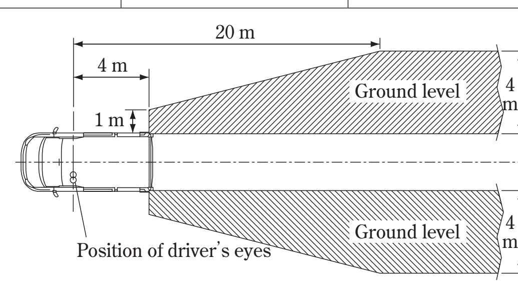


Fig. 1 Example of range of visibility stipulated in regulations (UN Regulation No. 46).

eral Safety Provisions (UN/ECE/TRANS/WP29/GRSG) sought to address the visible area immediately around large-size vehicles through UN Regulation No. 46. This regulation stipulated the range of visibility to be covered by close-proximity exterior mirrors (Class V) and wide-angle exterior mirrors (Class VI). An amendment to the regulation was then adopted and officially published in 2005, which allowed camera-monitor systems (CMS) to be used in place of those classes of mirrors. Furthermore, from 2008, due to the growing importance of reduced drag to improve fuel efficiency, an informal group of UN/ECE/TRANS/WP29/GRSG began examining whether it would be possible to replace all of the internal and external mirrors stipulated in UN Regulation No. 46, including those on passenger vehicles, with CMS. At that time a policy was adopted that specified that the technical standards should be discussed and created by the ISO. Therefore, a New Work Item Proposal (NWIP) for CMS was submitted to the ISO by the German TUV certification agency via the German Association of the Automotive Industry (VDA). This action was accepted and in 2010 ISO/TC22/SC17 decided to discuss this issue and launched a working group (WG) to address it. When created, these regulations need to define requirements and relevant test items CMS should fulfill. Additionally, issues related to ergonomic performance, such as monitor positions, screen contrast, and specific camera issues, such as communication speed within the CMS and image distortion must also be covered. This means that the technical coverage area must go beyond the framework of the conventional SC17 technical areas.

Rear view monitors were commercialized in early 1990s' in Japan and because of this; there are strong expectations within SC17 that Japan will contribute to the creation of these standards. The JSAE Driving Visibility Subcommittee established a committee in 2012 that was comprised of Japanese vehicle-mounted cameras manufacturers to begin examining the technologies. This also included dispatching experts to international conferences where CMS standardization issues were being debated. Incorporating Japanese proposals within CMS standards has helped Japan make strong cooperative contributions with other core member such as Germany, the U.S., and France.

2 Outline of Standardization

2. 1. Outline of standard and initiatives

Table 2 Composition of ISO/TC22/SC17/WG2 TFs.

TF No.	Examination items
TF1	Viewing conditions
TF2	Image quality and real time behavior
TF3	HMI and ergonomics
TF4	Functional safety
TF5	Commercial Vehicles

One of the basic concepts within the initiatives for creating CMS standards is that the stipulations for the range of CMS visibility shall be equivalent to existing rear view mirror standards and regulations. However, in addition to existing mirror standards, CMS have other unique and vital technology specific requirements, for things like camera performance, monitor characteristics, and response speed of the system. Therefore, as a result of ISO/TC22/SC17/WG2 discussions the ISO group was divided into the five task forces (TFs) shown in Table 2 so additional examinations can be performed by area experts.

Initially, it was proposed that the standards would be established by April 2012, but the number of issues requiring review and development was so large that this target date was extended. Currently, the Draft International Standard (DIS) was issued in May 2012 and the standards are on schedule to be formally issued in early 2014 through ISO/TC22/SC17 ballot.

The examinations carried out by each TF have defined a wide variety of requirements for this CMS standard. Examples of areas within the CMA standard includes basic requirements, start-up time, minimum viewing angles, level of visual magnification, system resolution, image quality, aspect ratios of vertical and horizontal magnification, integration of the monitor into the vehicle, countermeasures during a malfunction, plus many other ergonomic requirements. The following sections will explain how the CMS test methods were formulated and how some core portions of test content were created. Additional sections will describe further examinations of how to best conduct evaluations for image resolution, color rendering, image sharpness and depth of field evaluations being carried out based on Japanese proposals.

2. 2. Outline of each CMS requirement item

2. 2. 1. Basic requirements

When the vehicle is started, the displayed viewing area must be either a standard screen or driver defined customized setting or in either case the chosen screen is displayed each time after re-starting the vehicle (Table

3). It is also possible to temporarily change the viewing range (modified view) to assist the driver when backing up or when merging into traffic, but this must return to the standard screen or the driver defined view when the vehicle is re-started. It is permissible for other overlay images to be displayed on the image in the monitor so long as these are temporary and transparent.

2.2.2. Start-up time

The CMS must quickly start up by the time that the driver is ready to drive the vehicle. However, in consideration of a realistic start-up time, this standard stipulates that the CMS must display a valid image within 7 seconds of receiving the start-up command of the trigger.

2.2.3. Minimum viewing angles

The viewing angles for the CMS are defined as the same viewing angles that can display the areas required in the current regulations of each country using a conventional optical mirror. The viewing range of the conventional mirrors was adapted to the viewing range of the CMS without change.

Table 3 Types of views displayed on monitor and definitions.

Displayed image (view)	Definition
Default view	The status of the initial settings. It displays an image of the viewing area, which is stipulated by the regulations in the relevant country, at a magnification that is equivalent to that of a convex mirror.
Adjusted default view	This is the same as the mirror direction adjustment function performed by the driver. The viewing area set into the CMS is saved in the memory.
Modified view	The CMS viewing area is changed and displayed according to the driver's wishes, regardless of the range of visibility required by the regulations.

2.2.4. Visual magnification

The permissible level of magnification in the CMS display must be equivalent to the permissible level of magnification (reduction ratio) of an optical convex mirror. However, as shown in Fig. 2, when a scene is viewed through a mirror with a curvature, the magnification of the scene through the mirror fluctuates due to the change in reflection angle β. Fig. 2 (b) shows an example of the range of reflection angle β of a vehicle-mounted mirror.

The average values of the mounting locations of mirrors on vehicles that are currently available in the market in each country were used as a reference and the permissible average magnification was calculated. The permissible (minimum) average magnification for the CMS, $M_{\mathrm{mirror/avg}}$, was then determined based on that calculation. This permissible magnification is an important factor in determining the minimum resolution limit of the CMS. Next, the minimum value of the magnification at the outermost portion of the mirror was determined. This was done by assuming it was the point where the reflection angle β in the figure reaches the maximum value, and was based on surveys of the mirror arrangements on vehicles currently available in the market and other information.

2.2.5. System resolution

The precondition for CMS system resolution is a viewing angle resolution that is equal to or greater than that visible to a driver with the minimum eyesight acuity necessary to obtain a driver's license ($V_{\mathrm{eye/min}}$), through a convex mirror. This system resolution is a pillar of the standard, so the way in which the standard value of the resolution was determined is described in some detail. The calculation of this value uses the minimum magnification of the images seen through the mirror.

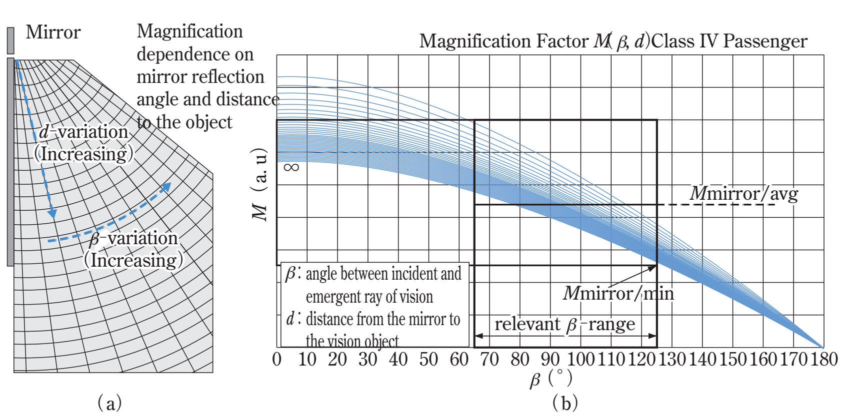


Fig. 2 Example of dependence of magnification seen in class IV mirror on the reflection angle and distance to object.

These were derived from the minimum permissible curvature of the mirror surface allowed in the current laws of each country and the mounting locations of mirrors on vehicles that are currently available in each market. The minimum magnification referred to here is not the minimum magnification value within the surface of an individual mirror, but instead refers to the permissible (minimum) average magnification, $M_{\mathrm{mirror/avg}}$, in the market that is mentioned above in section 2.2.4. The resolution of the target space that can be identified was defined as the system's resolution limit. This limit covers the range of visibility stipulated in the laws as being visible to a driver with minimum eyesight acuity via a conventional mirror ($V_{\mathrm{eye/min}}$). When the minimum viewing angle, $\alpha_{\mathrm{mirror/min}}$, is displayed on a screen with a 1:1 aspect ratio, this resolution limit can be calculated by the following equation in which the minimum viewing angle $\alpha_{\mathrm{mirror/min}}$ is divided by the minimum resolvable angle of view of the eyesight through the mirror ($1/(M_{\mathrm{mirror/avg}} \times V_{\mathrm{eye/min}} \times 60)$).

In other words, the aim is to identify the number of $\mathrm{MTF10P_{MIN\ (1:1)}}$ lines segments over the range within the minimum viewing angle $\alpha_{\mathrm{mirror/min}}$. The Modulation Transfer Function (MTF) used here is a transfer function that expresses the attenuation of the signal that occurs when the amplitude signal is transferred via the system. In this case, the spatial frequency of the signal where the attenuated amplitude of the input signal of the image fell to 10% was taken as MTF10P value. This was then introduced as the value that expresses the performance of the CMS as the limit resolution capable of identifying the scene details. In addition to the resolution measurement, there are requirement for depth of field measurement and also for sharpness (MTF50P) of the CMS. The relationship between the resolution measurement values (ISO 12233) and the values in this standard defined by a square screen are complicated, so the resolution measurement values must be handled very carefully.

2. 2. 6. Aspect ratio of vertical and horizontal magnification

The height and width dimensions of the screen have a significant impact on the magnification and also on the sense of depth and ability to recognize the approaching speed of an object from an ergonomic point of view. Therefore, a magnification aspect ratio of 1:1 is recommended, but the standards individually stipulate the permissible range depending on the type of mirror. For example, it is stipulated that the main external mirror (Class III) must at least fulfill the following.

$$-0.34 \leqq 1 - \frac{M_{\mathrm{system/hor}}}{M_{\mathrm{system/ver}}} \leqq 0.25$$

2. 2. 7. Cautions when integrating monitor into vehicle

The monitor must be integrated so that there is as little interference as possible with the minimum viewing angle range of the CMS monitor screen. There must also be as little interference as possible with the driver's direct field of vision around the vehicle when equipped with a CMS is. The displays of the right-side mirror and left-side mirror must not become reversed because this would confuse the driver. The limits of how far to the left or right monitors can be positioned and still be seen easily from the driver's seat (especially in trucks and other large vehicles) is still being debated, even though there are no strict regulations that concern the positioning of the monitor.

2. 2. 8. System evaluations

The main evaluation items for the CMS image quality are the image uniformity of the monitor itself, luminance and contrast reproducibility, adverse effects of a high-intensity light source on the cameras and monitor screen, point light source reproducibility, noise, sharpness, depth of field, distortion confirmation, confirmation of the adverse effects of flares, frame rate, and image delay. Besides the resolution, the proper reproduction of the brightness and contrast and the capability to distinguish of the basic colors of traffic signs are the main focus of this evaluation when we consider the CMS as a device for perceiving objects around the vehicle.

The following sections describe more details of the CMS evaluations.

(i) Resolution evaluation: The limit resolution evaluation is usually performed using a resolution chart that is printed with the spatial frequencies that varies according to different printed positions. In this resolution measurement method, when the signal amplitude of the input image is reproduced on the monitor screen, spatial frequency point that become less than 10% of the signal amplitude of the originals is determined as the limit resolution $\mathrm{MTF10P_{MIN(1:1)}}$ that was described previously. In actual practice, there are cases that spatial frequencies with output signal amplitude decreasing down to 10% are not observable due to the influence of the sampling frequency and image processing. In this case,

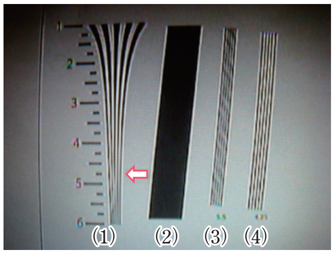
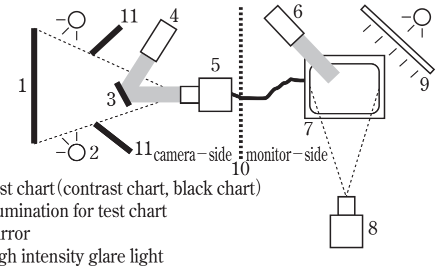


Fig. 3 Example of limit resolution check using resolution chart.

the periodicity of the chart is to be considered. Starting from the low frequencies to higher, the first spatial frequency point that loses periodicity is defined as the limit resolution. Then, the spatial frequency of the chart is compared to the stipulated value. In the case where the sampling frequency of the camera or monitor is low, it can be difficult to determine the limit resolution from the standard. In this case, a black and white stripe chart is used that contains four or more period's equivalent to the spatial frequencies stipulated in the standard. It is then evaluated whether these periodic stripes can be identified, regardless of position, after signal passses through the CMS. After this test, it should be possible to determine whether the metrics as defined in the standard are satisfied (see (3) for no good example and (4) for good example in Fig. 3).

(ii) Luminance and contrast ratio reproduction evaluation: The characteristics of the monitor have a large influence on the luminance and contrast reproducibility of the CMS. Therefore, an evaluation of the monitor's stand-alone characteristics is required. On a flat panel display (FPD) type of monitor, the luminance and contrast are affected by the direction of the view angle. Therefore, the dependence of the luminance on the viewable angle, or luminance directional uniformity, is measured according to the measurement method in ISO 9241-302 and the permissible variation range is determined. The orientation range which is defined by Standard Isotropy Range (SIR) , is a replacement of the variation range of driver's eyes from the eyellipse centroid (ISO 4513), and determined to be +/− 7 degrees left-right and +/− 6 degrees up-down. Further movements in the head position are taken into consideration, then the driver's extended view range which is defined by Extended Isotropy Range (EIR), and is determined 5 degrees wider than SIR. Additionally, the luminance directional variation of the viewable angle luminance is stipulated to be less than 45% within the standard isotropy range and less than 55% within the extended isotropy range. The luminance uniformity within the screen is stipulated to be less than 35% when the monitor is viewed from the one single angle. As such, the CMS is basically considered to be a single system for the other CMS evaluation items and so the overall performance of the system is evaluated using the images output onto the monitor's screen.



Key
1 Test chart (contrast chart, black chart)
2 Illumination for test chart
3 Mirror
4 High intensity glare light
5 Camera under test
6 Illumination for monitor under test
7 Monitor under test
8 Reference camera, digital photometer (e.g. area luminance photometer)
9 Diffuse illuminator
10 Optical or spatial isolation
11 Optical isolation barrier to avoid direct light into camera lens

Fig. 4 Example configuration of environment for brightness and contrast ratio evaluation.

The luminance and contrast reproducibility of a scene that is reproduced on the monitor via the CMS is subjected to several different evaluations using different surrounding outside light conditions. The following describes those conditions and the standard values. The standard stipulates that the contrast ratio on the screen shall be checked and found to be 2:1 or better under a direct sunlight environment, 3:1 or better under a daytime diffused light environment, 5:1 or better under a nighttime environment, and 2:1 or better under a sunset backlit environment. Some adverse effects can occur when a strong incoming light enters the camera, especially blooming, smearing, and lens flare, which can interfere with the visibility of objects around the vehicle. Therefore, adverse effects that exceed a certain standard should not be admitted on the CMS. Fig. 4 shows an example of the testing environment used for this evaluation. The figure shows that, in this evaluation, external sunlight or the other optical phenomena onto camera is simulated using light source 4 and then this light is reflected right into the lens of the camera being tested by mirror 3. Light source 6 is used to simulate direct sunlight falling onto the monitor screen and diffuse illuminator 9 is used to simulate a daytime ambient light. Reference camera 8 is used in the evaluation to measure the images and conditions that are actually visible on the monitor. This test is designed to make a comprehensive evaluation of the effects on the images that pass through the CMS and are then observed on the monitor's screen.

(iii) Color rendering properties evaluation: The proposal for the color rendering properties of the CMS was based on an ideal case that initially sought rigorous color reproducibility. However, in a realistic system, even if the latest technologies were used, such as estimating the color temperature of a light source, automatic white balance control cannot be universally achieved without errors. Therefore, it was decided to focus on the identification of basic colors that are mainly important to the traffic system. The standard evaluation chart contains five colors: red, green, blue, yellow, and white. The proposal was reviewed and the standard now stipulates that the CMS shall be able to distinguish each of the colors on the chart, accordingly.

Another consideration is the smear effect which is produced when a high-intensity light source enters the cameras (in the case of CCD cameras). The CMS standard stipulates that the permissible level for false signal generation due to smear shall be half of the luminance value of the light source image that is causing the generation of the false signals. The standards for blooming and lens flare state that adverse effects such as these that interfere with the visibility shall only affect an area that makes up 25% or less of the area of the effective display screen.

(iv) Sharpness and depth of field evaluation: In terms of the image sharpness, the spatial frequency when the signal amplitude of the scene has attenuated by 50% was determined to be MTF50P. This standard stipulates that the spatial frequency measured as MTF50P is at least half or more than the spatial frequency of $MTF10P_{MIN\ (1:1)}$ that is stipulated in the resolution standard. In terms of depth of filed evaluation, limit values for the permissible decrease in resolution have been set for several distances. Large decline in resolution should not occur in the distance direction of the viewable region stipulated in the laws. This standard states that a resolution that is equal to or greater than a certain predetermined value must be ensured for at least three measurement points at 4 m, 6 m, and 10 m. In this case, care is required since the term "depth of field" is used with a different meaning than the general optical definition. So, targets in the far sight need a certain resolution, but targets in the near sight do not need the same resolution because they appear bigger and area easier to understand. Therefore, the required resolution standard for the distance of 4 m was stipulated to be one-half of $MTF10P_{MIN\ (1:1)}$.

(v) Distortion evaluation: Initially, the examinations and discussions of distortion proceeded along the line of allowing no distortion at all, but in the case of wide-angle exterior mirrors (Class IV) and other convex mirrors that exhibit curvature, there is a remarkable amount of distortion depending on the viewing position of the mirror. Therefore, the examiners settled on the expression that it would be desirable for the distortion to be less than 20%, since there was no particularly important reason to make the distortion level equivalent to that of an optical mirror.

(vi) Image updating frame rate: Under normal forward driving conditions, the image updating frame rate is stipulated to be 30 fps or higher. However, some beneficial effects, such as improved sensitivity in the dark, are expected to be attained by lowering the frame rate. Therefore, CMS specifications in which the frame rate is lowered to 15 fps at night and under certain special environments are also allowed.

(vii) Appearance of monitor: External light that strikes the body of the monitor may be reflected from decorative surfaces toward the driver's eyes, making it difficult to see. Therefore, the standard stipulates that the decorative surfaces of the monitor shall have matte specifications with a gloss value of 10 or below to prevent any such surface reflections from the monitor.

(viii) Image response time and system latency: The image generation response time for FPD type monitors, such as an LCD, is 55 ms or less at a normal temperature of 22℃. The maximum permissible delay for displaying an image on the monitor when there is a visible target is 200 ms for the overall system.

(ix) Countermeasures for system malfunction: Some means of sending a malfunction alert and informing the driver that the CMS is in a malfunctioning state is required. An explanation of the way the system alerts driver must be included in the driver's operators manual.

(x) Consideration for elderly drivers and for driver's with acuity issues: Regarding the loss of eyesight acuity, usually associated with aging, these guidelines indicate how to reduce the strain of focusing on the monitor, such as using the contrast adjustment function. Additionally, a section describing the influence of bifocals, should be included in the driver's operators manual along with other considerations, such as placing the monitor at the appropriate visual distance from the driver, are also desirable.

(xi) Safety standards of CMS: The CMS must conform to the safety standards in each country. It is assumed that the CMS is a safety-relevant part. If the CMS is used in accordance with its intended purpose, then the stipulations in ISO 26262, for example, should be considered in regard to its functional safety.

2. 3. Application of CMS to large commercial vehicles (trucks, trailers, and the like)

The mirrors used in medium and large commercial vehicles, have different shapes and are more numerous than those used on passenger vehicles. Therefore, TF5 was formed around members from commercial vehicle manufacturers to create the sections in the Annex concerning the mirrors on medium and large commercial vehicles. The Annex collects together vehicle information about the unique ways that mirrors are used on medium and large commercial vehicles, which are different than usage on passenger vehicles. This information was gathered by sending out requests to vehicle manufacturers in each country. The Annex includes information on the amount of movement of the driver's eyes, the distance from the driver's eye point to the center of each mirror, and so on. This was used to examine the content of the relevant technical standards to see if CMS could be adopted on such vehicles. The examination work that was undertaken by TF5 was also performed in cooperation with TF2 and TF3 so that the separate sections for passenger vehicles and commercial vehicles would be consistent.

Some of the best survey data on this topic came from joint research that was conducted by a European large vehicle manufacturer and Chalmers University of Technology (Sweden). This research involved a questionnaire that was filled out by actual drivers of large vehicles and asked about usage methods of different vehicle mirrors and which mirrors were used under a large variety of different road conditions (such as when merging on a highway or at a roundabout) and driving conditions (such as backing up with a trailer attached). The drivers were also asked about how easy the monitor was to see and if it had any effect on the direct field of vision, depending on where the monitor was located in the vehicle cabin. TF5 utilized this data when examining whether all vehicle mirrors could be replaced with a CMS. Furthermore, mathematical formulas were also created and verified to find the necessary magnifications and coefficients described above so that the appropriate resolution could be determined.

Compared to mirrors for passenger vehicles, the mirrors that must be equipped on large vehicles are very different for compliance with the UN Regulations or for compliance with the Japanese Safety Regulations for Road Vehicles. The following points are provided as explanations of the differences between the mirrors that comply with European laws and mirrors that comply with the Japanese Safety Regulations.

- The European laws and Japanese Safety Regulations specify a different number of mirrors that must be equipped on the vehicle, different shapes, and different curvatures for the mirror surfaces.
- The European laws specify the indirect visible area for each mirror. In Article 44 of the Japanese Safety Regulations for Road Vehicles the visible area consists of both the direct field of vision and the indirect field of vision. Furthermore, multiple mirrors can be used to accomplish this.
- In the European laws, it is necessary for the ground level of the indirect visible area to be visible via the mirrors alone. In contrast, in the Japanese Safety Regulations, it is permissible if an obstacle (a pole with a diameter of 0.3 m and a height of 1.0 m) that is set within the visible area can be seen via the direct field of vision and/or the indirect field of vision.

Based on this information, Japanese large vehicle manufacturers is working in cooperation with each other to verify mathematical formulas for the CMS magnifying power and coefficients of the CMS so that it could replace mirrors and comply with the Japanese Safety Regulations for Road Vehicles.

3 Future Initiatives

Since the DIS was issued in May 2013, work on the standards has reached a certain accomplished development stage. However, technical discussions of the content are still necessary and comments on the DIS have been received from each country. In the future, Japan will continue to dispatch its experts and increase its contributions to this work.

References
(1) UN Regulation No.46
(2) ISO/DIS 16505