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TECHNICAL NON-PAPER

SECOND TEST CASE ON RECOGNITION OF EQUIVALENCE IN RELATION TO US AND EU LIGHTING AND VISION STANDARDS

EXECUTIVE SUMMARY

As part of the Transatlantic Trade and Investment Partnership (TTIP), a possible approach for assessing equivalence between EU and US motor vehicle regulations has been proposed. While, indeed, it is widely understood that there are differences with regard to individual technical requirements on motor vehicle safety in both regions, the overall level of safety in each of the regions can generally be regarded as equivalent.

The EU has provided a first Test Case on the Recognition of Equivalence with a proposed methodology for automotive regulations. This first Test Case was provided for the 7th negotiation round held last year.

In a further effort from the EU side to develop a successful approach to establish such recognition of equivalence on safety performance, this document considers, as a second Test Case, the respective US and EU legislation regarding vision and all its related aspects, namely the cluster of lighting, forward vision, glazing, windscreen wash/wipe and defrost/demisting systems.

The second Test Case analysis indicates that there are key differences between the adopted regulatory approaches. There are certain aspects that highlight a potential different level of safety performance in very specific instances.

As regards lighting, all individual lighting functions have been analysed. Concerning the headlamps, there is a trade-off between the safety issues of glare (i.e. blinding oncoming traffic) that is largely attributed to US headlamps and a comparatively lower level of illumination and sight distances towards the left and right sides of the road (i.e. detection of specific targets) of EU headlamps. The rear direction indicators on US cars may emit red light, but this is proven to increase the risk of rear crashes. Still US compliant rear indicators should be considered equivalent to EU ones, as long as they emit amber light, which is also permitted in the US. The effectiveness of the side marker lamps found as standard equipment on US compliant cars could essentially not be proven. Given that car shapes have evolved dramatically over the past decades, and the front and tail lamps are often wrapped around the corners and are usually clearly visible from the side, it can be envisioned that side marker lamps can be omitted on EU cars exported to the US on the condition that the head and tail lamps are indeed visible.

As regards vision, in terms of safety glazing, as the respective standards in the US and the EU are (to be) closely linked to UN Global Technical Regulation No 6, the equivalency in terms of safety can thus be assumed. A separate US standard on assuring the windshield retention in case of a crash can be deemed obsolete. There are notable differences on aspects of visibility through the windscreen involving obstructions caused by A-pillars and the direct view to the front, both specifically regulated only in the EU, ensuring that vulnerable road users can always be seen and are not hidden in blind spots. However, it could be argued that in the real-world, drivers tend to adjust their position to obtain the full view of his or her surroundings (i.e. they are looking around the obstacle) as suggested in some research. On the other hand, the areas of the windscreen that must

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be cleaned by wipers and defrosting systems may in certain cases, for large vehicles, be somewhat larger for US compliant vehicles than those that comply with the EU standards. However, when taking into account that this increase of crucial vision area is located notably near the top part of the windshield, the real-life safety relevance of this bigger required area is not evident. For these reasons an overall level of equivalency on glazing, forward vision, wash/wipe and defrost/demisting in terms of real-life safety could be concluded.

Also concerning vision, interior mirrors provide an equivalent level of safety in the EU and US, but the analysis on external rear view mirrors clearly shows that those on EU cars are safer. Specifically the driver's side external mirror on US cars would be detrimental to the safety situation in the EU. However, this could largely be overcome if a spherical or aspherical mirror glass were to be installed in the otherwise unmodified mirror housing of US cars, in combination with a US compliant passenger side mirror, when exported to the EU. Finally, the EU does presently not have plans to require a rear (back-up) camera to be installed, whereas the US will mandate this for all new cars from May 2018, which should therefore also be the case for all EU cars exported to the US for obvious safety reasons.

The above analysis gives a clear indication of what can be considered as the most effective and appropriate way forward in terms of the recognition of equivalence. To ensure that the level of safety is not compromised, rather than pursuing the simplistic approach of accepting a fully compliant US car in the EU without any adaptations, and vice versa, the areas of recognition of equivalence can be agreed based on an overall acceptance with a number of subtle technical adaptations to the vehicle that are essential for real-world safety.

In conclusion, this second Test Case is illustrative of a robust methodology that allows concluding on the recognition of equivalence of certain automotive safety standards organised in clusters, on the basis of their real-world performance.

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1. INTRODUCTION

As part of the Transatlantic Trade and Investment Partnership (TTIP), a possible approach for assessing equivalence between EU and US motor vehicle regulations has been proposed. While, indeed, it is widely understood that there are differences with regard to individual technical requirements on motor vehicle safety in both regions, the overall level of safety in each of the regions can generally be regarded as equivalent.

In this context, the EU has provided a first Test Case on the Recognition of Equivalence with a proposed methodology for automotive regulations. The non-paper was provided in advance of the 7^{th} negotiation round held in Washington in the week of 29 September to 3 October 2014 and discussed in the relevant session.

The first Test Case focussed on seat belt anchorages. The analysis was based on accidentology data in combination with other relevant sources, research and experiments.

This second Test Case considers the respective US and EU legislation regarding: lighting, direct visibility and indirect visibility. It defines the main areas in which the technical requirements differ. Published literature has been used to provide an assessment of real-world safety effects, if any, of these differences.

2. Comparison of EU regulations and US standards for Lighting

EU and US requirements for vehicle lighting and reflectors are prescribed by UN Regulation 48 'Uniform provisions concerning the approval of vehicles with regard to the installation of lighting and light-signalling devices'; and FMVSS 108 'Lamps, Reflective Devices, and Associated Equipment' respectively.

The following sections assess the technical requirements for each lighting/reflector type and define the notable differences and subsequent 'real world' effects on safety. The assessment of each light type considered; applicability, number, colour, position (height, width and length), geometric visibility angles, photometric visibility angles, photometric minima, photometric maxima and restrictions on signal flashing.

2.1 Headlamps

EU regulations and US standards both define two lamp categories that can be utilised as headlamps; main-beam (driving-beam) headlamps [*upper beam headlamps*] and dipped-beam (passing-beam) headlamps [*lower beam headlamps*]. The specific definitions of the applicability and functional intent of each headlamp category are presented, for both sets of legislation, in Table 1. From this it can be seen that the functional intent of both main-beam and dipped-beam headlamps are equivalent for both EU and US legislation.

Table 1: Applicability and functional intent of EU and US headlamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Lamp [Applicability]	**Functional Intent**	**Lamp [Applicability]**	**Functional Intent**
Main-Beam (Driving-Beam) Headlamps [Mandatory]	The lamp used to illuminate the road over a long distance ahead of the vehicle (R48, 2.7.9)	Upper Beam Headlamps [Mandatory]	A beam intended primarily for distance illumination and for use when not meeting or closely following other vehicles (F108, S4)
Dipped-Beam (Passing-Beam) Headlamps [Mandatory]	The lamp used to illuminate the road ahead of the vehicle without causing undue dazzle or discomfort to oncoming vehicles and other road users (R48, 2.7.10)	Lower Beam Headlamps [Mandatory]	A beam intended to illuminate the road and its environs ahead of the vehicle when meeting or closely following another vehicle (F108, S4)

2.1.1 Notable Differences

This section describes the most notable and potentially influential differences. Refer to Table 20 and Table 21 in Annex 1 for a detailed side-by-side comparison of the legislative requirements.

2.1.1.1 Main-beam (driving-beam) headlamps

Legislative requirements for main-beam (driving-beam) headlamps are specified by UN regulations 48, 112 and 98 in the EU, while US requirements are specified by FMVSS standard 108. EU and US requirements are identical for applicability, number, colour and length (Table 20), with both sets of legislation mandating the use of a white coloured headlamp system, that can use either two or four lamps, located at the front of all passenger cars. Despite several differences between EU and US requirements for the remaining properties, the most notable differences identified are the absence of mandatory mounting height positions in the EU, the absence of mandatory geometric visibility angles in the US (although it may be that photometric visibility angles are interpreted as geometric visibility angles in the US), the greater photometric minima (as measured in the reference axis) required in the EU for similar headlamp systems and the greater photometric maxima allowed in EU regulations regardless of either headlamp system or photometric angle.

2.1.1.2 DIPPED-BEAM (PASSING-BEAM) HEADLAMPS

Legislative requirements for dipped-beam (passing-beam) headlamps are specified by UN regulations 48, 112 and 98 in the EU, while US requirements are specified by FMVSS standard 108. EU and US requirements are identical for applicability, colour, length and the mandatory use of headlamp levelling systems (Table 21), with both sets of legislation mandating the use of a white coloured vertically adjustable headlamp system located at the front of all passenger cars. Despite several differences between the EU and US requirements for the remaining properties, the most notable differences identified are the absence of mandatory geometric visibility angles in the US (although it may be that photometric visibility angles are interpreted as geometric visibility angles in the US), the absence of standards on headlamp cleaning devices in the US, the different philosophies taken for automatic headlamp levelling devices (EU: mandatory for lamps of >2,000 lumens, optional for all others; US: optional only), the greater headlamp vertical inclination angles required by the EU, the mounting height specific headlamp vertical inclination angles required by the EU, the greater mounting height positions allowed by the US, the greater photometric minima required in the EU regardless of the headlamp system, the greater photometric maxima allowed in the EU regardless of headlamp system and the greater photometric maxima allowed by US standards for the particular aspect of the beam directed towards oncoming traffic.

2.1.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

Vehicle headlamps have the function to illuminate the road ahead and its surroundings to ensure visibility of the road delineation, pedestrians, signs, and objects on the road. The dipped beam is activated when other vehicles are around, which is why the photometric criteria for the beam pattern need to provide a balance between the aims of providing a long, sufficiently lit sight distance and not creating inappropriate levels of passing glare (for oncoming vehicles) or mirror glare (for leading vehicles).

Existing headlamp beam patterns and headlamp aiming in both jurisdictions are a compromise that has evolved over a long period of time and has proven to work in the practical application within each country's road infrastructure, traffic conditions and vehicle fleet composition. In early research, authors concluded that each beam pattern is beneficial under certain traffic conditions but neither was found to be universally preferable (Sivak, Helmers, Owens, & Flannagan, 1992).

Accident data are available for EU countries and the US that allow analysing the trend over time of the ratio between night time fatalities and daytime fatalities. Data from the EU (e.g. Germany, France, UK) and Japan showed a decline of this ratio over time, i.e. a relative improvement of night time safety. A study from Germany, for example showed this trend between 1991 and 2002 (Lerner, Albrecht, & Evers, 2005), whereas a US study failed to reproduce this finding for US fatalities between 1990 and 2006 (Sullivan & Flannagan, 2008). Sullivan & Flannagan conclude that the US have made smaller gains than other countries in improving night time traffic safety. It is, however, not conclusive from the data whether changes in forward lighting were a strong factor in these differences or if other factors, such as infrastructure improvements, dominated the trends.

A potential application of the historically evolved beam pattern of one jurisdiction in another world region might involve a certain risk, not least due to potential differences in road infrastructure that might require putting emphasis on different qualities of the beam pattern. Due to the apparent lack of real-world accident data involving cars equipped with the US headlamps operating in the EU road environment (and vice versa), it is not possible to reach an ultimate conclusion about the magnitude of this risk. Individual research in the US and EU allows however, to perform a qualitative comparison of relevant aspects such as sight distance and glare between EU and US headlamps. The main comments and analyses in research publications on these aspects are summarised below.

2.1.2.1 DIPPED-BEAM PATTERN

The required photometric distribution (beam pattern) varies between the US and EU legislation with different levels of photometric minima (to ensure sufficient visibility) and maxima (to avoid creating glare). Within the ranges defined for each jurisdiction the actual beam patterns vary between vehicle designs.

Sivak *et al.* conducted a market-weighted analysis to compare the beam patterns of the 20 best-selling vehicle models (model year 2000) each in the EU and US (Sivak, Flannagan, Schoettle, & Nakata, 2002). The authors concluded by stating the following general differences: Compared to the US lamps, the EU lamps provided more illumination in the foreground, more seeing light to the left (except near the horizontal), less seeing light to the right, less illumination for overhead traffic signs, and less glare for oncoming traffic (see Figure 1).

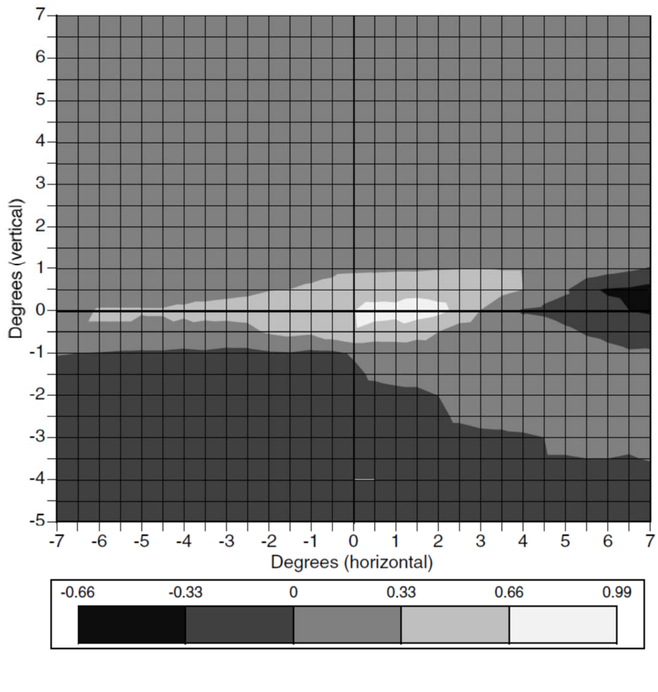

Figure 1: Differences between of the market-weighted light output between US and EU lamps; logarithmic differences (to represent the human visual system); positive numbers mean higher illumination by US lamps (Sivak, Flannagan, Schoettle, & Nakata, 2002)

The real-world differences are discussed in more detail in the following. Illumination of targets alongside the road was found to be higher from US beams: At 100 metres distance, US lamps provide approximately three times the illumination for right-side and two times for left-side targets (Sivak, Flannagan, Schoettle, & Nakata, 2002).

Mace *et al.* express the opinion that reduced sight distances of EU beams (approximately 60 metres or less) were not suitable on US roads. However, market weighted analysis of model year 2000 vehicles indicated that the performance of EU and US beams regarding seeing light intensity is substantially equal down to at least the 50th percentile, and only at the 25th percentile the US beams were categorically superior (Daniel Stern Lighting Consultancy, 2002).

However, it should be noted that for all dipped-beams, studies show that a sight distance of the magnitude offered is not sufficient to respond appropriately to some hazards at elevated driving speeds: The maximum safe speed with dipped-beams was estimated to lie between 25 km/h and 50 km/h (Johansson & Rumar, 1968). This maximum safe speed might have increased slightly since then because of better performing modern headlamps. However, it still must be expected to be much lower than the speeds commonly driven outside built-up areas (in the EU as well as the US) (Leibowitz, Owen, & Tyrrell, 1998). This indicates that apart from the vehicle-based question, of where the ideal balance between sight distance and glare of the dipped-beam lies, non-vehicle aspects, such as encouragement of regular use of high-beams, retro-reflective elements worn by pedestrians and street lighting are also major influencing factors for night time road safety.

The increased uplight of the US beam might ensure a better illumination of overhead road signs, which is sometimes suggested as an obstacle to using EU beams on US roads (Mace, Garvey, Porter, Schwab, & Adrian, 2001). American overhead road signs are not self-illuminated, but this is in fact also the case for most European overhead road signs. Both regions use retro-reflective signs instead. Daniel Stern Lighting (2002) argues that the EU beam pattern also contains explicit requirements for uplight and that any observed performance differences are in fact largely independent of the photometric standards to which the lamps have been produced.

With regard to the levels of glare to oncoming or leading vehicles, the EU beam pattern is generally believed to be more favourable, with US legislation allowing maximum photometric intensities for glare that can be twice as large as that specified by EU regulations. This was confirmed by Sivak *et al.* (2002) in an analysis of production vehicles which indeed found that the glare illumination for an oncoming driver was about twice as large for US lamps as for the EU lamps.

The difference in glare between EU and US might be exacerbated by different mounting heights: The allowable mounting height in the US is 172 mm higher than in the EU and the downward inclination in the US is not increased with the mounting height as in the EU legislation. This might result in large vehicles, such as SUVs, directing more light at greater elevations above the road. It was inferred from stakeholder communication that current vehicle models designed for a world market can be expected to have a mounting height compliant with EU legislation, even in the US version. US data from field studies and simulations show that larger mounting height generally increased passing and mirror glare which was found to result in a reduction of visual performance, increased reaction times and decreased detection distances (Akashi, Van Derlofske, Raghavan, & Bullough, 2008). The overall conclusion by NHTSA was, however, that the effects of mounting height on disability glare were minor and that it mainly contributed to discomfort glare

(NHTSA, 2008). These geometric factors, together with the other aspects of the beam pattern, result in reduced glare from EU headlamps (Mace, Garvey, Porter, Schwab, & Adrian, 2001).

No accident data is available that would allow quantifying potential casualty implications of reduced sight distances (EU legislation) or the increased glare levels (US legislation) if both beam patterns were mutually accepted. Nevertheless, the analytical inference must be accepted that both, glare and differences in sight distance, might have a deleterious effect on the primarily visual driving task. Bullough *et al.* point out that there was indirect evidence linking glare to crashes, i.e. glare reduces visibility and reduced visibility can be related to crashes (Bullough J. , Skinner, Pysar, Radetsky, Smith, & Rea, 2008). Mace *et al.* (2001) express the opinion that the effects of glare might not be catastrophic because drivers may compensate by driving more cautiously.

Some countries have changed from US to EU beam patterns in the past: The UK in the 1970s, Australia in the 1980s and Japan in the 1990s (Daniel Stern Lighting Consultancy, 2002). To the best of our knowledge, casualty outcomes of these changes have not been examined in scientific studies. Also, the legislation has changed considerably since (e.g., sealed beam headlamps were required before the 1980s in the US), which is why the consequences of switching from US to EU legislation back then would not necessarily be comparable to the consequences to be expected today where the legislation is already much more harmonised between both jurisdictions. There is at least one country accepting both beam patterns: Canada permits headlamps compliant with the UN regulations applicable to the EU as an alternative to US headlamps (CMVSS 108.1).

Past attempts to define a harmonised beam pattern did reach a certain maturity (for example in form of the GTB Proposal for Harmonised Passing Beam or SAE Recommended Practice J1735) but were not be developed to a stage that was implemented as mandatory legislation in both jurisdictions. Adaptive front lighting systems (see Section 2.4) might allow resolving the conflict between optimising sight distance and glare and might therefore present and opportunity for future harmonisation.

2.1.2.2 DIPPED-BEAM LEVELLING

Levelling and cleanliness influence the in-use performance of headlamps. Misalignment of headlamps can be introduced over time by road vibration, vehicle defects (e.g. suspension defects) or incorrect tyre pressure, or temporarily by changes in static loading conditions (e.g. heavy load in the boot) or dynamic loading conditions (e.g. driving uphill, road undulations). This can result in either reduced sight distance (downward misaim) or increased glare of other drivers (upward misaim).

Correct aiming of headlamps was found in research to be a key parameter in the control of passing glare to oncoming drivers (Bullough J. , 2013a). In both, EU and US headlamps, vertical misaim of about one degree can already introduce significant effects (Mace, Garvey, Porter, Schwab, & Adrian, 2001); however, the detrimental effects of vertical misaim increase with mounting height, the upper limit of which is higher in the US (Bullough J. , 2013a). The effects of mis-aim of US headlamps were found to have increased substantially in modern designs due to a sharper horizontal cut-off (model year 2004 tungsten or HID dipped-beams) compared to older designs (year 1997 tungsten dipped-beam) (Flannagan, Sivak, & Schoettle, 2007).

For the US, early studies showed that only about one of two vehicles on the road have both headlamps aimed correctly and that the problem increased with vehicle ageing

(Olson, 1985), (Copenhaver & Jones, 1992). This is supported by a more recent US survey which showed that about 62% of in-use vehicles (and 30% of new vehicles) had at least one headlamp misaimed (Bullough J. , Skinner, Pysar, Radetsky, Smith, & Rea, 2008). A considerable number was found to be mis-aimed upward above the H-H axis, thus potentially inducing glare, or downward, thus reducing sight distance (Bullough, Pysar, & Skinner, 2010).

EU legislation requires the provision of manual on-board levelling devices in order to allow the driver to adapt the headlamp levelling, for example to changed static loading conditions. However, it appears questionable whether a considerable proportion of drivers make use of the manual on-board levelling devices. Automatic levelling devices, which are mandatory for high flux headlamps in the EU, can be expected to ensure proper alignment throughout the vehicle life and under changing loading conditions and therefore reduce glare (Daniel Stern Lighting Consultancy, 2002). No data is available that allows a quantification of casualty implications of these different levelling device requirements in the EU and US.

Dirt accumulated on the lens of a headlamp acts as a diffusor and can result in additional stray light causing glare (Mace, Garvey, Porter, Schwab, & Adrian, 2001) or as a filter resulting in reduced illumination (Flannagan, Sivak, & Schoettle, 2007). Daniel Stern Lighting (2002) mentions a potential increase in glare of 200-300 percent. This problem is magnified by HID lamps due to their higher total light flux. It is countered in the EU by the requirement for headlamp cleaning devices for HID lamps.

Cleaning and automatic levelling devices are not mandatory in the US, although results of a study by Flannagan *et al.* (2007) emphasise their importance also for headlamps with US beam patterns. Mace *et al.* (2001) assert that these devices were often standard equipment on US vehicles equipped with HID lamps (presumably including vehicles from US manufacturers). EU vehicle manufacturers generally suggest that automatic levelling devices are also fitted to cars produced for the US market, although this information cannot be quantified. Fleet fitment rates for the US are not known.

2.1.2.3 MAIN-BEAM PHOTOMETRIC MAXIMA

The purpose of the main-beam is to provide long distance visibility in situations without oncoming or closely leading traffic. The EU allowed photometric maxima for main-beams are three times higher compared to the US requirements, which can allow, on the one hand, sight distance gains of about 5-35 percent, depending on detailed setup of the studies performed (Rumar, 2000). On the other hand, the potential for glare to other drivers is increased in cases where the main-beams are not dimmed when oncoming traffic is approaching.

NHTSA commented on the lower photometric limits for main-beams in the US in response to a petition for rulemaking to increase those limits (NHTSA, 1996): NHTSA acknowledged the general advantages of higher limits, such as increased sight distance, and stated that there was likely a sizeable population in the US that could benefit from better night time vision but no research was available to quantify casualty implications. Conversely, one could conclude that the lower US limits on European roads might have detrimental safety effects.

No quantification of the frequency of occurrence of main-beam glare and potential casualty effects is available.

In an analysis of existing research, Rumar (2000) concluded that most of the factors based on empirical studies and analytical arguments would favour a more intense main-beam maximum intensity and recommends increasing the US provisions to the respective EU levels.

2.2 DAY-TIME RUNNING LAMPS

EU regulations and US standards define the applicability and functional intent of day-time running lamps [*daytime running lamps*] as described in Table 2. While there are several similarities between the functional definitions of day-time running lamps in the EU and US, US standards require that day-time running lamps improve conspicuity from both the front and front sides, while the EU requires that these improve visibility in the forward direction only.

Table 2: Applicability and functional intent of EU and US day-time running lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Signal [Applicability]	Functional Intent	Signal [Applicability]	Functional Intent
Day-Time Running Lamps [Mandatory]	A lamp facing in the forward direction used to make the vehicle more easily visible when driving during daytime (R48, 2.7.25)	Daytime Running Lamps [Optional]	Steady burning lamps that are used to improve the conspicuity of a vehicle from the front and front sides when the regular headlamps are not required for driving (F108, S4)

2.2.1 NOTABLE DIFFERENCES

The legislative requirements for the day-time running lamps are specified in the EU by UN regulations 48 and 87, whereas US requirements are specified by FMVSS standard 108. EU and US requirements are identical for number and length only (Table 22, Annex 1), with both sets of legislation requiring the use of two lamps located at the front of all passenger cars. Despite several differences between EU and US legislative requirements for the remaining properties, the most notable differences identified are the optional requirement for day-time running lamps in the US, the option to install lamps that range in colour from white to amber in the US, the absence of US requirements for minimum mounting heights, geometric visibility angles and photometric visibility angles, the greater photometric minima and maxima required in the US and the more prescriptive definitions used in the EU for regulating the activation of day-time running lamps.

2.2.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

The primary objective for daytime running lamps (DRLs) is to improve the conspicuity of vehicles during the daytime through the use of front mounted lamps with both greater photometric intensities and vertical inclinations than standard passing-beam headlamps. While current EU regulations mandate the installation of DRLs on all new passenger cars, US standards require the optional installation of DRLs only. In addition to this fundamental difference between EU and US legislative requirements, US standards further allow the installation of DRLs that can range from white to amber in colour, while EU regulations require white coloured DRLs only.

2.2.2.1 APPLICATION OF DAYTIME RUNNING LAMPS

The potential real-world implications of DRLs on road accidents has long been a topic of debate amongst road-safety specialists and has given rise to a large body of both accident analysis studies and experimental research (Commandeur, Mathijssen, Elvik, Janssen, & Kallberg, 2003; Knight, Sexton, Bartlett, Barlow, Latham, & McCrae, 2006). Whereas the majority of historical research reports that the installation of DRLs is associated with a reduction in accident rates (Theeuwes & Riemersma, 1995; Elvik, 1996; Koornstra, Bijleveld, & Hagenzieker, 1997; Elvik, Christensen, & Olsen, 2003), full consensus has not yet been reached (Elvik, 2013) and concern remains over the effect of DRLs on the conspicuity of other vulnerable road users (Cavallo & Pinto, 2012; Peña-García, et al., 2010).

When considering the real-world implications of DRLs for passenger cars, a total of 25 studies have been evaluated by a meta-analysis investigating the effects of DRLs on accident rates (Elvik, Christensen, & Olsen, 2003). By calculating the best estimates of the effect of using DRLs on daytime accident rates, this systematic review reported that the use of DRLs was associated with a 6% [95% CI: 1-9%] reduction in multi-vehicle accidents, a 10% [95% CI: 1-18%] reduction in frontal or side-on collisions and a 24% [95% CI: 10-37%] reduction in pedestrian accidents. When calculating the effects of introducing mandatory DRL legislation on daytime accident rates, however, these accident rate reductions were observed for multi-vehicle accidents (5% [95% CI: 1-9%]) and frontal or side-on collisions (8% [95% CI: 5-12%]) only (Elvik, Christensen, & Olsen, 2003). Elvik *et al*. (2003) further concluded that these effects were greater for fatal accidents when compared to injury accidents, for injury accidents when compared to material-damage only accidents and for latitudes that are located further away from the Equator.

These relationships have since been revisited in a further study by Elvik (2013), which investigated the temporal and dose-response trends associated with the use of DRLs. This identified a temporal trend in research outcomes, with contemporary research becoming less conclusive, and including more anomalous results, when compared to earlier studies. It was suggested that these trends could be related to a game-theoretic model, particularly due to the absence of a clear dose-response relationship. This is where the safety benefits of using DRLs is largest when the share of cars using DRLs is at its lowest (as cars using DRLs will stand out from the crowd and therefore be more visible than other cars) and, as the proportion of cars using DRLs grows, the negative effects of not using DRLs may become larger (as road users start to use the sight of DRLs as a clue for identifying cars). This is theory has been shown experimentally (Hole & Tyrrell, 1995) and is supported, in part, by recent studies that find no or very little significant effect on accident rates with the use of DRLs (Wang, 2008; Farmer & Williams, 2002) and in the reduced effect sizes observed in studies that investigate the effects of introducing mandatory DRL legislation (Elvik, Christensen, & Olsen, 2003).

The only study that observed no significant effect for DRLs on accident rates is also the most recent observational study (Wang, 2008). This study evaluated the effects of DRLs across three types of target crashes (two passenger-vehicle crashes (excluding rear-end crashes), single passenger-vehicle to pedestrians/cyclists crashes and single passenger-vehicle to motorcycle crashes) and across three injury severity levels (fatal, injury and all severity) using the Fatality Analysis Reporting System (FARS) and State Data System

(SDS) databases. Aside from a statistically significant 5.7% reduction in the involvement of light trucks/vans in two vehicle crashes across all injury severities, the effects of DRLs on the remaining parameters made no significant difference.

Although methodologically strong, particularly through the use of a comparison-control study design and a ratio of odds ratios statistical analysis, this study does have several limitations. Firstly, the study highlights three of these limitations: (1) the DRL systems analysed in this study may not represent the current state-of-the-art for DRL technologies, (2) there may be potential selection bias towards the larger proportion of GM vehicles included in the study sample and (3) the results among States differed and sometimes contradicted each other, so these results may not be translatable to the national level. In addition to these limitations, the results of the analysis are likely to be sensitive to how many cases were accurately assigned to both the target and control groups (i.e. the target group might include accidents which could not be influenced by the presence of DRLs, such as those caused by excessive speeds), while differences between the average ages of DRL-equipped and non-DRL-equipped vehicles may result in a difference between the driver demographics of the two groups. Finally, and perhaps most importantly, this study fails to compare the effectiveness of DRLs during dawn and dusk, despite the data being available for analysis. As a 9% reduction in dawn and dusk accidents has been observed, when comparing models with DRLs against those without (Bergkvist, 2001), it is clear that it is important to reanalyse this study to understand whether any significant benefit is gained from DRLs during the dawn and dusk time period.

2.2.2.2 COLOUR OF DAYTIME RUNNING LAMPS

Only one experimental study has attempted to investigate the effects of DRL colour on safety (Peña-García, et al., 2010). This study compared the visual reaction times (VRTs) of observers for detecting the activation of a direction-indicator that was located beside a DRL across a range of DRL colours, observation angles and separation distances. This study reported that significant increases in VRTs were observed for both amber coloured DRLs (0.043 seconds) and observation angles (0.053 seconds) (Peña-García, et al., 2010), relating to a difference in reaction distances of 0.58 m and 0.71 m at 30 mph, respectively. These results demonstrate that although white DRLs are more effectively discriminated from direction-indicators than amber DRLs, these differences in DRL colour between EU and US legislation provides only marginal gains in reaction time that are unlikely to have any significant real-world implication on accident rates.

2.3 CORNERING LAMPS

EU regulations and US standards define both the applicability and functional intent of cornering lamps [*front cornering lamps*] as described in Table 3. While there are several similarities between the functional definitions of cornering lamps in the EU and US, US standards specify that cornering lamps can be used either in combination with the turn signal system or during very low speed manoeuvres, while EU regulations require these lamps to provide supplementary illumination in the direction of the turn only.

Table 3: Applicability and functional intent of EU and US cornering lamps (R48: UN Regulation No. 48; J852, SAE Standard No. J852)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Signal [Applicability]	**Functional Intent**	**Signal [Applicability]**	**Functional Intent**
Cornering Lamps [Optional]	A lamp used to provide supplementary illumination of that part of the road which is located near the forward corner of the vehicle at the side to which the vehicle is going to turn (R48, 2.7.26)	Front Cornering Lamps [Optional]	Steady burning lamps used in combination with the turn signal system to supplement headlamps by providing additional illumination in the direction of turn. They may be used independent of the turn signal to ease manoeuvring at very low speeds (J852, 3.1)

2.3.1 NOTABLE DIFFERENCES

Legislative requirements for cornering lamps are specified by UN regulations 48 and 119 in the EU, whereas SAE standard J852 specifies the requirements for the US. EU and US requirements are identical for applicability and number only (Table 23, Annex 1), with both sets of legislation providing an option to install two cornering lamps on all passenger cars. Despite several differences between EU and US legislative requirements for the remaining properties, the most notable differences identified are the option in the US to install lamps that range in colour from white to amber, the absence of geometric visibility angle requirements in the US (although it may be that photometric visibility angles are interpreted as geometric visibility angles in the US), the differences in reference axis and therefore photometric visibility angle range, the greater photometric minima required in the US, the greater photometric maxima required in the EU and the more prescriptive definitions used in the EU for regulating the activation of the cornering lamps.

2.3.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

The primary function of cornering lamps is to provide supplementary light to enhance driver visibility in the direction of a turning manoeuver, before the vehicle substantially executes the manoeuvre. While current EU and US legislation both provide the option to install cornering lamps, several differences between these standards exist that may have real-world safety implications. Most notably, EU and US requirements differ in defining a photometric reference axis; with US SAE standards (J852) specifying a reference axis located perpendicular to the longitudinal axis of the vehicle and EU regulations (R48, R119) specifying the reference axis parallel to this axis. In addition to this fundamental difference, US standards both require greater photometric minima and allow lamps that can range between white and amber in colour, while EU regulations allow considerably greater photometric maxima and require white coloured lamps only.

The legislative differences between the reference axes of EU and US cornering lamps is primarily a historical issue. Sullivan & Flannagan (2010) highlighted that early versions of US cornering lamps were located on the left and right front fenders and forward of the front wheel well, thus locating the reference axis of a cornering lamp perpendicular to the longitudinal axis of the vehicle, whereas the more modern EU models integrate cornering lamps with either AFS or fog lamps. Based on real-world low-speed turn trajectories, however, Sullivan & Flannagan (2010) established that the key zone for the illumination of corners is centred around 32° left and 32° right for moving turns and below 30° left and 15° right for turns initiated from stops and near-stops. It may therefore be presumed that, as both the EU and US require cornering lamps to illuminate these zones and test photometric minima and maxima at 30° left and 30° right, there is very little real-world evidence that supports the preferential use of one reference axis over the other.

While no previous research attempts to quantify the effects of cornering lamp colour on outcomes, evidence from DRL research may provide a useful comparison (Peña-García, et al., 2010). This study finds a small but significant reduction in observer visual reaction times (VRTs) associated with the detection of the activation of a direction-indicator that was located beside an amber coloured DRL compared to a white DRL (0.043 seconds) (Peña-García, et al., 2010). As cornering lamps can be activated at the same time as both the direction-indicator and side-marker lamps, it may be hypothesised that similar effects could also be observed. This may mean that the introduction of amber coloured cornering lamps could be less effective as a safety measure when compared to the introduction of white coloured cornering lamps. Further research must be performed, however, before confirming this effect. When considering the considerably greater absolute photometric maxima allowed by EU regulations (14,000 cd vs. 500 cd), however, it is important to note that the EU allow this level of illumination below a downward photometric angle of 0.57° to remove the effects of glare for oncoming vehicles while still providing greater illumination of vulnerable road users. When comparing photometric maxima between the EU and US legislative requirements in the “glare zone” (600 cd vs. 500 cd) it is clear that these differences are minimal and unlikely significantly affect real-world outcomes.

Finally, it must be noted that the real-world implications of installing cornering lamps has been the subject of several high quality experimental and accident database studies that have highlighted the advantages and potential safety benefits of their installation (Sullivan & Flannagan, 2002; Sullivan & Flannagan, 2007; Sullivan & Flannagan, 2010; Sullivan & Flannagan, 2011). In particular, a recent analysis of insurance collision claims has provided real-world data on the relationship between cornering lamps and passenger vehicle crashes (HLDI, 2012a). When comparing the effects of Mercedes-Benz’s Active Cornering Lamps on insurance claims, the HLDI reported a significant reduction in both insurance collision claim frequency (2.7% [95% CI: 0.9-4.5%]) and severity ($198 [$85-308]). No significant difference was observed for property damage liability.

2.4 ADAPTIVE FRONT-LIGHTING SYSTEMS

EU regulations and US standards define the applicability and functional intent of adaptive front-lighting [*full adaptive forward lighting*] systems (AFS) as described further in Table 4. With only EU regulations formally define the functional intent of AFS systems, the US further prohibits the installation of full AFS systems (i.e. allowing bending beams only).

Table 4: Applicability and functional intent of EU and US adaptive front-lighting (full adaptive forward lighting) systems (R48: UN Regulation No. 48; J2838, SAE Standard No. J2838)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Signal [Applicability]	**Functional Intent**	**Signal [Applicability]**	**Functional Intent**
Adaptive Front-Lighting System (AFS) [Optional]	A lighting device that provides beams with differing characteristics for automatic adaption to varying conditions of use for the dipped-beam (passing-beam) and the main-beam (driving-beam) (R48, 2.7.28)	Full Adaptive Forward Lighting System (AFS) [Optional]	No formal definition in SAE standard (J2838)

2.4.1 Notable Differences

Legislative requirements for AFS are specified by UN regulations 48 and 123 in the EU, whereas FMVSS standard 108 specifies requirements for the US. EU and US requirements are identical for number, colour, AFS vertical alignment targets, the requirement for an AFS lamp levelling systems and photometric visibility angles, maxima and minima (Table 24), with both sets of legislation providing the option to install a single system of white, photometrically identical and vertically adjustable, lamps on all passenger cars. Despite several differences between the EU and US requirements for the remaining properties, the most notable differences identified are that the installation of AFS passing and driving beams are prohibited in the US, the absence of US standards for geometric visibility angles (although it may be that photometric visibility angles are interpreted as geometric visibility angles in the US), the absence of a requirement for AFS lamp cleaning devices in the US, the different philosophies taken for automatic AFS levelling devices (EU: mandatory for lamps of >2,000 lumens, optional for all others; US: optional only), the greater AFS vertical inclination angles allowed in the EU, the mounting height specific AFS vertical inclination angles required by the EU and key differences in the activation requirements for each AFS class.

2.4.2 Discussion of real-world implications

The primary objective for adaptive front-lighting systems (AFS) is to actively control the headlamp beam pattern to meet the dynamic requirements of both changing roadway geometries and visibility conditions. Currently, AFS beams are categorised by both beam "type" and "class", including the adaptive driving-beam, basic passing-beam (Class C), town passing-beam (Class V), motorway passing-beam (Class E), the adverse weather passing-beam (Class W) and their associated bend lighting (Class T) modes. Each AFS beam aims to increase driver forward visibility, while reducing the effects of glare for oncoming vehicles, by optimising the beam pattern for a specific driving scenario.

Current EU and US standards both provide the option to install AFS systems in passenger cars, with US SAE standards (J2838, J2591) attempting to harmonise with the more established EU regulations (R48, R123). Despite this attempt at harmonisation between EU and US legislative requirements, US standards provide a statement warning that the installation of AFS driving and passing beams may be prohibited by some agencies within the US. Although it is currently perceived that on that basis the use of full AFS systems are de facto prohibited across the US (IIHS, 2012), the installation of bend lighting systems are currently permitted based on SAE standard J2591. Clearly, this is the most important difference between AFS legislative requirements in the EU and US, so the following sections seek to compare the relative benefits of each AFS beam type and class to provide a structured overview of the key safety implications associated with AFS lighting. For discussions involving the safety implications of the differences in AFS levelling and cleaning devices, please see Section 2.1.2.2 where this is discussed from the perspective of the dipped-beam headlamps.

Prior to reading the following sections, however, it should be noted that there are many studies that are performed on AFS systems by manufacturers for development purposes and, because of this, are for internal use only. Consequently, as this research could not be accessed, many of the included AFS studies do not always supply enough information, such as light levels, specific beam distributions, experimental procedures and common performance metrics that are correlated to traffic safety. These factors make it difficult to reproduce the studies (and thus, the results), generalize the findings to other conditions and ultimately determine the real-world effectiveness of AFS systems.

2.4.2.1 ADAPTIVE DRIVING-BEAMS

Adaptive driving-beams (ADB, i.e. matrix beams) have generated significant interest in recent feasibility studies (Bullough J. , 2014; Neuman, 2014; Courcier, Reiss, & Sanchez, 2013; Hamm M. , 2013). ADB systems use forward facing camera technologies to allow the driver to constantly use the driving-beam headlights at all times, while reducing glare for oncoming and preceding drivers by selectively dimming the portion of the ADB directed at them.

In a series of experimental studies, Skinner and Bullough (2009) demonstrated that the forward visibility of a prototype ADB system was comparable to that for driving-beams, while disability and discomfort glare for oncoming drivers were comparable to the levels of glare experienced when facing a passing-beam. Measuring driver response times to targets located in the forward field of view, this research found that the prototype ADB system resulted in improved driver response times vs. passing-beams for targets located across the field of vision apart from the angle where the beam was dimmed. Furthermore, this study found that glare from oncoming vehicles fitted with ADB systems, vs. passing-beams, resulted in comparable driver reaction times for targets that were located on the same side of the road and a slight increase in reaction times for targets located on the opposite side of the road. Combining these results using the relative visual performance model (Rea & Ouellette, 1991; Bullough, Donnell, & Rea, 2013b), Skinner and Bullough (2009) hypothesised that the installation of AFS driving beams would correspond to a net reduction in night-time crashes of 6.7%.

Neuman (2014) further demonstrated the advantages of ADB systems when compared to halogen and high-intensity discharge (HID) headlamps. By measuring detection distances for obstacles positioned on the same side of the road as the driver, this study concluded that only HID driving-beams provided considerably better forward visibility than the ADB system (21m (17%) increase in detection distance), while the ADB system improved the forward visibility of the driver when compared to halogen and HID passing-beams (62m (107%) & 32m (36%) increase in detection distance, respectively). When investigating the effects of glare, Neuman (2014) observed that, for subjects seated in parked vehicles that faced an oncoming vehicle travelling at 80km/h, the glare from the ADB system was no more discomforting (on the de Boer scale (De Boer, 1967)) than that from either the halogen or the HID passing-beams, while providing considerable comfort improvements when compared to both halogen and HID driving-beams (7.1 vs. 2.1 & 1.7, respectively).

Unfortunately, there remains a considerable paucity of evidence directly relating the use of ADB systems with either changes in driver behaviour or, perhaps most importantly, to accident or collision rates. As such there is currently no empirical, real-world, safety data to support whether or not such systems are beneficial to safety and thus considered for use on vehicles.

2.4.2.2 ADAPTIVE TOWN (CLASS V) PASSING-BEAMS

AFS town (Class V) passing-beam patterns become both shorter and wider in response to high ambient light and low speed conditions. As forward lighting is dimmed according to both traffic density and ambient lighting, Class V beams aim to effectively manage glare for the drivers of both oncoming and preceding vehicles, while increasing beam throw to further highlight pedestrians and junction entrances.

In a series of experimental studies, Akashi *et al*. (2003) researched the effectiveness of Class V beams for a range of ambient lighting scenarios. The first study proved it was possible to considerably dim headlamp beams in lit areas without impairing the forward visibility of the driver. This study documented that, while target detection distances decreased as result of a reduction in roadway illuminance, a corresponding reduction in headlamp beam intensity had little effect on target detection distances, regardless of roadway illuminance. The second study observed that oncoming headlamp glare impaired the forward visibility of drivers. This study observed an increase of up to 30 m in target detection distances with oncoming headlamp glare, suggesting that dimming forward lighting is an effective strategy for reducing oncoming vehicle glare in lit areas. This is supported by further field work performed by Bullough *et al*. (NHTSA, 2008), which also reported that headlamp glare impairs forward visibility and results in increased driver discomfort, even in the presence of street lighting, and that it is possible for headlamps to be dimmed by over 50% in lighted areas, to reduce glare for oncoming and preceding vehicles, without significantly impairing driver detection distances.

Bacelar (2003) further proved that the contribution of the street lighting can be adequate for satisfactory visibility of targets located on the surface of the road and that the use of headlights did not improve, in all circumstances, the visibility of these targets. This study further found that, although the detrimental effects of headlamp glare on driver visibility are most pronounced during the night-time, driver visibility levels can still be reduced by up to 20 m in lighted areas with glare from oncoming vehicles (Bacelar, 2003).

To study the behavioural effects of AFS systems in a night-time city scenario, Jenssen *et al*. (2007) performed a six day simulation study to investigate the behavioural adaptation of 22 subjects to the simulation for both AFS and non-AFS systems. Although there was a general speed increase for both systems after the initial familiarisation phase, the use of the AFS system was observed to result in a reduced increase in speed when compared to standard headlamps. This was particularly evident for a reduction in simulated speeds on the approach to, and when passing, both obstructed and unobstructed corners; with AFS drivers having a speed profile that better represented daylight speed profiles, resulting in a smoother approach with lower decelerations and speeds than non-AFS drivers.

Although evidence demonstrates the benefits of Class V passing beams for reducing both glare and driver speeds when compared with standard headlamps, there still remains a considerable paucity of evidence directly relating the Class V beams to changes in real-world accident or collision rates. As such, there is currently no empirical data to assist in determining whether or not such systems have real-world benefits for safety.

2.4.2.3 ADAPTIVE MOTORWAY (CLASS E) PASSING-BEAMS

The aim of the AFS motorway passing-beam (Class E) pattern is to provide an enhanced range of forward vision to drivers, when driving on high-speed roads or motorways, while minimizing glare for oncoming traffic. Through the modification of standard dipped-beam patterns to project light further down the road, Class E passing-beams aim to increase both the forward visibility and contrast sensitivity of the driver.

Hamm (2002) conducted an experimental study to evaluate the effectiveness of a Class E beam provided by an AFS prototype in comparison to standard halogen and HID passing-beams. This study demonstrated that the use of Class E beams resulted in a considerable improvement in target detection distances, with Class E beams achieving target detection distances of 148 m in comparison to 70 m and 85 m for the standard halogen and HID passing-beams, respectively. Kobayashi et al. (1999) further evaluated the performance of a full AFS prototype which used a supplemental beam to provide high speed motorway lighting when speeds exceeded 100 km/h. The results of this study indicated substantial improvements in visibility comfort (7.6 vs. 6.1 for a 10-point scale) for the Class E beam.

Sivak *et al*. (2002) further evaluated Class E beam illuminance by vertically shifting the beams of standard (non-AFS) headlamps, from both EU and US mean market-weighted models (year 2000), by 0.25° and 0.5° upwards to simulate a Class E beam. The results indicated that the simulated Class E beams in both regions would result in increased illuminance and forward visibility for the driver (0.25°, EU: 158% and US: 138%; 0.5°, EU: 248% and US: 187%), but also increase glare for oncoming traffic (0.25°, EU: 124% & US: 117%; 0.5°, EU: 151% & US: 137%). Because of the steeper vertical inclination of EU driving-beams, the relative visibility benefit from shifting the beam upward is greater for EU driving-beams. Despite this improvement, the nominally aimed US beams tended to outperform the EU beams that were shifted upwards by 0.25°.

Finally, by interrogating both the NHTSA Fatality Analysis Reporting System (FARS) and the North Carolina Department of Transportation Crash (NCDOT) datasets, Sullivan and Flannagan (2006) evaluated the relative magnitudes of risk in darkness associated with motorway crash scenarios. The results of this analysis found that relative risk of a fatal crash in darkness is overwhelmingly predicted by posted speed limit and, if this was 45 mph or greater on a motorway, the average predicted dark/light ratio would be about 10 (i.e. the chance of a fatal crash on a motorway is 10 times greater in darkness than in daylight). These results were reflected for all fatal and non-fatal crashes with pedestrians, with an average predicted dark/light ratio of around 9 calculated from the NCDOT dataset. Finally, Sullivan and Flannagan (2006) evaluated the absolute safety benefit potential for Class E AFS passing-beams, calculating that their introduction throughout the US could considerably reduce both fatal (768 /year) and non-fatal (1,344 /year) crashes.

Although evidence demonstrates the potential benefits of Class E AFS passing-beams for improving illuminance and reducing darkness associated motorway accidents, there still remains a considerable paucity of evidence that directly relates the use Class E beams to any difference in real-world accident or collision rates. With a significant increase in glare for oncoming vehicles, the net benefits of Class E beams remain unknown. As such, there is currently no empirical data to assist in determining whether or not such systems have any real-world benefits for safety.

2.4.2.4 ADAPTIVE ADVERSE WEATHER (CLASS W) PASSING-BEAMS

AFS adverse weather (Class W) passing-beam patterns become both longer and wider, with a shielded zone immediately in front of the vehicle, in response to conditions, such as rain, snow, fog and wet road surfaces, which can significantly impair driver visibility. The functional intent of Class W passing-beams is to therefore provide high intensity light at the outward edge of a road in a distant zone, illuminate the road edges on both sides of the road and reduce the intensity of the light in the immediate frontal zone.

As adverse weather conditions drastically change the reflective property of road surfaces, water on the road can increase forward reflection, causing increased glare for oncoming drivers, while also reducing backward reflection. This creates a unique scenario where the visibility of both drivers can become considerably reduced, particularly if the target reflectance is lower than the reflectance of the road. Freiding (1999) found differences in road luminance between both dry and wet road surfaces, with wet road surfaces causing considerably greater glare for oncoming drivers (wet: 25,000 cdm^{-2} vs. dry: 80 cdm^{-2}). This was further confirmed in an experimental study by Rosenhahn (1999), which found, for distances of less than 90 m, significant differences between the wet and dry road condition glare illuminance values for both halogen and HID headlamps. On developing a prototype adverse weather passing-beam, which sought to reduce illuminance within the specific angular zone characterised by Class W passing-beams, Rosenhahn (1999) was able to reduce glare by 52% in the critical zone and improving both contrast sensitivity and re-adaption time. This was further supported by an alternate prototype developed by Kalze (2001), which reduced reflection glare to 30% that of a standard beam pattern.

Finally, the effects of adverse weather conditions on the extent of the forward visibility of the driver have been evaluated by two studies. Bullough and Rea (2001) first identified that the use of narrowly-distributed lamps, which are mounted as far away from the line of sight of the driver as possible, give rise to the lowest levels of back-scattered light. This was confirmed through a computational study by Rosenhahn (2001), which further observed that the inclination angle of the beam is also fundamental to the luminance of back-scattered light. Neither study, however, specifically investigated the effects of Class W passing-beam patterns, so it is difficult to directly transfer the results of this research to the situation of this particular AFS beam pattern. This difference was found to increase as the oncoming driver approached the light source.

Although evidence demonstrates the benefits of Class W passing beams for reducing the effects of both forward and backward reflection during adverse weather conditions (when compared to standard headlamps), there still remains a considerable paucity of evidence to directly relate Class W beam patterns to improved real-world accident or collision rates. As such, there is currently no empirical data to assist in determining whether or not such systems have real-world benefits for safety.

2.4.2.5 ADAPTIVE BEND LIGHTING (CLASS T) MODES

AFS bend lighting (Class T) is a specific mode for each of the preceding beam classes to provide automated direction control that allows the beam to turn into road bends to direct the beam to where it is required. As it becomes more difficult to illuminate forward road surfaces with standard (non-bending) headlamps, particularly as the curve radius of the road decreases, Class T beams are intended to turn with the bend to improve the forward visibility of the driver.

As US requirements for AFS bend lighting in SAE Standard number J2591 are consistent with the bend lighting mode specific aspects of UN Regulations 48 and 123, this review does not identify any safety critical differences between the EU and US passenger car fleets for the optional installation of AFS bend lighting. The benefits of installing bend lighting for road safety must not be underestimated, with this particular AFS beam class the subject of several high quality experimental studies that highlight the advantages of installing bend lighting (Sullivan & Flannagan, 2006; Sivak, Flannagan, Schoettle, & Nakata, 2002; Sivak, Schoettle, Flannagan, & Minoda, 2005; Hagiwara, Morishita, Horii, Miki, & Ohshima, 2007; Jenssen, Bjørkli, Sakshaug, & Moen, 2007; McLaughlin, Hankey, Green, & Larsen, 2004; Reagan, Brumbelow, & Frischmann, 2015).

In particular, a recent analysis of insurance collision claims has provided real-world data on the relationship between passenger vehicle crashes and crash avoidance technologies (HLDI, 2011a; HLDI, 2011b; HLDI, 2012a; HLDI, 2012b). When comparing the effects of AFS bend lighting systems on the frequency and severity of insurance collision claims, the HLDI reported a consistent reduction in insurance claim frequency for vehicles with AFS bend lighting systems (HLDI, 2011a; HLDI, 2011b; HLDI, 2012a; HLDI, 2012b). In particular, the HLDI identified a significant reduction in property damage liability claims ($p<0.05$) for three of the four manufacturers studied (with the final manufacturer indicating a similar non-significant trend) and a significant reduction in collision claims ($p<0.05$) for one out of four manufacturers (with the final three manufacturers indicating a similar non-significant trend), indicating a significant real-world safety benefit for AFS bend lighting systems. In an experimental analysis of this real-world data, Reagan *et al*. (2015) found that the forward visibility of the driver, in a test car from one of the above manufacturers, was significantly improved for detecting low reflectance targets located at the inside of curves when using HID AFS bend lighting. The authors hypothesised that the use of HID AFS bend lighting may therefore assist the driver in identifying dimly lit obstacles located on the inside of bends on the road.

2.5 DIRECTION-INDICATOR AND SIDE-MARKER LAMPS

For ease of comparison, this section compares EU regulations and US standards for front, rear and side direction-indicator lamps and side-marker lamps together because of their functional overlap; i.e. side-marker lamps can be used as direction indicators.

EU regulations and US standards both define four lamp categories that can be utilised for this purpose; front direction-indicator lamps [*front turn signal lamps*], rear direction-indicator lamps [*rear turn signal lamps*], side direction-indicator lamps [*side direction indicator lamps*] and side-marker lamps [*side marker lamps*]. Specific definitions for the applicability and functional intent of each direction-indicator lamp category are presented, for both sets of legislation, in Table 5. While the functional definitions for front, rear and side direction-indicator lamps are equivalent, EU side-marker lamp regulations require lamps to only indicate the presence of the vehicle whereas US standards require lamps to indicate the length of the vehicle as well.

2.5.1 NOTABLE DIFFERENCES

This section describes the most notable and potentially influential differences. Refer to Table 25 to Table 28 in Annex 1 for a detailed side-by-side comparison of the legislative requirements.

Table 5: Applicability and functional intent of EU and US direction-indicator (turn signal) and side-marker lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; J914: SAE Standard No. 914)

<table>
<tr><th colspan="2">EU (UN Regulations)</th><th colspan="2">US (FMVSS/SAE Standards)</th></tr>
<tr><th>Lamp [Applicability]</th><th>Functional Intent</th><th>Lamp [Applicability]</th><th>Functional Intent</th></tr>
<tr><td>Front Direction-Indicator Lamps [Mandatory]</td><td rowspan="3">Lamps used to indicate to other road-users that the driver intends to change direction to the right or to the left (R48, 2.7.11)</td><td>Front Turn Signal Lamps [Mandatory]</td><td rowspan="2">The signalling element of a turn signal system which indicates the intention to turn or change direction by giving a flashing light on the side toward which a turn will be made (F108, S4)</td></tr>
<tr><td>Rear Direction-Indicator Lamps [Mandatory]</td><td>Rear Turn Signal Lamps [Mandatory]</td></tr>
<tr><td>Side Direction-Indicator Lamps [Mandatory]</td><td>Side Direction Indicator Lamps [Optional]</td><td>A lighting device (homologated with UN R6 Category 5) mounted on the side of a vehicle, at or near the front, and used as part of the turn signal system to indicate a change in direction by means of a flashing warning signal on the side toward which the vehicle operator intends to turn or manoeuvre (J914, 3.4)</td></tr>
<tr><td>Side-Marker Lamps [Optional]</td><td>Lamps used to indicate the presence of the vehicle when viewed from the side (R48, 2.7.24)</td><td>Side Marker Lamps [Mandatory]</td><td>Lamps which show to the side of a vehicle, mounted on the permanent structure of the vehicle as near as practicable to the front and rear edges to indicate the overall length of the vehicle (F108, S4)</td></tr>
</table>

2.5.1.1 FRONT DIRECTION-INDICATOR LAMPS

The legislative requirements for front direction-indicator lamps are specified in the EU by UN regulations 48 and 6, whereas FMVSS standard 108 specifies requirements for the US. EU and US requirements are identical for applicability, number, colour and photometric visibility (Table 25), with both sets of legislation mandating the use of two amber coloured lamps, with identical photometric visibility angles, for all passenger cars. Despite several differences between the EU and US requirements for the remaining properties, the most notable differences identified are the different philosophy employed by the US standards for determining visibility of the lamp ("lens area" or "luminous intensity" option) and the lower photometric minima allowed by EU regulations across all lamp locations and photometric visibility angles.

2.5.1.2 REAR DIRECTION-INDICATOR LAMPS

The legislative requirements for rear direction-indicator lamps in the EU are specified by UN regulations 48 and 6, whereas FMVSS standard 108 specifies requirements for the US. EU and US requirements are identical for applicability, number and photometric visibility (Table 26), with both sets of legislation mandating the use of two lamps, with identical photometric visibility angles, for all passenger cars. Despite several differences between the EU and US requirements for all other properties, the most notable differences are the optional use of amber or red coloured lamps in the US, the optional use of steady burning or variable intensity lamps in the EU, the different philosophy employed in US standards for determining the visibility of the lamp ("lens area" or "luminous intensity" option), the lower photometric minima allowed in EU regulations and the greater photometric maxima allowed in the EU for variable intensity lamps.

2.5.1.3 SIDE DIRECTION-INDICATOR LAMPS

The legislative requirements for side direction-indicator lamps in the EU are specified by UN regulations 48 and 6, whereas SAE standard J914 specifies the requirements for the US. EU and US requirements are identical in both number and colour only (Table 27), with EU and US legislation both requiring that side direction-indicator lamps be amber in colour for all passenger cars and that only two side direction-indicator lamps be implemented if used. Despite several differences between the EU and US requirements for the remaining properties, the most notable differences are the optional requirement for side direction-indicator lamps in the US, the lower upward geometric visibility angles mandated in the EU and the lower photometric minima allowed by US standards.

2.5.1.4 SIDE-MARKER LAMPS

The legislative requirements for side-marker lamps are specified by UN regulations 48 and 91 in the EU, whereas FMVSS standard 108 specifies the requirements for the US. EU and US requirements are different for all properties (Table 28), with the most notable differences including an optional requirement for side-marker lamps in the EU, the option of installing either high performance and low performance side-marker lamps in the EU (SM1 and SM2, respectively), the absence of requirements for geometric visibility angles in the US (although it may be that the photometric visibility angles are interpreted as geometric visibility angles in the US), the smaller photometric visibility angles required for high performance lamps in the EU, the greater photometric minima required in the EU for high performance lamps, the lower photometric minima required by the US standards for rear side-marker lamps and the absence of photometric maxima regulation in the US.

2.5.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

2.5.2.1 REAR DIRECTION-INDICATOR LAMPS

With regard to rear direction-indicator lamps, the European legislation is more stringent and requires consistent amber colour coding of the indicator function, which might facilitate recognising the meaning of the indicator signal and might also make it more conspicuous among other red light signals. The research cited below paints a fairly consistent picture of significant safety benefits of amber rear-direction indicator lamps.

In 2009, NHTSA performed a study into accident involvement rates of vehicles in the US equipped with amber rear direction indicators as compared to those with red indicators (Allen, 2009). The study analysed the frequency of front-to-rear collisions when the leading vehicle was engaged in a manoeuver where turn signals were assumed to be engaged – turning, changing lanes, merging, or parking. It compared the pre- and post-involvement rate of passenger vehicle models that switched rear indicator colour at some point between 1981 and 2005, thus eliminating confounding factors such as body size, body style or size and shape of the rear lighting housings. Allen found a statistically significant effectiveness of 5.3% of amber rear direction-indicators compared to red signals. This means that 5.3% of all front-to-rear collisions during the relevant manoeuvres were prevented by amber signals. There were indications that the effectiveness in preventing collisions involving injuries might even be slightly higher.

In a previous study, Sullivan & Flannagan (2008) conducted logistic regression of US crash data and found a 22% reduction of collision involvement for vehicles with amber rear direction-indicators during relevant manoeuvres. Part of this benefit might be attributable to other characteristics commonly associated with amber signals, such as lamp separation between direction-indicators and stop lamps (see below). Edwards (1988) found a similar effectiveness of about 20% when analysing collision involvement in five US states.

An early study by Taylor & Ng (1981) analysed Canadian insurance data and failed to identify a significant effectiveness of amber signal colour at reducing accident involvement. However, the sample size used in this study was small compared to other studies and the results may be confounded by vehicle age and fleet composition. No study yielded results in favour of red rear direction-indicator lamps.

The requirement to separate the function of the rear direction-indicator and the stop lamps is another aspect where the European requirements are more stringent compared to US requirements and which can be assumed to facilitate recognition of the direction indicator.

Sullivan & Flannagan (2008) performed a US study to examine the safety implications of a range of rear direction indicator signal characteristics. Logistic regression was used to determine the influence of aspects such as signal colour and lamp separation on the risk to be involved in a collision of a relevant type. Apart from the above cited results regarding signal colour, the research found that separated lamps for indicator and brake light might also associated with a reduced risk of rear impacts. The effectiveness was found to be approximately 11% hence somewhat smaller than that of lamp colour. The researchers suggest, however, that the chosen methodology makes it difficult to clearly separate the effects of colour and lamp separation.

2.5.2.2 SIDE-MARKER LAMPS

Side marker lamps, which are optional in the EU and mandatory in the US, are intended to aid detection of vehicles approaching at an angle in night time conditions and to signal to other road users, that are located laterally to the vehicle, the intent of the driver to either manoeuvre or change direction to the left or right.

A laboratory setting reaction time study found that cars with side marker lamps were generally detected and recognized earlier and more accurately (Theeuwes & Alferdinck, 1997).

Kahane (1983) analysed US crash data to evaluate the US rule which mandated the fitment of passenger cars with side-marker lamps from the year 1969. The study found that angled side-collisions of all severities at night were reduced by 16% by side-marker lamps. The effectiveness was slightly higher, 21%, when focusing on injury accidents only. Fatal accidents were not found to be reduced by side-marker lamps.

It appears questionable, however, whether these findings (based on data from the 1970s) would reappear in studies using crash data from recent years or decades. Firstly, as Rice (2010) points out, side-marker lamps were introduced in the US as a result of vehicle design changes taking place in the 1960s: Before that time, vehicles were generally designed such that the edge of the headlamp lens was visible from the side, at least to some extent. The change of car design towards sealed beam headlamps put into a deep styled bezel or fenders extended beyond the headlamps meant that the additional function of headlamps to make vehicles conspicuous from the side was dropped. Car designs from recent decades are assumed to provide more conspicuity again when seen from the side, even without side-marker lamps. Secondly, the average performance of headlamps has increased considerably since the 1970s (sealed beam headlamps were used at the time) which supports drivers in detecting obstacles, including vehicles seen from the side, earlier. It is therefore expected that the real-world effectiveness of side-marker lamps in modern cars is considerably smaller than found by Kahane (1983).

It is unknown how exactly the US findings would translate to the European traffic situation with differing junction layouts from the US, such as a higher frequency of roundabouts.

2.5.2.3 SIDE DIRECTION-INDICATOR LAMPS

Side direction-indicator lamps, which are mandatory in the EU and optional in the US, are used to signal to other road users, that are located laterally to the vehicle, the intent of the driver to manoeuvre or change direction to the left or right. Although US legislation only provides an option to install side direction-indicator lamps in passenger cars, current US SAE standards (J914) attempt to harmonise with the more established EU regulations (R48, R6), minimising the differences between EU and US passenger cars. The real-world implications of using US cars in the EU without side direction-indicator lamps installed could, therefore, be detrimental to safety. Despite this, no studies were identified by this review that attempt to analyse the implications of these differences between EU and US legislation. When considering the historical development of these requirements, it may be reasonable to assume that the differences in road types, road layouts, junction designs, and also modal splits (such as a higher share of cyclists in Europe) might have led to this difference in applicability.

2.6 STOP LAMPS

EU regulations and US standards define two lamp categories that can be utilised as stop lamps; S1/S2 category stop-lamps [*stop lamps*] and S3/S4 category stop lamps [*high mounted stop lamps*]. The specific definitions of the applicability and functional intent of each headlamp category are presented, for both sets of legislation, in Table 6. While the functional definition of all stop-lamps in the EU are considered equivalent, US standards require that stop lamps provide a steady burning light to the rear of the vehicle to indicate that the vehicle is braking and that high-mounted stop lamps provide a stop warning light through intervening vehicles to the operators of following vehicles.

Table 6: Applicability and functional intent of EU and US stop-lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108)

<table>
<tr><th colspan="2">EU (UN Regulations)</th><th colspan="2">US (FMVSS/SAE Standards)</th></tr>
<tr><th>Lamp [Applicability]</th><th>Functional Intent</th><th>Lamp [Applicability]</th><th>Functional Intent</th></tr>
<tr><td>S1/S2 Category Stop Lamps [Mandatory]</td><td rowspan="2">A lamp used to indicate to other road users to the rear of the vehicle that the longitudinal movement of the vehicle is intentionally retarded (R48, 2.7.12)</td><td>Stop Lamps [Mandatory]</td><td>A lamp giving a steady light to the rear of the vehicle to indicate a vehicle is stopping or diminishing speed by braking (F108, S4)</td></tr>
<tr><td>S3/S4 Category Stop Lamps [Mandatory]</td><td>High-Mounted Stop Lamps [Mandatory]</td><td>A lamp mounted high and possibly forward of the tail, stop, and rear turn signal lamps intended to give a steady stop warning through intervening vehicles to operators of following vehicles (F108, S4)</td></tr>
</table>

2.6.1 NOTABLE DIFFERENCES

This section describes the most notable and potentially influential differences. Refer to Table 29 and Table 30 in Annex 1 for a detailed side-by-side comparison of the legislative requirements.

2.6.1.1 S1/S2 CATEGORY STOP-LAMPS

The legislative requirements for S1/S2 category stop-lamps are specified in the EU by UN regulations 48 and 7, whereas FMVSS standard 108 specifies requirements for the US. EU and US requirements are identical for number, colour, length and photometric visibility (Table 29), with both sets of legislation mandating the use of two red coloured lamps, with identical photometric visibility angles, located at the rear of all passenger cars. Despite several differences between EU and US requirements for the remaining stop lamp properties, the most notable differences identified are the optional use of steady burning or variable intensity lamps in the EU, the greater maximum mounting heights allowed in the US, the different philosophy employed in the US for determining the visibility of the lamp ("lens area" or "luminous intensity" option), the lower photometric minima allowed by EU regulations and the greater photometric maxima allowed by the EU for variable intensity lamps.

2.6.1.2 S3/S4 CATEGORY STOP-LAMPS

The legislative requirements for S3/S4 category stop-lamps are specified in the EU by UN regulations 48 and 7, whereas FMVSS standard 108 specifies requirements for the US. EU and US requirements are identical for number, colour, width and photometric visibility (Table 30), with both sets of legislation mandating the use of one red coloured lamp, with identical photometric visibility angles and minima, located on the longitudinal plane (i.e. centreline) of all passenger cars. Despite several differences between EU and US requirements for the remaining properties, the most notable differences identified are the option to use either steady burning or variable intensity lamps in the EU, the absence of a requirement to mount the lamp above the level of the S1/S2 stop lamps in the US, the greater geometric visibility angles required in US standards and the lower photometric maxima required by EU regulations for steady burning lamps (photometric maxima for variable intensity lamps are identical with US standards).

2.6.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

Variable intensity stop lamps are permitted in EU regulations but are prohibited by US regulations. Variable intensity stop lamps can adapt to different weather conditions to change the visibility of the lamp. The stop lamp intensity may be increased during hours of sunlight and in bright conditions or the intensity may be decreased during hours of darkness to reduce glare. Variable intensity stop lamps may also be used to provide a rear collision warning signal to the driver behind.

The photometric minima, permitted by EU regulations are lower than the photometric minima required by US regulations for category S1 and category S2 lamps. The photometric maxima are lower in the EU for category S1 lamps and but category S2 lamps are permitted higher photometric maxima than US S1 lamps. The photometric maxima specified for category S3 stop lamps in the EU are lower than the requirements set out in US regulations.

Moćko et al carried out a study investigating the effect of lighting surface and stop lamp intensity on visual comfort. A series of experiments were carried out where participants described the visual impressions they experienced when viewing stop lamps at different intensities under day and night time conditions (Moćko et al, 2013). The assessments were conducted at an observation distance of both 150 meters (to represent motorway driving) and 5 meters (to represent queuing traffic) in daylight conditions and of 5m in night conditions. In the first experiment, the visibility of brake lights shining at an intensity of 60 cd was assessed by participants over an observation distance of 150m. Only 25% of participants reported that their visibility of the brake light was optimal while 75% described the light as poorly visible or not visible at all. This indicates that there may be some negative safety implications for US highways if the minimum EU photometric minima were adopted. However, an assessment was not carried out at the US defined photometric minima. Experiments should be carried out to determine whether experiments at 80cd provide similar results, meaning safety implications of mutual acceptance would be minimal. No tests were conducted at 260 and 300 cd meaning no results could be referred to in order to assess any safety implications caused by the difference between the photometric maxima specified.

The highest luminosity tested during the experiment was 520 cd. This was found to be uncomfortable by all respondents as the lamp caused a very strong glare. Therefore, the photometric maxima specified by EU regulations could have negative safety implications for US roads if used over long periods of time. It may be argued that long-term exposure to stop lights with high luminous intensity is tiring for drivers, and can also result in the occurrence of an interfering glare phenomena. Consequently, the ability of the driver to perceive changes in traffic situations is decreased.

However, a study carried out by NHTSA in 2010 found that flashing brake lights at brightness levels of 840 cd and above are most effective when providing a braking alert signal to drivers behind (NHTSA, 2010). The study also found that increasing the steady-burn brightness to levels of 420cd and 840cd resulted in little or no improvements to the number of participants who’s eyes were drawn back to the forward view (0% and 10%

look-up respectively), suggesting that increasing the brightness of steady-burn brake lamps does not appear to be an effective means of drawing attention to the brake signal.

In contrast to EU regulations, there is no requirement within US regulations to mount S3/S4 category stop lamps above the level of S1/S2 stop lamps. Theeuwes and Alferdinck carried out a laboratory study in order to investigate the effect of a vertical separation between the S3/S4 stop lamp and the horizontal plane of S1/S2 lamps. While performing a laboratory tracking task, subjects were sat 30m behind two lighting rigs (a distance comparable to travelling behind another vehicle in traffic). Both rigs displayed different car lighting arrangements with brake lights applying randomly. Participants responded to brake lights by depressing a brake pedal. Based on reaction time measures (speed and accuracy) recorded during the tests, the study concluded that higher centre high mount stop lamp (CHMSL), located away from the horizontal plane of the other rear lights, resulted in better performance than a CHMSL located adjacent to that horizontal plane (Theeuwes and Alferdinck, 1995). However, since the study was carried out with 14 participants, its results could be regarded with a greater level of confidence if the sample size was increased. However, the results suggest that US vehicles with S3 lamps not located above S1/S2 stop lamps may present a negative safety implication for EU roads.

2.7 POSITION, SIDE-MARKER, END-OUTLINE MARKER AND PARKING LAMPS

For ease of comparison, this section compares EU regulations and US standards for front and rear position lamps, side-marker lamps, end-outline marker lamps and parking lamps together because of their functional overlap in indicating the presence of a vehicle either during operation or when stationary.

EU regulations and US standards both define five lamp categories that can be utilised for the purpose of indicating the presence of a vehicle; front position lamps [*front position lamps*], rear position lamps [*taillamps*], side-marker lamps [*side marker lamps*], end-outline marker lamps [*clearance lamps*] and parking lamps [*parking lamps*]. The specific definitions for the applicability and functional intent of each lamp category are presented, for both sets of legislation, in Table 7. While functional definitions for rear position and end-outline marker lamps are equivalent in the EU and US, the remaining lamps differ in functionality. Side-marker lamps are required to indicate the presence of a vehicle in the EU and US, while US standards require lamps to further indicate the length of the vehicle. EU regulations for front position lamps require lamps to indicate both the position and width of the vehicle, while US standards primarily require the front position lamps to mark the front of a vehicle while parked and stand in as front position indicating lamps in the event of headlamp failure. Finally, EU regulations require parking lamps to draw attention to the presence of a stationary vehicle in a built up area, while parking lamps in the US are primarily required to mark the front of a vehicle when parked and stand in as front position indicating lamps in the event of headlamp failure. It is important to further note that parking lamps have dual functionality with front position lamps in the US and front position, rear position and side mounted lamps in the EU.

2.7.1 NOTABLE DIFFERENCES

This section describes the most notable and potentially influential differences. Refer to Table 28 and Table 31 to Table 34 in Annex 1 for a detailed side-by-side comparison of the legislative requirements.

Table 7: Applicability and functional intent of EU and US front position, rear position (taillamp), parking and side-marker lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; J222: SAE Standard No. 222)

EU (UN Regulations)		**US (FMVSS/SAE Standards)**	
Lamp [Applicability]	**Functional Intent**	**Lamp [Applicability]**	**Functional Intent**
Front Position Lamps [Mandatory]	Lamps used to indicate the presence and width of the vehicle when viewed from the front (R48, 2.7.14)	Front Position Lamps [Mandatory]	Lamps on both the front left and right of the vehicle which show to the front and are intended to mark the vehicle when parked or serve as a reserve front position lamp in the event of headlamp failure (J222, 3.1)
Rear Position Lamps [Mandatory]	Lamps used to indicate the presence and width of the vehicle when viewed from the rear (R48, 2.7.15)	Taillamps [Mandatory]	Steady burning low intensity lamps used to designate the rear of a vehicle (F108, S4)
Side-Marker Lamps [Optional]	Lamps used to indicate the presence of the vehicle when viewed from the side (R48, 2.7.24)	Side Marker Lamps [Mandatory]	Lamps which show to the side of a vehicle, mounted on the permanent structure of the vehicle as near as practicable to the front and rear edges to indicate the overall length of the vehicle (F108, S4)
End-Outline Marker Lamps [Optional]	Lamps fitted near to the extreme outer edge and as close as possible to the top of the vehicle and intended to indicate clearly the vehicles width and bulk (R48, 2.7.23)	Clearance Lamps [Optional]	Lamps which show to the front or rear of the vehicle, mounted on the permanent structure of the vehicle as near as practicable to the upper left and right extreme edges to indicate the overall width and height of the vehicle (F108, S4)
Parking Lamps [Optional]	Lamps used to draw attention to the presence of a stationary vehicle in a built up area (R48, 2.7.22)	Parking Lamps [Mandatory]	Lamps on both the front left and right of the vehicle which show to the front and are intended to mark the vehicle when parked or serve as a reserve front position lamp in the event of headlamp failure (F108, S4)

2.7.1.1 FRONT POSITION LAMPS

The legislative requirements for front position lamps are specified by UN regulations 48 and 7 in the EU, whereas FMVSS standard 108 and SAE standard J222 specify US requirements. Front position lamps, known as “parking lamps” or “parking lights” in the US, act to primarily provide night-time standing-vehicle conspicuity, while also acting as reserve lamps for indicating the presence of the vehicle from the front in the event of a headlamp failure. These were designed to use little electricity, so they could be left on for periods of time while parked. In the EU, front position lamps act to indicate the presence and width of the vehicle from the front only.

EU and US requirements are identical for applicability, number, photometric visibility and photometric minima (Table 31), with both sets of legislation mandating the use of two lamps, with identical photometric visibility angles and minima, for all passenger cars. Despite several differences between the EU and US requirements for the remaining properties, the most notable differences identified are the option to install lamps in the US that can be either white or amber in colour, the different philosophy employed by US standards for determining lamp visibility (“lens area” or “luminous intensity” option), the greater photometric maxima allowed in the US below the horizontal axis and across all photometric angles and the greater photometric maxima allowed in the US above the horizontal axis at larger photometric angles.

2.7.1.2 REAR POSITION LAMPS

The legislative requirements for rear position lamps are specified by UN regulations 48 and 7 in the EU, while US requirements are specified by FMVSS standard 108. EU and US requirements are identical for applicability, number, colour, length and photometric visibility (Table 32), with both sets of legislation mandating the use of two red coloured lamps, with identical photometric visibility angles, located at the rear of all passenger cars. Despite several differences between the EU and US requirements for the remaining properties, the most notable differences identified are the optional use of steady burning or variable intensity lamps in the EU, the greater maximum mounting heights allowed in the US, the different philosophy employed by US standards for determining the visibility of the lamp (“lens area” or “luminous intensity” option), the greater photometric minima required by the EU regulations and the greater photometric maxima allowed in the EU for variable intensity lamps.

2.7.1.3 SIDE-MARKER LAMPS

The legislative requirements for side-marker lamps are specified by UN regulations 48 and 91 in the EU, whereas FMVSS standard 108 specifies the requirements for the US. EU and US requirements are different for all properties (Table 28), with the most notable differences including an optional requirement for side-marker lamps in the EU, the option of installing either high performance and low performance side-marker lamps in the EU (SM1 and SM2, respectively), the absence of requirements for geometric visibility angles in the US (although it may be that the photometric visibility angles are interpreted as geometric visibility angles in the US), the smaller photometric visibility angles required for high performance lamps in the EU, the greater photometric minima required in the EU for high performance lamps, the lower photometric minima required by the US standards for rear side-marker lamps and the absence of photometric maxima regulation in the US.

2.7.1.4 END-OUTLINE MARKER LAMPS

Legislative requirements for end-outline marker lamps are specified by UN regulations 48 and 7 in the EU, whereas the requirements for the US are specified by FMVSS standard 108 and SAE standard J2042. EU and US requirements are identical for rear mounting height only (Table 33). Despite several differences between the EU and US requirements for the remaining properties, the most notable differences identified are the differences in EU and US applicability requirements (EU: mandatory for vehicles >2.1 m in width, optional for vehicles between 1.8-2.1 m in width and prohibited for vehicles <1.8 m; US: mandatory for vehicles ≥2.032 m in width and optional for vehicles <2.032 m in width) the optional use of steady burning or variable intensity lamps in the EU, the requirement to use white front facing lamps in the EU and amber front facing lamps in the US, the requirement to ensure that lamps are located ≥200 mm vertically from position lamps in the EU, the absence of US requirements for geometric visibility angles (although photometric visibility angles may be interpreted as geometric visibility angles in the US), the smaller photometric visibility angles required in the EU, the greater photometric minima required in EU regulations in the reference axis, the greater absolute photometric minima required by EU regulations for rear end-marker outline lamps, the smaller absolute photometric minima required by the EU regulations for front end-marker outline lamps, the absence of photometric minima regulation for front end-marker outline lamps in the US, the greater photometric maxima allowed in the EU for the rear end-marker outline lamps in the reference axis and the smaller absolute photometric maxima allowed in the EU for rear end-marker outline lamps.

2.7.1.5 PARKING LAMPS

The legislative requirements for parking lamps are specified by UN regulations 48 and 77 in the EU, whereas US requirements are specified by both FMVSS standard 108 and SAE standard J222. Parking lamps, also known as “front position lamps” in the US, primarily provide night-time standing-vehicle conspicuity, while also acting as reserve lamps for indicating the presence of the vehicle from the front in the event of a headlamp failure. In the EU, parking lamps act to draw attention to the presence of a stationary vehicle in a built up area and can light up on one side of the vehicle only. EU regulations further allow the function of the parking lamps to be performed by simultaneously switching on the front and rear position lamps on one side of the vehicle. In this case, lamps that meet the requirements of front or rear position lamps are deemed to meet the requirements of EU compliant parking lamps.

EU and US requirements are identical for photometric visibility only (Table 34), with this lack of similarity primarily due to the differences in the philosophy between the US and EU definitions for the functional intent of a parking lamp. Most notably current EU regulations allow the use of either front/rear mounted lamps or side mounted lamps only, while also providing the option to activate parking lamps on one side of the vehicle. US standards, however, require two front mounted and forward facing parking lamps to be activated. EU regulations further require parking lamps to be white for front mounted lamps, red for rear mounted lamps and amber for side mounted lamps, while parking lamps in the US are allowed to be either white or amber in colour. These requirements are, however, only optional for vehicles that are ≤6 m in length and ≤2 m in width in the EU, while US parking lamp standards are mandatory for all passenger vehicles. Finally, US photometric minima and maxima requirements are both at least double those required in EU regulations.

2.7.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

Fitment of lights on the side of the vehicle provides improved lateral conspicuity for vehicles approaching on perpendicular courses. In the United States, the fitment of side marker lamps has been compulsory since January 1, 1968, In Europe, the fitment of side marker lamps is not compulsory for M1 and N1 vehicles under 6m in length, but EC Regulation 48 does specifies the location (as well as other aspects) of the lights should they be fitted.

It has been estimated that side marker lamps reduced the number of night-time angled collisions in US by 16%, from 661,000, assuming no vehicles were equipped, to 555,000 if all vehicles were equipped with side marker lamps (Kahane C. J., 1983). It was also reported by the same study that the accident reduction was statistically significant, with confidence bounds of between 10% and 22% percent.

However, it is not clear whether this finding is still valid bearing in mind the age of the study, or whether the results can be applied to Europe bearing in mind differing road geometries. For example, vehicle design has changed in the period since the 1980s and cars are equipped with better lighting systems that would aid detection of vehicles on perpendicular paths. In night-time accidents the headlights of current vehicles in both regions are considered likely to facilitate detection of vehicles, even in situations where two vehicles are approaching perpendicular to each other.

The US analysis also concluded that the fitment of side marker lamps did not affect fatal collisions with confidence intervals of -25% to 13% (Kahane C. J., 1983). It was speculated that this was because the efficacy of side marker lamps in fatal accidents was at least 75% lower than non-fatal accidents because the side marker lamps were detected too late for the drivers to take the appropriate braking or avoiding action. The finding seems to contradict the benefits stated for accidents of other severities.

There are several small differences between US and EU regulations regarding front and rear positional lamps and also parking lamps. However, no relevant literature was found to provide evidence that these differences would result in any safety implications.

2.8 FOG LAMPS

EU regulations and US standards both define two lamp categories that can be utilised as fog lamps; front fog lamps and rear fog lamps. The specific definitions of the applicability and functional intent of each fog lamp category are presented, for both sets of legislation, in Table 8. From this it can be seen that the functional intent of both the front and rear fog lamps are equivalent for EU and US legislation.

Table 8: Applicability and functional intent of EU and US fog lamps (R48: UN Regulation No. 48; J583, SAE Regulation No. 583; J1319, SAE Regulation No. 1319)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Lamp [Applicability]	**Functional Intent**	**Lamp [Applicability]**	**Functional Intent**
Front Fog Lamp [Optional]	The lamp used to improve the illumination of the road ahead of the vehicle in case of fog or any similar condition of reduced visibility (R48, 2.7.19)	Front Fog Lamp [Optional]	A lighting device designed to provide illumination forward of the vehicle under conditions of fog, rain, snow, or dust (J583, 3.1)
Rear Fog Lamp [Mandatory]	The lamp used to make the vehicle more easily visible from the rear in dense fog (R48, 2.7.20)	Rear Fog Lamp [Optional]	A lighting device providing a continuous red light of higher intensity than a taillamp for the purpose of marking the rear of a vehicle during fog or similar conditions of reduced visibility (J1319, 3.1)

2.8.1 Notable Differences

This section describes the most notable and potentially influential differences. Refer to Table 35 and Table 36 in Annex 1 for a detailed side-by-side comparison of the legislative requirements.

2.8.1.1 Front fog lamps

The legislative requirements for front fog lamps are specified in the EU by UN regulations 48 and 19, whereas SAE standard J583 specifies US requirements. EU and US requirements are identical for applicability, number and colour (Table 35), with both sets of legislation providing the option to install two white, or selective yellow, coloured fog lamps for all passenger cars. Despite several differences existing between EU and US requirements for the remaining properties, the most notable differences identified are the absence of US standards requiring the installation of headlamp levelling systems and defining geometric visibility angles (although it may be that the photometric visibility angles are interpreted as geometric visibility angles in the US), the smaller vertical inclination angles required in the EU for lamps with a luminous flux of ≤2000 lumens, the greater maximum vertical inclination angles allowed by the EU, the greater photometric angles required in the EU when comparing Class B and Class F fog lamps, the greater photometric minima and lower photometric maxima required for Class F3 fog lamps in the EU when compared to all US fog lamp classifications and photometric angles, the lower photometric minima and greater photometric maxima required in the EU for Class B fog lamps when compared to all US fog lamp classifications and photometric angles and the greater photometric maxima allowed in the EU for Class B fog lamps, and the greater photometric maxima allowed by US standards for Class F3 fog lamps, for the particular aspect of the beam directed towards oncoming traffic.

2.8.1.2 REAR FOG LAMPS

Legislative requirements for rear fog lamps are specified in the EU by UN regulations 48 and 38, whereas SAE standard J1319 specifies US requirements. EU and US requirements are identical for number, colour, the distance from a stop lamp and photometric visibility angle (Table 29), with both sets of legislation mandating the use of either one or two red coloured lamps, with identical photometric visibility angles, located >100 mm from a stop lamps for all passenger cars. Despite several differences between EU and US legislation for the remaining properties, the most notable differences identified are the optional requirement for rear fog lamps in the US, the optional use of steady burning or variable intensity lamps in the EU, the greater horizontal geometric visibility angles required in the US, the greater photometric minima required in the EU and the greater photometric maxima allowed in the EU.

2.8.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

Accidents in fog are relatively rare, but when they do occur, they can be severe and involve multiple vehicles. A US study cites data from the OECD that in Europe and North America, accidents in foggy conditions comprise between 1% and 5% of accidents (Flannagan M. , 2001).

Fog lights are designed to be operated in these conditions of impaired visibility to aid detection of vehicles ahead and to provide improved detection of positional cues for vehicle control, with beam patterns more angled towards the near foreground to reduce light back scatter. In conditions of reduced visibility the negative effect on visual cues also has the effect of encouraging faster driving. Therefore, fog lights which provide better illumination of the immediate foreground (front fog lights) and the distance to vehicles ahead to be more accurately judged (rear fog lights) been shown to be a positive safety feature in these conditions (Cavallo V. C., 2001).

Front fog lights are optional in both the EU and US. The EU requirements have higher photometric minima and greater photometric maxima in EU, but no studies could be found that quantified the effect of this difference on safety. EU front fog lights have a requirement for automatic levelling if unable to satisfy vertical inclination limits across the range of static loading conditions, and also for lamps with luminous flux above 2,000 lumens. These measures control potential glare which has the potential to cause negative safety effects if the lights are used in conditions of good visibility. There are no such requirements for automatic levelling in the US regulation, although as stated earlier, the lights have lower photometric maxima.

Rear fog lights are mandatory in EU and optional in US. In conditions of poor visibility drivers tend to overestimate distances to the preceding vehicle; (Cavallo V. C., 2001) found that driver’s overestimated distance by 60% compared with normal driving conditions. (Cavallo V. C., 2001) showed that distance estimation was improved with two fog lights as opposed to one. After accidents in fog, US studies have suggested fog lights as an effective countermeasure (Flannagan M. , 2001). Fog lights in the EU have greater photometric minima and photometric maxima, but no studies were found that quantified the effect of these brighter lights on distance estimation or safety in general. Glare may be increased when the lights are used inappropriately (i.e. used in good visibility conditions), but when used in the intended conditions, this level of brightness might be appropriate to improve detectability.

2.9 Retro-reflectors

For ease of comparison, this section compares EU regulations and US standards for retro-reflectors together because of their functional overlap. EU regulations define three retro-reflector categories and US standards define two reflex reflector categories that can be utilised for the purposes of indicating the presence of a passenger vehicle; rear non-triangular retro-reflectors [*rear reflex reflectors*], front non-triangular retro-reflectors and side non-triangular retro-reflectors [*side reflex reflectors*]. Combined definitions for the functional intent, and specific definitions for the applicability, of each retro-reflector are presented, for both sets of legislation, in Table 9. While the functional intent of retro-reflectors are, on the whole, equivalent, it is important to highlight that US standards prohibit front mounted reflex reflectors.

Table 9: Applicability and functional intent of EU and US retro-reflectors (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108)

<table>
<tr><th colspan="2">EU (UN Regulations)</th><th colspan="2">US (FMVSS/SAE Standards)</th></tr>
<tr><th>Reflector [Applicability]</th><th>Functional Intent</th><th>Reflector [Applicability]</th><th>Functional Intent</th></tr>
<tr><td>Rear Non-Triangular Retro-Reflectors [Mandatory]</td><td rowspan="3">Devices used to indicate the presence of a vehicle by the reflection of light emanating from a light source not connected to the vehicle, the observer being situated near the source (R48, 2.7.16)</td><td>Front Reflex Reflectors [Mandatory]</td><td rowspan="3">Devices used on vehicles to give an indication to approaching drivers using reflected light from the lamps of the approaching vehicle (F108, S4)</td></tr>
<tr><td>Front Non-Triangular Retro-Reflectors [Optional]</td><td>-</td></tr>
<tr><td>Side Non-Triangular Retro-Reflectors [Optional]</td><td>Side Reflex Reflectors [Mandatory]</td></tr>
</table>

2.9.1 Notable Differences

This section describes the most notable and potentially influential differences. Refer to Table 37 to Table 39 in Annex 1 for a detailed side-by-side comparison of the legislative requirements.

2.9.1.1 Rear non-triangular retro-reflectors

Legislative requirements for rear non-triangular retro-reflectors are specified in the EU by UN regulations 48 and 3, whereas US requirements are specified by FMVSS standard 108. EU and US requirements are identical for applicability, colour, length and maximum angle of divergence (Table 37), with both sets of legislation mandating the use of red coloured retro-reflective markers, with identical maximum angles of divergence, at the rear of all passenger cars. Despite several differences existing between EU and US requirements for the remaining properties, the most notable differences identified are the regulation of the reflector shape by the EU (EU prohibits triangular shaped reflectors), the option to install additional retro-reflective devices or materials in the EU, the absence of geometric visibility angle regulation in the US (although it may be that photometric visibility angles are interpreted as geometric visibility angles in the US), the greater maximum vertical illumination angles required in the EU, the greater maximum horizontal illumination angles required in the US, the smaller minimum angle of divergence required in the EU and the greater coefficients of luminous intensity required in the US.

2.9.1.2 FRONT NON-TRIANGULAR RETRO-REFLECTORS

Legislative requirements for front non-triangular retro-reflectors are specified in the EU by UN regulations 48 and 3, while no equivalent US standard currently exists (Table 38). It should be noted that stakeholders identified that no EU passenger car model is known to have front non-triangular retro-reflectors.

2.9.1.3 SIDE NON-TRIANGULAR RETRO-REFLECTORS

Legislative requirements for side non-triangular retro-reflectors are specified in the EU by UN regulations 48 and 3, while US requirements are specified by FMVSS standard 108. EU and US requirements are different for all properties (Table 39), with the most notable differences including the optional requirement for side non-triangular retro-reflectors in the EU, the regulation of the reflector shape by the EU (EU prohibits triangular shaped reflectors), the option to install additional retro-reflective devices or materials in the EU and the requirement for four reflectors only in the US, the absence of geometric visibility angle regulation in the US (although it may be that the photometric visibility angles are interpreted as geometric visibility angles in the US), the greater maximum vertical illumination angles required in the EU, the greater maximum horizontal illumination angles required in the US, the smaller minimum angle of divergence required in the EU and the greater coefficients of luminous intensity required in the US.

2.9.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

There are several small differences between US and EU regulations regarding retro-reflectors. However, no relevant literature was found to provide evidence that these differences would result in any safety implications.

2.10 REVERSING LAMPS

EU regulations and US standards define both the applicability and the functional intent of the reversing [*backup*] lamps to be equivalent (Table 10).

Table 10: Applicability and functional intent of EU and US reversing lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Lamp [Applicability]	**Functional Intent**	**Lamp [Applicability]**	**Functional Intent**
Reversing Lamp [Mandatory]	The lamp used to illuminate the road to the rear of the vehicle and to warn other road-users that the vehicle is reversing or about to reverse (R48, 2.7.21)	Backup Lamp [Mandatory]	A lamp or lamps which illuminate the road to the rear of a vehicle and provide a warning signal to pedestrians and other drivers when the vehicle is backing up or is about to back up (F108, S4)

2.10.1 Notable Differences

Legislative requirements for reversing lamps are specified in the EU by UN regulations 48 and 23, whereas FMVSS standard 108 specifies US requirements. EU and US requirements are identical for applicability, number, colour and length (Table 40, Annex 1), with both sets of legislation mandating the use of either one or two white coloured lamps located at the rear of all passenger cars. Despite several differences between EU and US legislative requirements for the remaining properties, the most notable differences identified are as follows. In the EU, electrical connections shall be such that the lamp can light up only if the reverse gear is engaged and if the device which controls the starting and stopping of the engine is in such a position that operation of the engine is possible. It shall not light up or remain lit if either of the above conditions is not satisfied. In the US the lamp must be activated when the ignition switch is energised and reverse gear is engaged and must not be energised when the vehicle is in forward motion, but this does not prohibit the activation of the lamp when the vehicle is stationary and not running, notably as a courtesy lamp. Further, the different philosophy employed by US standards for determining the visibility of the lamp (visibility zone method), the greater photometric minima required by US standards for one lamp systems, the greater photometric maxima allowed in the EU for photometric angles greater than 5° downwards, the greater photometric maxima allowed in the EU for two lamp systems at angles below 0° and the greater photometric maxima allowed in the US for single lamp systems at angles above 0°.

2.10.2 Discussion of real-world implications

There are several small differences between US and EU regulations regarding reversing lamps. However, no relevant literature was found to provide evidence that these differences would result in significant safety implications, as regards the function during reversing.

2.11 Hazard warning signal

EU regulations and US standards define the applicability and functional intent of hazard warning signals as described in Table 11. While the functional definition of hazard warning signals are considered equivalent in the EU and US, US standards require that the hazard warning signal is provided by turn signal lamps and the EU require that this is provided by direction-indicator lamps, resulting in no requirement for hazard warning signals to be provided by side mounted signalling lamps in the US.

Table 11: Applicability and functional intent of EU and US hazard warning signal lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Signal [Applicability]	**Functional Intent**	**Signal [Applicability]**	**Functional Intent**
Hazard Warning Signal [Mandatory]	The simultaneous operation of all of a vehicle's direction-indicator lamps to show that the vehicle constitutes a special danger to other road users (R48, 2.7.18)	Hazard Warning Signal [Mandatory]	Simultaneous flashing of all required turn signal lamps to indicate to approaching drivers the presence of a vehicular hazard, meeting, as a minimum, the turn-signal photometric requirements (F108, S4; F108, S6.1.5.1)

2.11.1 Notable Differences

The legislative requirements for the hazard warning signal are specified in the EU by UN regulation 48, whereas FMVSS standard 108 specifies requirements for the US. Both EU and US requirements refer primarily to the requirements of the regulations associated with both direction-indicator and turn signal lamps (Table 29). Many of the notable differences between hazard warning signals may therefore be found with their associated lamps in Section 2.2. The mandatory use of side direction-indicator lamps for hazard warning signals in the EU is the only notable difference in the regulations specifically associated with hazard warning signals.

2.11.2 Discussion of real-world implications

Hazard warning signals are mandatory in the EU and the US. However, there are some small differences between systems permitted by EU and US regulations. In the EU, the colour of the signal must be amber while the US permits amber and red signals. Therefore, it is possible that red hazard warning signals permitted on US roads may confuse road users travelling behind a vehicle producing a hazard signal as it would appear similar to a braking signal. No studies were identified to provide evidence for this.

In the EU, side marker lamps are permitted to flash to provide a hazard warning signal. This feature is optional and no studies have been identified which provide evidence to suggest that including side marker lamps in the hazard warning signal would have a negative safety effect if European vehicles were sold in the US.

Requirements for the activation of the hazard warning signal are not defined in US regulations. However, EU regulations state that the signal must be manually controlled. EU regulations also allow the option of producing a hazard warning signal automatically following a collision or after an emergency stop signal. No accident data was identified to suggest that this would cause a negative safety effect on US roads.

2.12 Emergency stop signal

EU regulations define the applicability and functional intent of the emergency stop signal (Table 12), while no equivalent US standard currently exists. Legislative requirements for emergency stop signals are specified in the EU by UN regulation 48 (Table 42), with the emergency stop signal provided by the simultaneous in-phase operation of all stop or direction-indicator lamps at a frequency of 4.0±1.0Hz. The emergency stop signal should be automatically activated if the emergency braking logic signal is activated at vehicle speeds of >50 km/h, while the signal must be deactivated on the deactivation of the emergency braking logic signal or activation of the hazard warning lights.

Table 12: Applicability and functional intent of EU and US emergency stop signals (R48: UN Regulation No. 48)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Signal [Applicability]	**Functional Intent**	**Signal [Applicability]**	**Functional Intent**
Emergency Stop Signal [Optional]	A signal to indicate to other road users to the rear of the vehicle that a high retardation force has been applied to the vehicle relative to the prevailing road conditions (R48, 2.28)	-	-

2.12.1 Discussion of real-world implications

The emergency stop signal is optional in the EU and may be produced by flashing all stop lamps or all direction indicator lamps. However, flashing stop lamps are prohibited in US regulations.

A study commissioned by NHTSA found that the most common factors for rear-end crashes include driver inattention, distraction and following too closely (Wierwille et al, 2009). A series of experiments were carried out to assess the eye drawing capability and comfort level of several different rear lighting configurations with varying flashing frequencies and intensities. The study found that driver's exposed to increased lamp intensities coupled with the simultaneous flashing of all lamps were most likely to brake in response to the signal.

No studies or accident data were found to suggest that emergency stop signals negatively affect road safety (Wierwille et al, 2009). It is also worth highlighting the peculiarity that US regulations allow flashing red hazard lights, if stop lamps are combined with rear turn signal lamps, but will not allow red flashing stop lamps as part of the ESS signal.

2.13 Rear-end collision alert signal

EU regulations define the applicability and functional intent of a rear-end collision alert signal (RECAS) (Table 13), whereas no equivalent US standard currently exists. Legislative requirements for a RECAS are specified in the EU by UN regulation 48 (Table 43), with a RECAS provided by the simultaneous in-phase operation of all direction-indicator lamps at a frequency of 4.0±1.0Hz. The RECAS must not be activated if the direction-indicator lamps, hazard warning signal or emergency stop signal is activated. The RECAS should be automatically activated if the relative speed (v_r) of a following car is ≥30 km/h and time to collision (t_c) is ≤1.4 seconds or if v_r is ≤30 km/h and t_c is $\leq 1.4 * v_r / 30$ seconds, while the signal must not stay activated for >3 seconds.

Table 13: Applicability and functional intent of EU and US rear-end collision alert signals (R48: UN Regulation No. 48)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Signal [Applicability]	**Functional Intent**	**Signal [Applicability]**	**Functional Intent**
Rear-End Collision Alert Signal [Optional]	An automatic signal given by the leading vehicle to the following vehicle warning the following vehicle that it should take emergency action to avoid a collision (R48, 2.33)	-	-

2.13.1 Discussion of real-world implications

US regulations do not specify any form of rear-end collision alert signal. However, in European regulations this feature is optional. EU regulations were updated to include rear-end collision alert signals due to evidence provided by experts in Japan (Expert from Japan, 2007). A simulation study was carried out using European data. The study estimated that if the feature was made mandatory, 23 per cent of rear-end collisions and at least 20,000 whiplash injuries a year could be avoided. However, as the installation of this feature is currently only optional in Europe, these benefits are unlikely to be realised in practice.

2.14 Rear registration plate lamps

EU regulations and US standards define both the applicability and the functional intent of the rear registration plate [*license plate*] lamps to be equivalent (Table 14).

Table 14: Applicability and functional intent of EU and US rear registration plate lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Lamp [Applicability]	**Functional Intent**	**Lamp [Applicability]**	**Functional Intent**
Rear Registration Plate Lamp [Mandatory]	The lamp used to illuminate the space reserved for the rear registration plate (R48, 2.7.13)	License Plate Lamp [Mandatory]	A lamp used to illuminate the license plate on the rear of a vehicle (F108, S4)

2.14.1 Notable Differences

Legislative requirements for rear registration plate lamps are specified in the EU by UN regulations 48 and 4, whereas FMVSS standard 108 specifies US requirements. EU and US requirements are identical for applicability, number, colour and length (Table 44, Annex 1), with both sets of legislation mandating a minimum of one white coloured lamp located at the rear of all passenger cars to illuminate the rear registration plate. Despite several differences between EU and US legislative requirements for the remaining properties, no difference is thought to have any potential safety implications.

2.14.2 Discussion of real-world implications

There are several small differences between US and EU regulations regarding rear registration plate lamps. However, no relevant literature was found to provide evidence that these differences would result in any safety implications.

2.15 Exterior courtesy lamps

EU regulations define the applicability and functional intent of the exterior courtesy lamp (Table 15), while no equivalent US standard currently exists. Legislative requirements for exterior courtesy lamps are specified in the EU by UN regulation 48 (Table 45), with exterior courtesy lamps used to illuminate steps and door handles with a single lamp only.

Table 15: Applicability and functional intent of EU and US exterior courtesy lamps (R48: UN Regulation No. 48)

EU (UN Regulations)		US (FMVSS/SAE Standards)	
Signal [Applicability]	**Functional Intent**	**Signal [Applicability]**	**Functional Intent**
Exterior Courtesy Lamp [Optional]	A lamp used to provide supplementary illumination to assist the entry and exit of the vehicle driver and passenger or in loading operations (R48, 2.7.29)	-	-

2.15.1 Discussion of real-world implications

Exterior courtesy lamps are not incorporated within US legislation and no design requirements are specified. In the EU, these lamps are optional. However, if fitted by a manufacturer, lamps must comply with the criteria specified within Regulation 48. No relevant literature was found to identify any negative safety implications caused by the inclusion of exterior courtesy lamps on vehicles. It is however noted that a number of US cars are equipped with a function that activates the reversing lamps when unlocking the vehicle. This feature would be in contradiction with EU legislation. It can further be argued that other road users, notably pedestrians in parking areas, misinterpret this as a vehicle signalling function.

3. COMPARISON OF EU REGULATIONS AND US STANDARDS FOR DIRECT VISION

Direct vision requirements for the EU and the US are specified in the regulatory acts and federal standards, respectively, shown in Table 16 below.

Table 16: Regulatory Acts and federal standards that specify direct vision related requirements for the EU and the US, respectively.

Item	EU Regulatory Act	USA Federal Standard
Forward field of vision (Driver)	UN regulation 125	None
Safety glazing materials and their installation on vehicles	UN regulation 43 GTR 6	FMVSS 205 'Glazing materials' FMVSS 212 'Windshield mounting' (GTR 6)
Windscreen wiper and washer systems	Regulation EU 1008/2010	FMVSS 104
Windscreen defrosting and demisting systems	Regulation EU 672/2010	FMVSS 103

It should be noted that:

- Although there are no standards equivalent to UN Regulation 125 that specifically address the driver forward field of vision in the USA, FMVSS 104 effectively does this to some extent, for the size of the transparent area of the windshield. It achieves this by requiring a large portion of the windshield glazing surface to be wiped which serves to optimize the design wipe pattern and restrict encroachment of A-pillars or headers. This is discussed further in Section 3.1.1.

- GTR 6 has been transposed into the EU legislation, mainly Regulation 43, but its transposition into US legislation is still ongoing. Until this is complete the differences that GTR 6 resolves described in Section 3.2 will remain.

- The EU regulatory acts and US federal standards listed above both define various fields of view related to the driver's forward field of vision originating from driver vision reference points. However, the vision reference points used in the EU and the US are slightly different although they are fundamentally similar.

    - The EU legislation defines two distinct points, called 'V' points (vision origin points), which represent average eye positions for tall and short drivers referenced to a vehicle coordinate system and a seat back angle. The fields of view are defined by lines drawn at specified angles directly intersecting the two vision reference points.

- The US legislation defines ellipsoids, called eyellipsoids, containing the probable eye locations of drivers in a range of statures referenced to the seating position. The fields of view are defined by lines drawn tangent to the eye position ellipsoids at specified angles.

- It is interesting to note that the EU 'V' points were generated by ISO from eyellipsoids and also that the eyellipsoids defined in the latest versions of the ISO and SAE standards, namely ISO 4513: 2010 and SAE J941: 2010, are exactly the same. Also, the eyellipsoids in both these standards are no longer positioned according to the driver's torso angle. This must cause problems with the position of the 'V' points which vary according to seat back angle, i.e. driver torso angle.

3.1 FORWARD FIELD OF VISION

In the EU the forward field of vision is regulated by UN Regulation 125, which contains requirements for the driver's field of vision in terms of:

- Transparent area of windscreen
- A-pillar obscuration
- Forward direct field of vision
  - Driver 180° vision.
  - Obscuration of short objects.

In the US, the forward field of vision is not regulated directly as in UN Regulation 125. However, it is effectively regulated indirectly to some extent through requirements such as FMVSS 104 for windscreen wiper and wash systems which specifies requirements for the size of the swept area – see Section 3.3 below.

3.1.1 TRANSPARENT AREA OF WINDSCREEN

UN Regulation 125 requires that the transparent area of the windscreen shall contain at least the following datum points (sight lines):

- A horizontal datum point forward of V_1 and 17° to the left (see Figure 2 top)
- The horizontal datum point is also mirrored to the right
- An upper vertical datum point forward of V_1 and 7° above the horizontal
- A lower datum point forward of V_2 and 5° below the horizontal

This is EU 'entire' windscreen zone "B". The 'critical' area zone "A" (See Figure 2 bottom) is considered specifically for performance of the wash/wipe and defrost/demist systems.

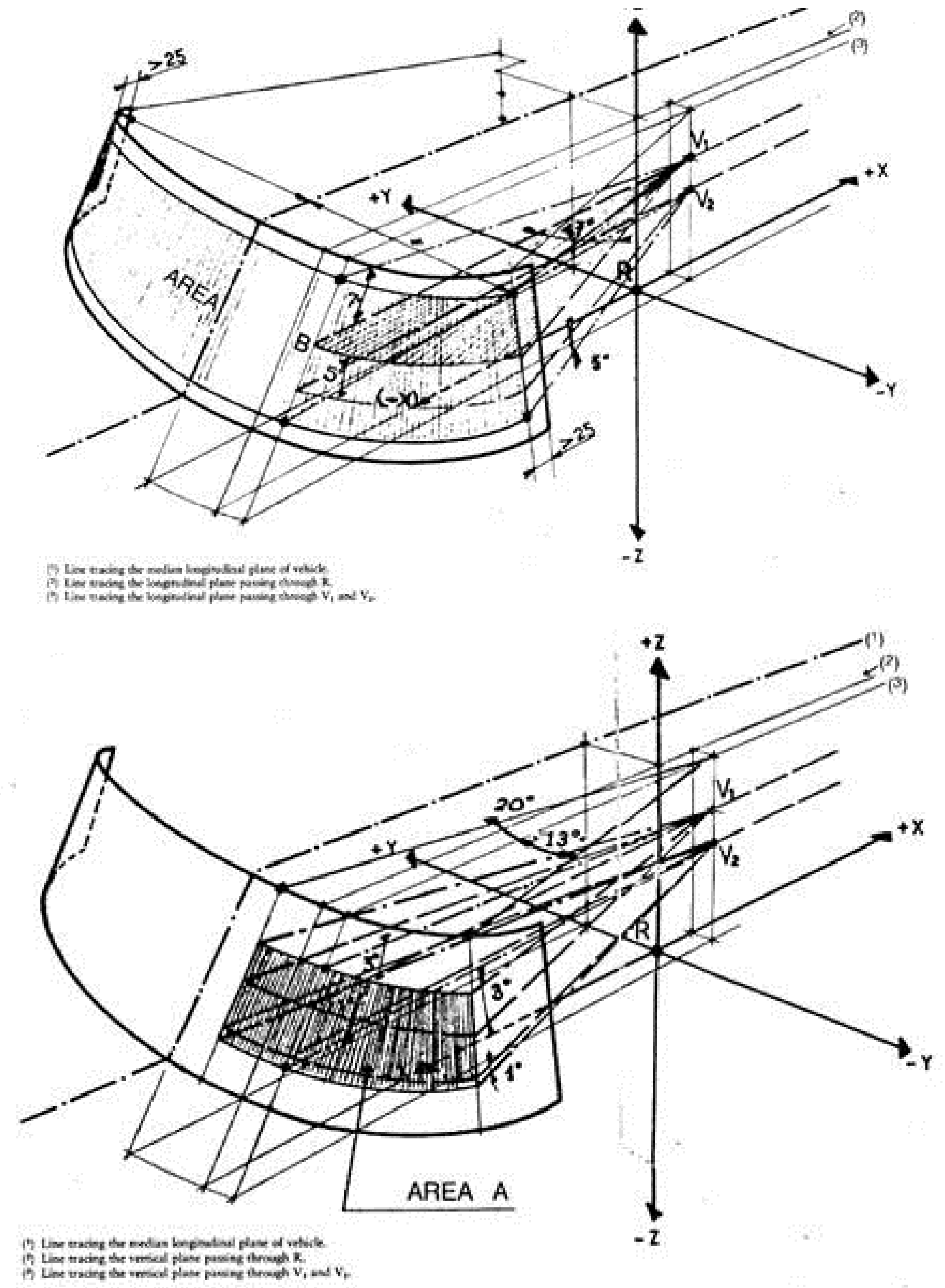

Figure 2: Illustrations of EU ‘entire’ and ‘critical’ windscreen zones.

For comparison FMVSS 104 defines the following ‘entire’ windscreen area “A” for passenger cars, which the windshield wiping system should clear 80% of. This area is dependent on the car’s overall width and defined by the sight lines shown in Table 17. The ‘critical’ area “C” is used in the context of wash/wipe and defrosting systems performance.

Table 17: Comparison of sight line angles for UN Regulation 125 (windscreen transparent area) and FMVSS 104 (windshield wiped area A) showing similarities.

EU Reg 125 / US FMVSS 104	Car overall width (mm)	Left (deg)	Up - above horizontal (deg)	Down - below horizontal (deg)	Right (deg)
Entire windscreen Area – minimum 80% swept (EU: area B, US area A)					
EU R125	All	**17**	**7**	**5**	**symmetrical to left side**
US F104	<1520	16	**7**	**5**	**49**
US F104	<1630 >1520	**17**	8	**5**	**51**
US F104	<1730 >1630	**17**	9	**5**	**53**
US F104	>1730	18	10	**5**	**56**

EU / US	Minimum % swept	Up (deg)	Down (deg)	Left (deg)	Right (deg)
Critical Area (EU: area A, US: area C)					
EU	98%	3	1	13	20
US	99%	3 ~ 5	1	7 ~ 10	15

It is important to note that in Regulation 125, the sight lines are defined using V points as shown in Figure 2, whereas in FMVSS 104 the sight lines are defined using eyellipsoids as shown in Figure 3 and Figure 4. In the EU, V points have been used for many years (since at least 1977 - Directive 77/649/EEC) in lieu of the complete eyellipse to standardise the driver's field of view for legislative purposes.

The comparisons show that there is a tendency towards higher sight lines in the US than in the EU and although this increases the vision area, the safety benefit of better upward view can be questioned. The approach of symmetry of the EU 'entire' winscreen zone is likely to result in a wider and more rectangular vision area compared to the US specified left/right angles, although it is advisable to further analyse this with real vehicle data. Finally, the 'critial' windscreen area of the EU is wider, when taking into account the left and right angles. Again, some increased upward view is applicable for larger vehicles, but its benefit may evenly be questioned.

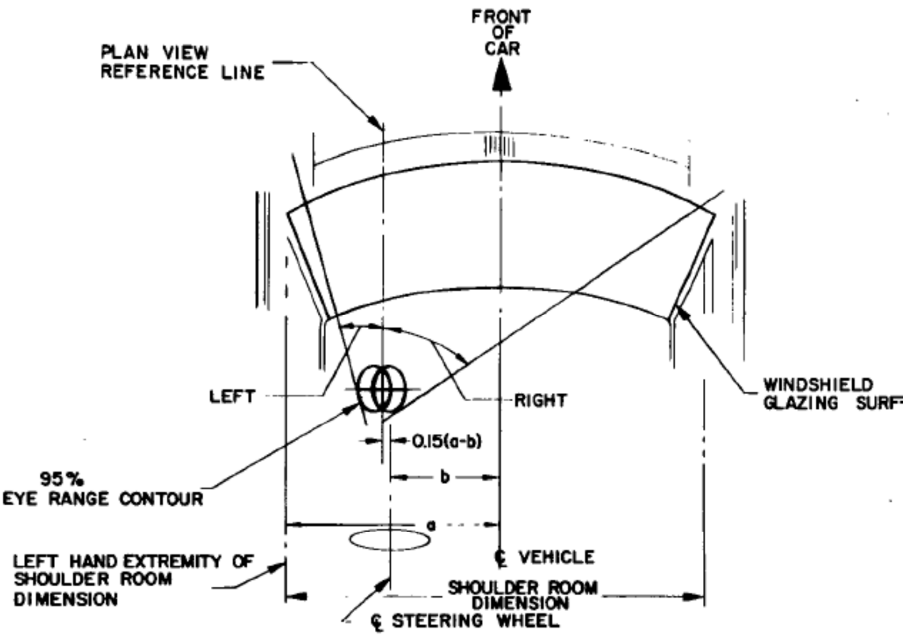

Figure 3: Windscreen 80% swept area A required by FMVSS 104 – plan view.

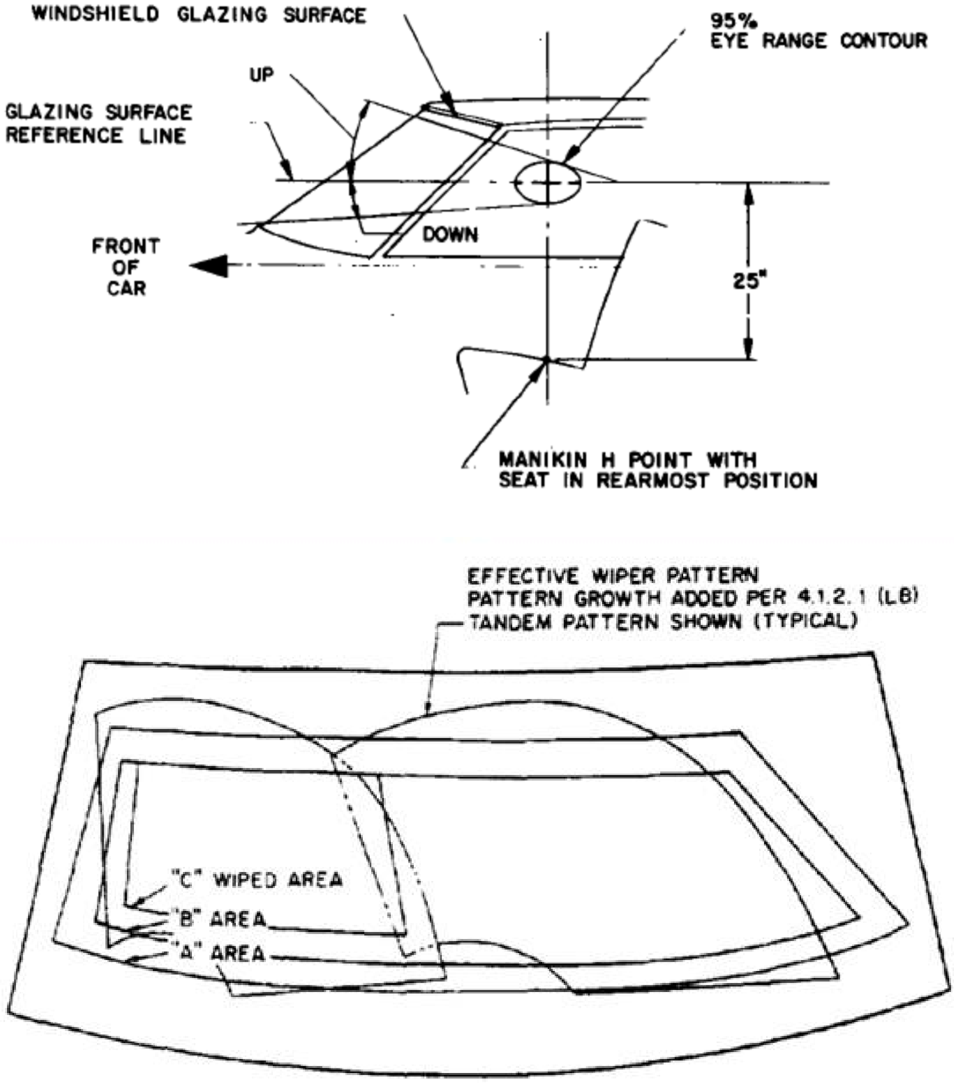

Figure 4: US 'critical' and 'entire' windscreen swept areas required by FMVSS 104.

The effect of using the different origin methods (i.e. V points compared to eyellipsoids) can make a significant difference to the areas defined even if the sight line angles are the same. This is illustrated in Figure 5 and Figure 6 below. In the example, the difference is small for the up and down sight lines but is larger for the left sight line mainly because of the difference in the mid-eye lateral position compared to the V point (46 mm left for a car of overall width approx. 1630 mm compared to 5 mm) and that the eyellipsoid method moves the sight line origin point rearwards significantly compared to the V point.

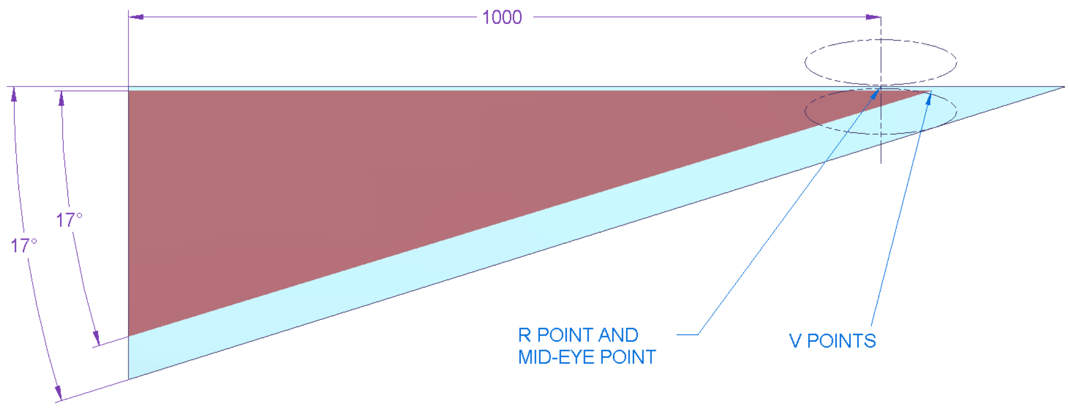

Figure 5: Plan view of differences caused by use of different origin methods for left sight line – EU V points (red) compared to US eyellipsoids (blue).

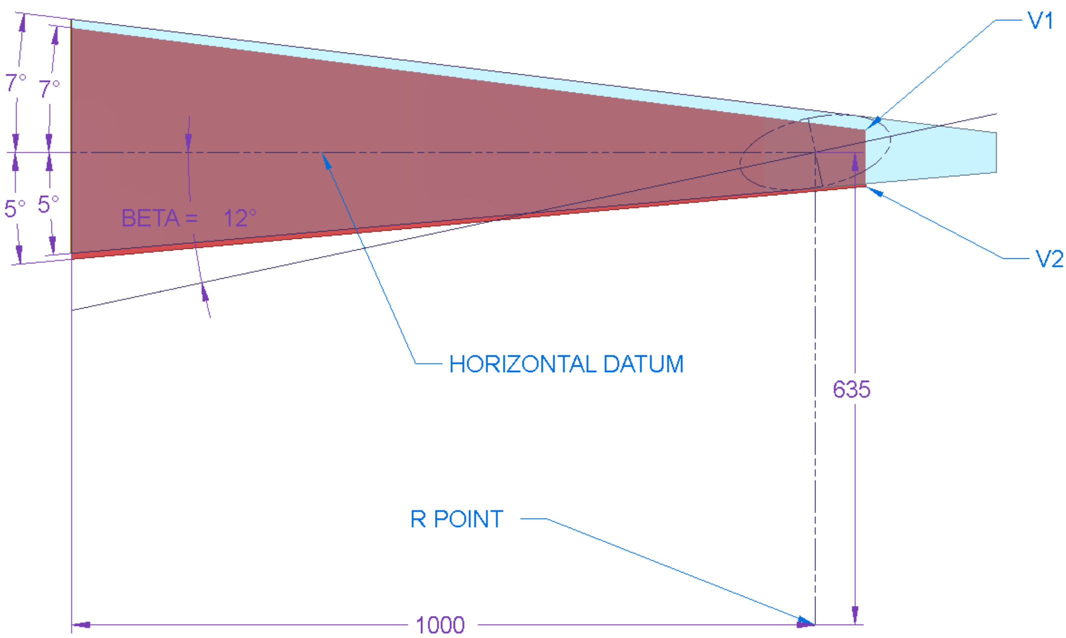

Figure 6: Side view of differences caused by use of different origin methods for up and down sight lines - EU V points (red) compared to US eyellipsoids (blue).

In summary, the EU legislation, UN Regulation 125, has specific requirements for the size of the windscreen transparent area. In contrast, the US legislation has no specific requirements for the windscreen transparent area. However, for the US the windshield swept area requirements in FMVSS 104 do control the windscreen transparent area to some extent. However, although sight line angles in both legislations are similar, other factors such as the origin points and area definition are not. Therefore, it is not possible to determine, in general, whether or not the requirements are similar in terms of the windscreen transparent area. The only way to make a comparison would be to measure specific exemplar vehicles.

3.1.2 A-PILLAR OBSCURATION

UN Regulation 125 requires that the angle of obstruction for each A-pillar shall not exceed 6^o (apart for armoured vehicles for which 10^o is allowed) defined using two planes (inclined at 2^o upwards and 5^o downwards) passing through P_m situated at (43.36 mm, 0 mm, 627 mm) relative to the vehicle's R point..

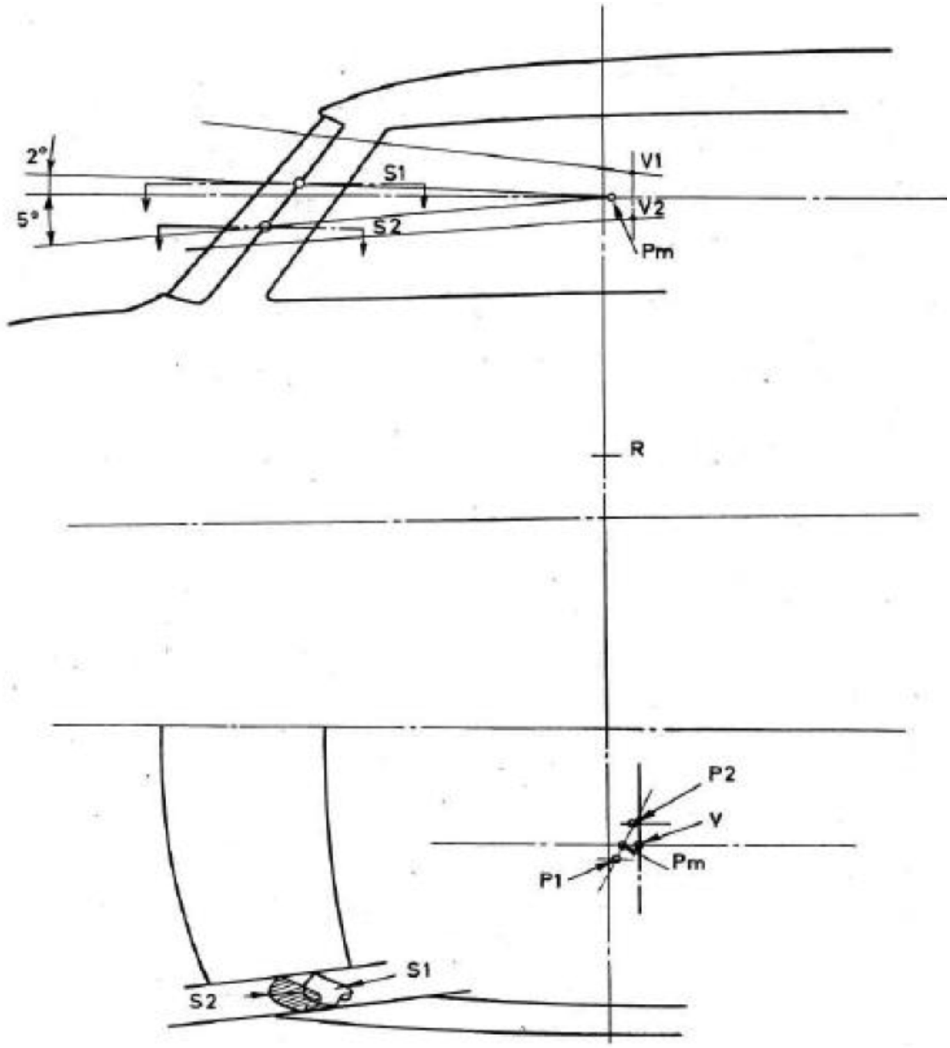

Figure 7: Observation points of the A-pillars.

There are no requirements in the US federal standards for A-pillar obscuration.

3.1.3 FORWARD DIRECT FIELD OF VISION

Driver 180^o vision

In short, UN Regulation 125 requires that with other than obstructions created by the A-pillars, the fixed or movable vent or side window division bars, outside radio aerials, rear view mirrors and windscreen wipers and certain other specific exceptions for small obstructions such as the steering wheel, there should be no obstruction in the driver's 180^o forward direct vision below a horizontal plane passing through V_1 and above three angled planes passing through V_2, one being perpendicular to the plane X-Z and declining forward 4^o below the horizontal and the other two being perpendicular to the plane Y-Z and declining 4^o before the horizontal (Figure 8).

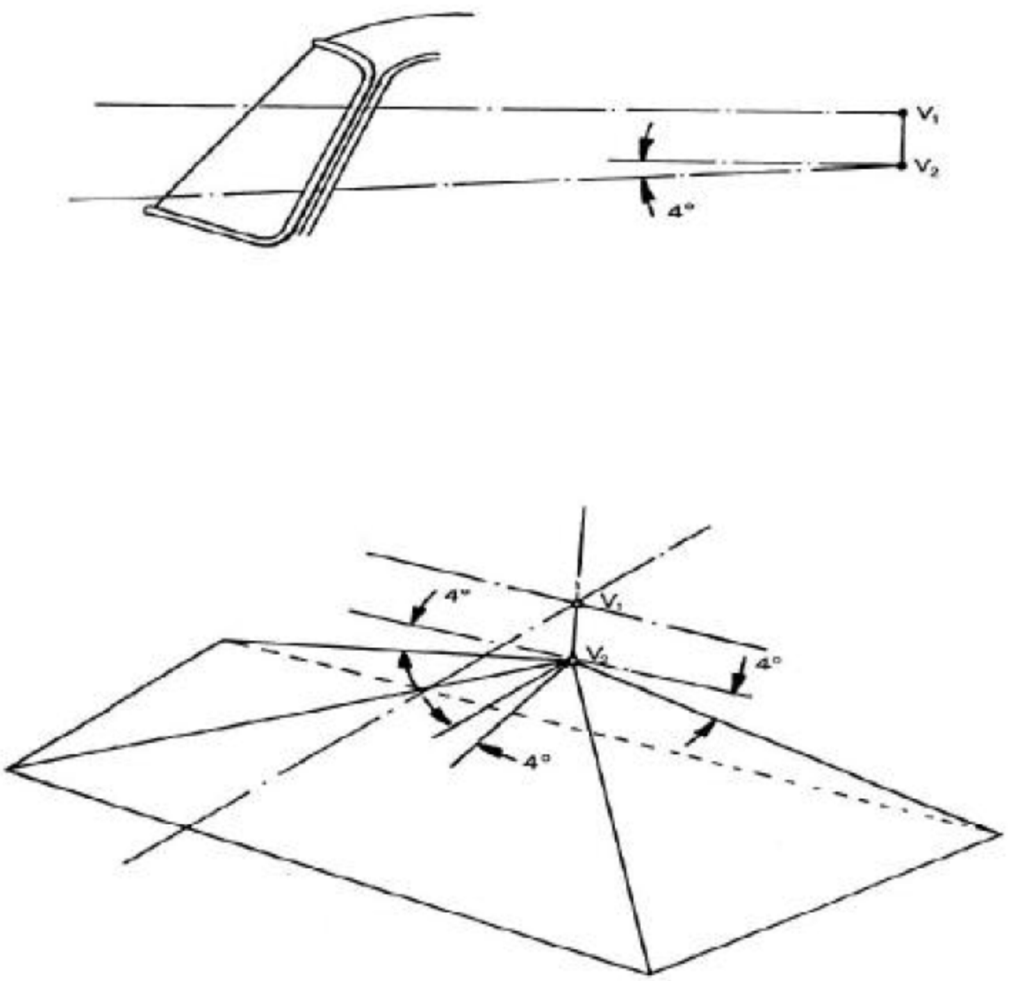

Figure 8: Evaluation of obstructions in the 180^o forward direct field of vision of the driver.

Obscuration of short objects

In short, UN Regulation 125 requires that in vehicles in which the V_2 point exceeds 1650 mm above the ground (i.e. R point > 1061 mm high for seat-back angle of 25 degrees) it should be possible to see part of a 1200 mm high cylindrical object placed 2000 mm in front of the vehicle when viewed directly from V_2.

There are no requirements in the US federal standards for forward direct field of vision, either for driver 180^o vision or for obscuration of short objects.

3.1.4 SUMMARY OF NOTABLE DIFFERENCES

Notable differences are:

- A-pillar obscuration

- Regulation 125 specifies requirements in terms of angles (obscuration must not exceed 6°) whereas there are no requirements for the US.

- Forward direct field of vision

  - Regulation 125 specifies requirements in terms of obstructions allowed in the driver's 180° forward direct vision whereas there are no requirements in the US federal standards. In particular, only limited obstructions (steering wheel, radio aerials, A –pillars, etc) are allowed above planes angled down at 4^o down from the lower V point.

  - Regulation 125 specifies requirements for vehicles where the driver has a high seating position that it should be possible to see short objects (1.2 m) close to the front of the vehicle (2.0 m). There are no requirements in the US federal standards.

- Transparent area

  - Regulation 125 specifies that the transparent area must contain the following datum points:

    - A horizontal datum point forward of V1 and 17° to the left.

    - An upper vertical datum point forward of V1 and 7° above the horizontal

    - A lower datum point forward of V2 and 5° below the horizontal.

  - There is no direct equivalent to Regulation 125 in the US legislation. However, FMVSS 104 defines an area A which the windshield wiping system should clear 80% of. This area is similar to that defined by Regulation 125 in terms of sight lines. However, other factors such as the origin points and area definition are not. Therefore, it is not possible to determine, in general, whether or not the requirements are similar in terms of the windscreen transparent area.

In summary, for forward direct vision for the EU there are requirements to limit A-pillar obscuration and other obstructions rear of the A-pillar in the driver's 180^o forward direct vision whereas for the US there are no requirements. For the windscreen transparent area, there are specific requirements for the EU, whereas there are no specific requirements for the US, although the windshield wiping requirements may effectively control the area to some extent.

It should also be noted that in the EU, Regulation 43 requires that the light transmittance for glazing for driver forward vision should be equal or greater than 70%, whereas for the US FMVSS 205 (ANSI/SAE Z 26.1-1996) requires that the windshield light transmittance should be equal or greater than 70%, but the requirements for left and right windows adjacent to driver are state dependent for passenger cars, e.g. Washington state light transmission > 24%, reflectance ≤ 35% provided two exterior rear-view mirrors fitted. So there is a large difference between Europe and the US for the light transmission of side windows within the driver 180^o forward vision. However, since this is state dependent, it is assumed that this is mainly an 'after-market' issue, i.e. US only vehicles are supplied by the OEMs with front side windows with a light transmittance ≥ 70% and are tinted by non-OEMs following this. Therefore, this should not be an issue in the context of this Test Case.

3.1.5 DISCUSSION OF REAL-WORLD IMPLICATIONS

It is widely acknowledged that drivers receive most of the sensory information necessary for the driving task through visual means. Inadequate visibility or obstructions affecting the vision of the driver have the potential to increase the accident risk, both for the driver of the vehicle and for any interacting road users. One of the main problems associated with the forward field of view from passenger cars is the obstruction caused by the 'A'-pillars (Leening, 1988; King, 1998; Clark, 1996). However, virtually all forward vision extending through 180^{o} is needed when a driver pulls out from a T-junction, i.e. minor road onto a major road. Indeed, this scenario puts the most stringent demands on the forward field of vision lateral visibility and as might be expected many accidents occur in this scenario. In 1991 in GB, accidents at major/minor priority junctions accounted for around one third of the total number of road accidents (Chinn et al 2002). More recent work showed that accidents that potentially involved A-pillar obscuration as a contributory factor were significantly more likely to occur at T-junctions and more likely to involve car drivers failing to see vulnerable road users (motorcyclists, pedal cyclists and pedestrians) (Millington et al.) However, while the work highlighted A-pillar obscuration could be a contributory factor for a number of these accidents other factors such as observational failures on the part of the driver or environmental factors could also have contributed.

Wade and Hammond (2002) have investigated the relationship between the size of the forward looking blind-spot (FLB) produced by vehicles' A-pillar (windshield frame), the speeds of two vehicles approaching an intersection at right angles, and driver behaviour relative to a likely accident event using a simulator. They found that the collision rate decreased significantly if the scanning rate of the driver became active with movement of the head (inactive eye movement only). Only problem was that not many drivers engaged in active scanning, possibly because the rural environment simulated was bland and did not encourage it. However, if this is representative of the real world and generally drivers do not actively scan, then it emphasizes the importance of A-pillar obscuration.

More recently (Reed 2008) investigated the effect of A-pillar geometry on detection of pedestrians in turn manoeuvres. The analysis showed that A-pillars that are closer to the forward line of sight result in high-obscuration regions that are closer to the vehicle travel path. Pedestrians in these regions would be at risk of remaining undetected by a driver. However, this analysis did not consider the possibility that A-pillar geometry might affect turning trajectories or that drivers often tend to move their heads from side to side to view the area behind the pillar.

For this analysis a statistical analysis of vehicle A-pillar geometry was used to develop a set of "boundary vehicles" representing extreme combinations of two variables previously shown to be associated with crash risk (Sivak et al. 2006): the angle of the inside edge of the driver-side A-pillar with respect to forward and the angular width of the A-pillar, both measured in plan view with respect to the centroid of the J941 cyclopean eyellipse. A set of four vehicles was constructed using 5th- and 95th-percentile values of the two variables, which were respectively 21.5 and 29.8 degrees for the angle of the pillar with respect to forward and 9.0 and 13.0 degrees for the angular width. It should be noted that these angular width measurements cannot be compared directly with the Regulation 125 requirement (obscuration angle shall not exceed 6 degrees) because of the different measurement processes both in terms of the eyepoint and the method to determine angular width. However, the results do show the large variation in A-pillar angular width that is present in the vehicle fleet (cars, minivans, SUVs and light trucks) in the USA.

There is a considerable volume of research on the transmission of light through windscreens and its effect on driver perception. All of the material agrees that tinted and/or dirty windscreens reduce the transmission of light and that this has a negative effect on the driver's visual perception, particularly for older or colour deficient drivers. There are no accident statistics directly linking the tinting of windscreens to accidents. However, an Australian study (Clark, 1996b) showed that the number of accident claims from a large insurance company fell over a number of years until the regulations regarding tinted windscreens were relaxed in 1991. There was then a steady increase until 1995 and newer cars (more likely to have tinted screens) were statistically over-represented in the data. Further problems can arise if the tinting is spectrally selective, particularly the effect on the visibility of coloured signals

From the above it is clear that the driver's 180^{o} forward direct vision is important and that obstructions within it, such as A-pillars, have a significant effect on accident risk, in particular for emerging from T-junctions and turning manoeuvres. It is clear that limiting these obstructions is a positive step for reducing the accident risk. However, quantification of the change in risk with different sizes of obstruction is not easily possible because a driver's behaviour can adapt to compensate to some extent.

Also, it is not known what proportion of US cars would not meet the European Regulation 125 requirements although it is known that many 'world' cars do. Some may not because interior A-pillar trim may be changed (increasing the overall size of the A-pillar) for the US market to comply with FMVSS 201 free motion headform prescriptions. Meeting Regulation 125 requirements for A-pillars for world cars is achieved in spite of the roof strength (FMVSS 216a) and interior impact (FMVSS 201) standards which require stronger A-pillars and protection (padding) for head impact, respectively, both of which tend to increase the size of the A-pillar.

It should also be noted that Regulation 125 has requirements for forward direct vision, in particular for vision for short objects in front of the vehicle. These requirements comprise two parts, firstly that only limited obstructions are allowed above a plane angled down at 4^{o} down from the lower V point and secondly that for vehicles in which the seating position is high, it must be possible to see short objects close to the front of the vehicle. There are no equivalent requirements in the US.

The real-world implications of this is that vehicles may be allowed in the US which have obstructions, such as the bonnet (hood), which would prevent seeing short objects close to the front of the vehicle, even though the windscreen transparent area may be sufficient. This could have a significant effect on pedestrian accidents, in particular short pedestrians, i.e. children.

With this lack of information, it is not possible to estimate the effect of allowing the use of US compliant cars on European roads as far as direct vision is concerned. However, it is likely that there could be some detrimental effect for US compliant vehicles on European roads because some of them may have more obscuration of the driver's forward vision, in particular for the A-pillar and the ability to see short objects close to the front of the vehicle. It is interesting to note that, as mentioned above, tinting of front side windows is allowed in the US in certain states. This, assuming Clarke's conclusions for tinted windscreens also apply to side windows, is likely to have a detrimental effect on accident risk. However, since it is permitted in US, it is assumed that the detrimental effect cannot be that large, although this is somewhat surprising.

3.2 SAFETY GLAZING MATERIALS AND THEIR INSTALLATION

This section compares EU regulations and US standards for safety glazing and their installation. The legislative requirements are: for the EU: UN Regulation 43 ‘Glazing materials and their installation on vehicles’ and for the US FMVSS 205 ‘Glazing materials’ and FMVSS 212 ‘Windshield mounting’. There is also a Global Technical Regulation (GTR) for ‘Safety glazing materials’, namely GTR No 6, established in the global registry in March 2008. It should be noted that this GTR is limited to glass safety glazing (i.e. excluding other materials such as plastics).

A UN Global Technical Regulation is not a legal document. However, a contracting party to the 1998 Agreement that voted in favour of establishing a global technical regulation is obliged to begin the process of transposing the global requirements into their local legislation. It should be noted notification that GTR No 6 was transposed into the European legislation (i.e. UN Regulation 43) was received February 2013. However, transposition into US legislation (FMVSS205) is still ongoing. A Notice for Proposed Rulemaking (NPRM) has been issued but NHTSA are still evaluating comments submitted, according to the latest status report submitted to WP.29.

As part of the process to develop GTR No 6, the similarities and differences in requirements between UN Regulation 43 and FMVSS 205 (and also the Japanese regulation) were identified for the following items:

- Application
- Note that the GTR specifies requirements for glazing as an item of motor vehicle equipment and not for the vehicle.
- Mechanical properties
- Optical, properties
- Atmospheric resistance

For the differences found, resolutions were agreed and included in GTR No 6. The reasons for the decisions made are described in the GTR. These included:

- Optical: Light transmittance level for forward field of vision glazing.

  Prior to the GTR, UN Regulation 43 required a glazing light transmittance minimum level of 75%, whereas US FMVSS 205 required 70%. The lower limit (i.e. 70%) was chosen, because laboratory test studies and vehicle accident data (Cook et al. 20001) do not show any influence on safety with a lower limit. Note for the laboratory test studies Cook et al. actually concluded that, ‘This work has

[1] Cook S, Quigley C, Tait R. PPAD 9/33/39: Quality and field of vision – a review of the needs of drivers and riders – Final report. Dec 2000. Accessed: https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/522/1/TT1130%20AR2172.pdf. Retrieved Dec 2014.

not found there to be a significant reduction in the ability to detect pedestrians at night until visor/windscreen transmissions fall below around 27%' and recommended that further objective, and potentially real-world, trials should be performed to validate the results.

- Mechanical properties:

  The purpose of the 2.26 kg steel ball test is to assess the penetration resistance of laminated glazing materials used for windscreens to impact from a heavy object. FMVSS 205 required a resistance to penetration from 3.66 m drop height while UN Regulation 43 required performance from 4.0 m. Many windscreens produced in the US. are dual certified for both the 3.66 m and the 4.0 m performance levels already. Therefore the higher height of 4.0 m was selected for inclusion in the GTR.

Table 46 shows a comparison of current legislative requirements in Europe (UN Regulation 43), the USA (FMVSS 205) and Global Technical Regulation No. 6. The current differences between FMVSS 205 and GTR 6 are also highlighted because GTR No 6 is not transposed into US legislation yet. However, these differences will be resolved once the transposition process, which is currently ongoing, is complete.

Furthermore, it should be noted that the current version of GTR did not resolve the differences for the following items and thus they remain:

- Markings

  Markings generally fall into the following three categories:

  (i) The type of material the glazing is constructed from;
  (ii) The manufacturer of the glazing; and
  (iii) The regulation(s) the glazing is manufactured to comply with.

  The GTR specifies marking requirements for the first category only, generally based on the approach used in UN Regulation 43. However, markings for this category only form a small proportion of the markings required in total. Also, because the US marking system is different, it still requires, in FMVSS 205 (which refers to ANSI/SAE Z 26.1-1996), American national Standard (AS) markings for what is effectively the type of material the glazing is constructed from, i.e. where it can be used in a motor vehicle in terms of the tests that it complies with, e.g. laminated tests, tempered tests, etc.

- Glazing installation

Table 18: Comparison of glazing installation requirements for USA and EU

Item	USA	Europe
Windshield retention	FMVSS 212 In 48 km/h full-width crash test, for vehicles equipped with passive restraints, not less than 50% of the portion of the windshield periphery on each side of the longitudinal centreline shall be retained, for vehicles not equipped with passive restraints not less than 75%	No test, but general requirement to remain in position under normal operating conditions
Glazing for Driver forward vision	FMVSS 205 (ANSI/SAE Z 26.1-1996) Windshield light transmittance not less than 70%, i.e. ≥ 70% Left and right windows adjacent to driver, state dependent for passenger cars, e.g. Washington state light transmission > 24%, reflectance ≤ 35%provided two exterior rear-view mirrors fitted.	Reg 43 Light transmittance ≥ 70%
Glazing for Driver rearward vision	State dependent, as for left and right windows above.	Reg 43 Light transmittance ≥ 70% unless two exterior rear-view mirrors fitted. Please note that two exterior mirrors are mandatory for passenger cars in the EU, thus the light transmittance may always be < 70%

3.2.1 Notable differences and discussion of real-world implications

In summary, once the USA has transposed GTR No 6 into their legislation, the legislative requirements for safety glazing materials and their installation will be similar with the following exceptions:

- Markings with regard to the manufacturer of the glazing and the regulation(s) the glazing is manufactured to comply with.

- This may cause some problems when replacement glazing needs to be fitted for the purposes of repair. However, it is believed that this should not cause a major safety issue as long as all marking data is readily accessible to fitters.

- The requirement for windshield retention in a 48 km/h full-width crash test in the USA (FMVSS 212), which is not required in Europe.

    - With typical bonded windshields fitted to passenger cars nowadays, it is not believed that a vehicle would fail to meet this requirement. No compliance failures with recent vehicles could be found in the literature. Crash tests carried out by TRL on vehicles that have recently undergone windscreen replacement confirm that the performance of modern windscreen bonding systems exceed the strength requirement to comply with FMVSS 212 at one hour after replacement. This supports the view that fully cured windscreen bonds have strength considerably greater than that required by FMVSS 212.

- The requirements for light transmission for side glazing are different, with Europe requiring a transmittance greater than 70% for driver forward vision, i.e. left and right windows adjacent to driver, and a transmittance of greater than 70% for glazing for driver rearward vision unless two exterior rear-view mirrors are fitted, whereas the US requirements vary from state to state and are often lower than for Europe.

    - Since the US requirements are state dependent, it is assumed that this is mainly an ‘aftermarket’ issue, i.e. US only vehicles are supplied by the OEMs with front side windows with a light transmittance > 70% and are subsequently tinted by non-OEMs. Therefore, this should not be an issue in the context of this Test Case.

3.3 WINDSCREEN WIPER AND WASHER SYSTEMS

Fitment of windscreen wiper and washer systems is mandatory both in Europe (EU 1008/2010) and the US (FMVSS 104). A detailed comparison of the legislative requirements can be found in Annex 2, Table 47.

3.3.1 NOTABLE DIFFERENCES

The main notable difference between the legislative requirements is the difference in the swept test area requirements. These are difficult to compare directly because of different definitions used for the driver eye point as explained previously in Section 3.1.1. However, it is known that wiped area required for the US is larger than that for Europe, because of the modifications that had to be made to the Fiat 500 from its ‘European’ specification for export to the US, namely increasing the length of the wiper blades in order to meet FMVSS 104 requirements[2]. The US legislation also includes an additional mid-sized test area which the European legislation does not.

[2] New York times article: How a European Fiat had to change before it could immigrate, http://www.nytimes.com/2011/03/27/automobiles/27LIST.html?_r=1&

The other notable differences are:

- For Europe, a test for operation at high vehicle speed and a test at low temperature, with no equivalent tests for the USA.

- For the US, durability tests for both wiper and washer systems, with no equivalent tests for Europe.

3.3.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

Rain reduces driver perception in several ways and is especially debilitating at night. It both directly affects perception (seeing through rain) and also produces visibility changes through its action on headlamps, windscreens, the road and road markings. Drivers normally see an object when light from a source, for example the sun, street lamps, headlights, is reflected from the object back to the eye; rain interferes with this process.

Rain also affects ability to see through the car windscreen; even with windscreen wipers operating, the splashing of rain and the windscreen wipers themselves block vision periodically. The rain acts like a lens, which scatters lights and distorts the visual scene image. The clutter and movement caused by the raindrops falling on the windscreen further draw attention and masks objects on the road. Wipers are never 100% efficient and typically leave a smear of water across the windscreen. More importantly, wipers only sweep part of the visual field clean of rain. Therefore the size of the swept area affects accident risk, the larger the swept area the lower the risk.

In 1999 NHTSA[3] denied a petition for rulemaking submitted jointly by the AAMA[4] and AIAM[5] to amend FMVSS 104 (windshield wiping and washing systems) to accept a European Union (EU) Directive as an optional ‘functionally equivalent’ alternative. The reason for this denial was that when detailed comparisons were made on specific vehicles, it was found that the European test zone was smaller than the corresponding US zone. On average, the test zone representing the critical area in front of the driver generated by the European method was stated to be only 81.3 percent as large as the corresponding area generated by the US method. The larger European test zone representing the bulk of the windshield was stated to average 88.3 percent of the area of the corresponding US test zone. Because no evidence to rebut the obvious presumption that sizable reductions in cleared area would reduce visibility and provide less safety, the petition was denied. The petition also included a proposal to amend FMVSS 103 (windshield defrosting and defogging systems) in a similar manner. Noting that the test zones for the wiping and washing systems and defrosting and defogging systems are the same for the respective legislations, this petition was also denied on the same basis, i.e. the reduction in cleared area would reduce visibility and provide less safety, however, NHTSA stated that it believed that harmonization of windshield wiping / washing and defrosting / defogging regulations is possible using worldwide best practices.

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[3] Federal Register, Vol. 64, No 74 / Monday April 19 1999/Proposed Rules, page 19106

[4] American Automobile Manufacturers Association (AAMA)

[5] Association of International Automobile Manufacturers (AIAM)

Concerning the stated percentages of 81.3 percent of the ‘critical’ windscreen and 88.3 percent of ‘entire’ windscreen areas of EU vs US zones, and specifically in view of the information contained in Section 3.1.1., the opportunity may be taken to re-evaluate the situation, as there is reason to believe that EU zones extend further towards the left and right side, which may have safety benefits over only an increased upward resulting from the FMVSS approach.

Two problems to which vehicle windscreen wipers are inevitably subject are wind lift and blade chatter. Wind lift is caused by the exposure of blade support structures to higher speed air streams at higher vehicle speeds, which can catch and lift the blade away from the windscreen. This phenomenon becomes worse as windscreens become more raked or slanted. In the absence of an anti-lift air foil or some other external wipe force adjustment mechanism, stronger wiper arm springs are necessary to pull the wiper blade more strongly against the glass. Wiper chatter is caused by friction between the blade and the glass as the blade is swept across the windscreen surface. Being rubber, the blade is somewhat tacky, and tends to stick to the surface, and is also elastic, tending to stretch as it sticks. When it has stretched enough to overcome the coefficient of friction the blade can slip and actually bounce or hop up slightly relative to the windshield, before the stick-slip cycle begins again. Because of these two problems, the design of wiper systems that perform well at low and high vehicle speeds is not straight- forward because of competing requirements; namely too much downforce leads to chatter and not enough leads to lift at high speed. There are many patents for wiper systems for schemes which use air-foils to optimise these competing requirements.

The European legislation requires a test for wiper operation at high vehicle speed and a test at low temperature. There are no equivalent tests for the USA. Hypothetically, this could allow the fitment of wiper systems in the US that do not operate well at high vehicle speeds and / or low temperatures. However, no evidence could be found in the literature that this occurs. This could possibly be because consumer market pressure helps to prevent it.

The US legislation requires durability tests whereas the EU legislation does not. Hypothetically, this could allow fitment of wiper systems in Europe that wear out quicker than the ones fitted in the USA. However, no evidence could be found in the literature that this occurs. Again, this could possibly be because consumer market pressure helps to prevent it.

In summary, the main notable difference between the between the EU and US legislation for windshield wipers and washers is the larger swept area required for the US. Possibly, this could cause a reduction in safety for European legislation compliant only cars on US roads. However, no information could be found in the literature to quantify the size of any possible safety reduction, although the obvious presumption is that there would be some. The other notable differences are the tests at high vehicle speed and low temperature in Europe with no equivalent in the USA and in contrast durability tests in the USA with no equivalent in the EU. Hypothetically, these differences could also cause problems, such as the fitment of wiper systems on US only compliant vehicles which do not perform well at high speeds. However, no evidence could be found in the literature that these types of problems occur, which could possibly be because consumer market pressure helps to prevent them.

It is interesting to note that in April 1996, NHTSA issued a Notice for Proposed Rule Making (NPRM) which contained an option that FMVSS 104 should be rescinded (dropped)[6]. This implies that the safety issues related to the detailed implementation of FMVSS 104 are probably not particularly important. It was decided not to rescind (drop) it on the basis that it did not impose any unnecessary regulatory burden. However, in 1999 NHTSA denied a petition to accept European regulations as an optional 'functionally equivalent' alternative to FMVSS 104 because of the difference in test areas and possible safety implications.

3.4 WINDSCREEN DEFROSTING AND DEMISTING (*DEFOGGING*) SYSTEMS

Fitment of windscreen defrosting and demisting (defogging) systems is mandatory both in Europe (EU 672/2010) and the US (FMVSS 103) apart for vehicles for sale in the non-continental US, i.e. Hawaii, where only a defogging system is mandated. A detailed comparison of the legislative requirements can be found in Annex 2, Table 48.

3.4.1 NOTABLE DIFFERENCES

As for windshield wiper and washer systems, the main notable difference between the legislative requirements is the difference in the test area requirements. The test areas required for the US are larger than those for the EU. The large and small areas used for the respective jurisdictions, are the same as those used for wiper and washer systems.

The other notable difference is for the demisting (defogging) system. The EU legislation specifies performance requirements and test conditions, whereas the US does not specify any.

3.4.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

Defrosting systems operate by applying heat to the windscreen (windshield) by blowing hot air onto it. Optionally, some vehicles supplement this by also heating the windscreen electrically using fine wires embedded in it.

Regarding the real-world implications of the difference test areas for European and US legislation, although no directly related literature could be found, it is believed that they are negligible, if any. This is because defrosting systems blow hot air onto the windscreen through vents. The area of windscreen that the hot air interacts with is controlled, to a large extent, by the position and size of the vents. However, the area cleared is not critically dependent on the position and size of these vents as the area cleared by wipers is on the wiper blade length. Therefore, it is considered that the performance of defrosting / demisting systems fitted to European and US vehicles will not be influenced greatly by the differences in the test areas between the legislations. This belief is supported by the observation that modifications to the defrosting and defogging system are not mentioned in the list of modifications made to the European version of the Fiat 500 to enable it to be exported to the US[7], whereas changing the length of the wiper blades is.

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[6] http://www.gpo.gov/fdsys/pkg/FR-1996-04-08/pdf/96-8648.pdf

[7] New York times article: How a European Fiat had to change before it could immigrate, http://www.nytimes.com/2011/03/27/automobiles/27LIST.html?_r=1&

Demisting (defogging) systems operate by blowing hot air onto the windscreen. Optionally, some vehicles also use air conditioning to dehumidify the air and help demist (defog) the windshield. On this basis, it is presumed that the US legislation effectively assumes that if the defrosting and defogging system meets the defrosting requirements then it is adequate for defogging.

Regarding that EU legislation specifies performance requirements for the demisting (defogging) system whereas the US does not, it is believed that the real-world implications, in general, should not be that large if the system meets the defrosting requirements. However, there may be some increased risk of inadequate performance for specific US only compliant cars. Furthermore, it is likely that the presence or not of an air conditioning (A/C) system to cool and dehumidify the air before it is heated and blown onto the windscreen will have a large influence on the performance of the demisting (defogging) system. A/C is not regulated in either the EU or US, although it is fitted to a large proportion of vehicles.

4. Comparison of EU regulations and US standards for indirect vision

Indirect vision or visibility is a term used to describe areas around the vehicle that cannot be observed by direct vision, but can be seen using conventional mirrors, camera-monitors, or other devices which improve the field of view afforded to the driver.

This section compares EU regulations and US standards for indirect visibility, namely UN Regulation 46 ‘Uniform provisions concerning the approval of devices for indirect vision and of motor vehicles with regard to the installation of these devices’; and FMVSS 111 ‘Rear view mirrors’ for the US.

Both regions specify the indirect visibility that must be provided by interior and exterior mirrors and FMVSS 111 also includes mandatory standards for improving driver visibility while reversing. Table 19 summarises the applicability and functional requirements of UN Regulation 46 and FMVSS 111.

Table 19: Applicability and functional intent of EU and US indirect visibility requirements (R46: UN Regulation No. 46; 48 CFR Part 571.111: FMVSS 111)

EU (UN Regulations)		**US (FMVSS Standards)**	
Indirect visibility [Applicability]	Functional Intent	Indirect visibility [Applicability]	Functional Intent
Class II and III: Main exterior rear-view mirror [Mandatory]	..., which can be mounted on the external surface of a vehicle (UN R46, 2.1.1.2.) ... the driver can see … behind the driver’s ocular points (UN R46, 15.2.4.2. and 15.2.4.3.)	Outside rear-view mirror-driver’s side [Mandatory]	provide a view of a level road surface extending to the horizon … behind the driver’s eyes (49 CFR 571.111, S5.2)
		Outside rear-view mirror—passenger’s side [Optional]	Each passenger car whose inside rear-view mirror does not meet the field of view requirements of S5.1.1 [inside rear-view mirror] shall have an outside mirror … installed on the passenger’s side (49 CFR 571.111, S5.3)
Class I: Interior rear-view mirror	..., which can be fitted in the passenger compartment of a vehicle (UN R46, 2.1.1.1.) ... the driver can see … behind the driver’s ocular points (UN R46, 15.2.4.2.	Inside rear-view mirror	...provide a field of view ... to provide a view of a level road surface extending to the horizon… (49 CFR 571.111, S5.1)

EU (UN Regulations)		US (FMVSS Standards)	
[Mandatory]	and 15.2.4.3.)	[Mandatory]	
No equivalent EU Regulation		Rear visibility systems [Mandatory]	Requirements for rear visibility devices and systems (49 CFR Part 571.111)

In Europe, mirrors are classified in UN Regulation 46, Rev 5, Amendment 3, by the following classes:

- Class I: Interior rear-view mirror
- Classes II and III: Main exterior rear-view mirror [i.e. door or wing mirrors]
- Class IV: Wide-angle exterior mirror
- Class V: Close-proximity exterior mirror
- Class VI: Front mirror
- Class VII: Mirrors intended for L category vehicles with bodywork

Paragraph 15.2.1.1.1 of Regulation 46 states that for M1 vehicles, Class I and III are mandatory, while Class II can be used as alternative to Class III. Class IV, V and VII are optional for M1 vehicles and the latter two must be placed at least 2m above the ground. In any case, exterior mirrors other than Class III (and rarely Class II) are unlikely to be fitted to M1 vehicles and thus not found on the EU market. The indirect visibility afforded by the other classes of mirror can be alternatively supplied by camera systems, but these requirements have not been reviewed here because they relate to optional and rarely fitted systems on passenger cars. There is also no equivalent option in US regulation.

Under the US legislation, mirrors on passenger cars (light duty vehicles up to Gross Vehicle Weight of 8,500 lb or 3,855 kg), must meet specified criteria for the interior and exterior mirrors and there are differing requirements for the driver and passenger side.

4.1 Exterior rear-view mirrors

4.1.1 Notable Differences

The following sections describe the most notable and potentially influential differences with regards to real world performance. An in-depth ‘side-by-side’ comparison of the legislative requirements is provided in Annex 3 (Table 50 and Table 51).

In summary, the legislative requirements for exterior rear-view mirrors in the EU and US can be grouped as those elements which are similar and those which differ. For example, in the EU and US rear–view exterior mirrors share the same coefficient of reflectivity for night modes and the upper range of mirrors both extend to the horizon. However, the extents of the field of view are defined differently in each region. Further, vibration requirements, impact testing, minimisation, mirror markings, and the coefficient of reflectance (for day mode) are not harmonised. Moreover, the US legislation permits vehicles without passenger side exterior mirrors if the required view is afforded by the interior mirror.

4.1.1.1 FIELD OF VIEW

There are notable differences between the US and EU legislation with regards to the field of view requirements, including differing:

- areas to view;
- driver eye point position; and
- vehicle configuration for the test.

In addition, under the US legislation, the mirrors on passenger cars have different requirements for the driver and passenger sides, while for the EU they are the same. However, within the EU there are two different mirror configurations which can be used on the vehicle; Class III is mandatory, while Class II can be used instead as an option.

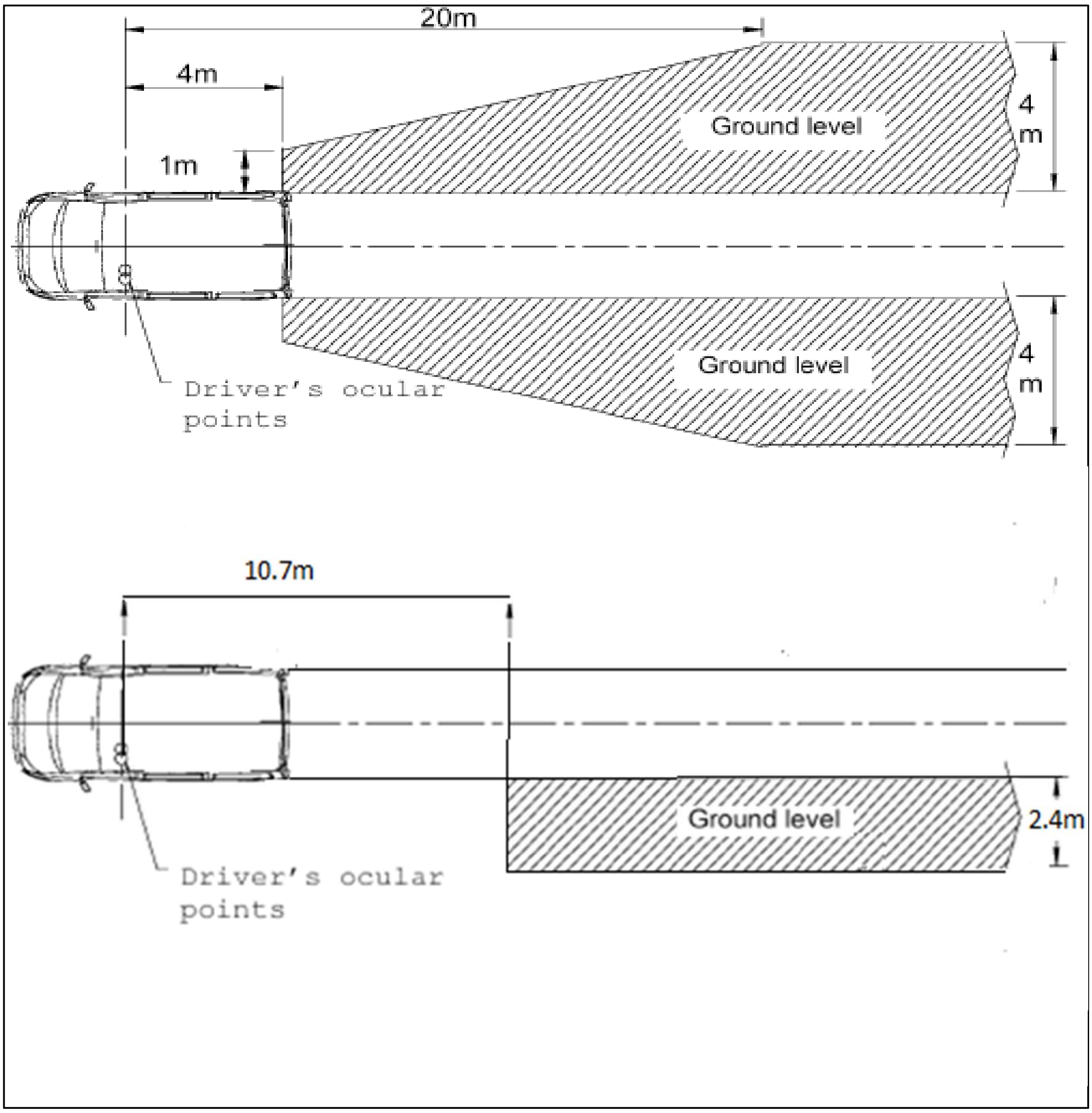

Figure 9: External mirror fields of view. Top; UN Regulation 46 Class III (Mandatory), bottom, US FMVSS 111 Driver side mirror

The mandatory EU Class III mirror requirements describe a portion of the road starting 4 metres behind the driver's ocular points, which extends out perpendicularly by 1 metre and then widens to a width of 4m which then continues back to the horizon from 20m behind the vehicle (Figure 9). The optional Class II mirror describes a portion of the road starting 4 metres behind the driver's ocular points, which extends out perpendicularly by 1 metre and then widens to a width of 5m which then continues back to the horizon from 30m behind the vehicle.

For the driver side mirror, the US legislation states that the ground must be visible from 10.7 m (35 feet) rearward of the driver's ocular points, and is 2.4m wide perpendicular to the vehicle's longitudinal plane.

The US requirements for the external passenger side mirror are dependent on the capability of the internal mirror. If any required view (see requirements for interior mirror) is not provided by the internal mirror, which is commonly the case, the vehicle must be fitted with a passenger side external mirror, and this mirror must provide the missing portion of the field of view.

The driver's ocular points in UN Regulation 46 are defined in reference to the vehicle's R point, while the US legislation refers to FMVSS 104 (§ 571.104), which in turn refers to SAE J941 and SAE J826. These standards define the eye position based on eye ellipses of 90th, 95th, and 99th percentile drivers. This means that the eye positions for the two tests are different.

In the US the vehicle is loaded with four passengers at test (each 68kg), while the EU specifies that the vehicle should be in running order as defined by the consolidated Resolution on the Construction of vehicles (R.E.3) (ECE/TRANS/WP.29/78/Rev.2, para. 2.2.5.4.), including two front occupants (75kg). These differing vehicle loading conditions may also affect the indirect field of view.

Figure 10 shows the minimum requirement for indirect visibility from the interior and exterior mirrors in the EU and US.

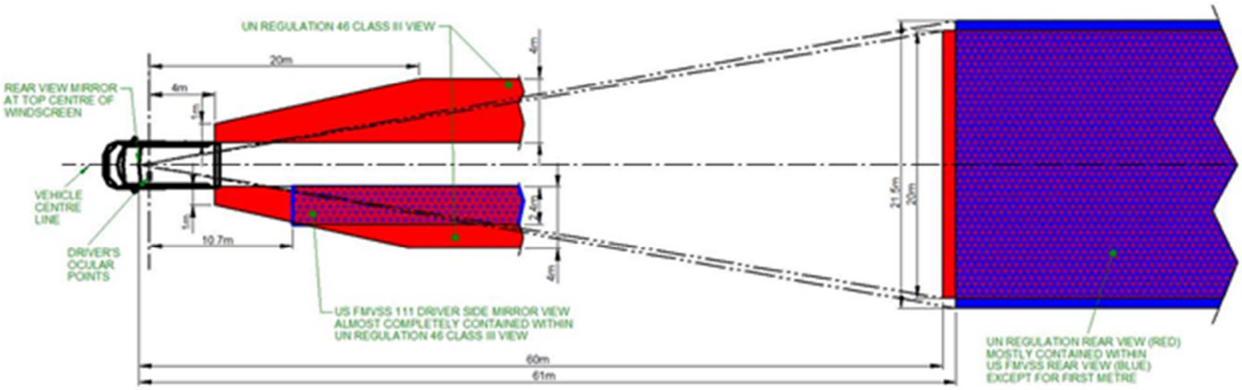

Figure 10: Mandatory minimum indirect visibility requirements in EU and US

As an example of the possible indirect field of view that might be realised by a driver in the EU and US, Figure 11 compares visible areas for interior and exterior mirrors. The smaller visible area provided by the planar driver’s side mirror is demonstrated in this diagram. Note that the limits for the radius of curvature of the spherical exterior mirrors differ in the US and EU: In the EU there is only a lower limit of 1200mm; in the US there is a lower limit of 889mm and an upper limit of 1651mm.

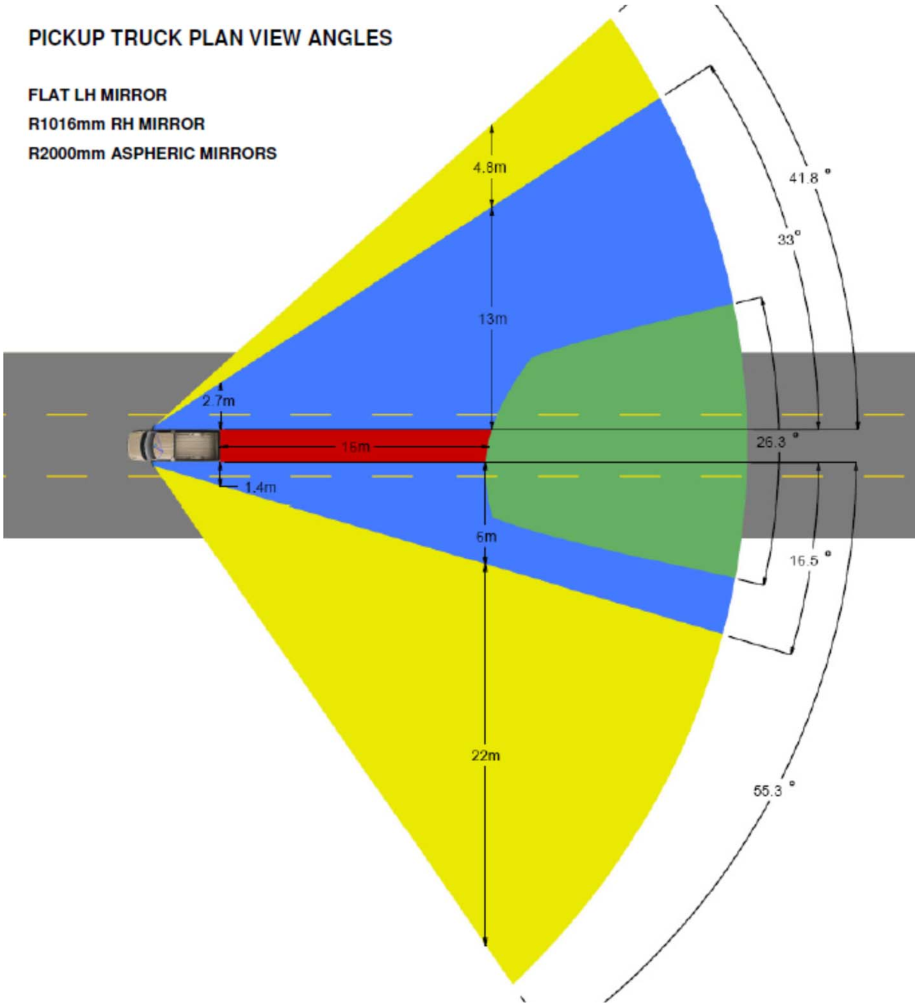

Figure 11: Comparison of US and UN side mirror fields of view (Magma mirrors, Magma electronics, 2009)

Key:

The various colours used illustrate where a typical driver might see rearward using

- Green area: The interior mirror;
- Blue areas: a combination of a flat driver-side and a 1,016 mm radius passenger-side exterior mirror;
- Yellow areas: a combination of an ECE R46 2,000 mm radius aspheric driver-side and an ECE R46 2,000 mm radius aspheric passenger-side exterior mirror
- Red area: The rear blindzone (below the rear window bottom edge). Note this area is now covered in FMVSS 111 by the requirements for rearview (backover) visibility.

4.1.1.2 MINIMISATION

The US legislation requires a flat mirror on the driver side, defined within the legislation as having Unit magnification "a reflective surface through which the angular height and width of the image of an object is equal to the angular height and width of the object when viewed directly", effectively prohibiting convex and aspheric mirrors from being installed on the driver side of a passenger car sold in the US. On the passenger side a flat or spherically curved convex mirror is permitted. The convex portion of the passenger side mirror must have an average radius of curvature between 889 and 1651 mm. The curvature is measured at 10 points within the spherically curved portion of the mirror; none of the readings can deviate by more than ± 12.5% from the average.

We assume that provided the mirror meets the requirements, an additional area on the mirror could be aspherical; however, this is not mentioned explicitly in the legislation and this is rather unclear. We are however aware that such feature is found on certain passenger car models in the US. For instance, at the introduction of its 2009 Edge model, Ford issued a press release on their claimed industry-first Blind Spot Mirror introduced in the US. The Blind Spot Mirror is a traditional side view mirror designed with a secondary convex spotter in the top outer corner (see also Figure 12) which provides a view of the driver’s blind spot. When traffic enters the driver’s blind spot on either side of the vehicle, it is visible in the secondary convex mirror, alerting the driver of potential danger.

Concerning the driver side, we wonder how this would be treated differently from a flat mirror with aspherical portion, believed to be not permitted, yet not contested on the US market.

UN Regulation 46 permits flat or spherically curved exterior mirror with a radius of curvature ≥ 1,200 mm; in practice spherical exterior mirrors are fitted. Moreover, an additional aspherical portion is permitted provided that the minimum requirement is met by the spherical portion of the mirror. The, transition of the reflecting surface from the spherical to the aspherical must be marked. The spherically curved portion shall be tested in three places with a spherometer, with limits defined both between each test point and relative to the arithmetic mean.

Therefore, the objects viewed in an EU exterior mirror will appear smaller when compared to a US flat mirror, but objects in a US convex mirror may appear smaller than those in a EU convex mirror (depending on the radius of curvature).

4.1.1.3 VIBRATION

US FMVSS 111 states for both driver and passenger side mirrors that the mounting shall provide a stable support for the mirror. The EU legislation (UN Regulation 46) states that it should not vibrate to a level which would cause the driver to misinterpret the nature of the image perceived. This qualitative assessment is required to be maintained for all speeds up to 80% of the vehicles maximum design speed, but not exceeding 150 km/h (93mph).

4.1.1.4 IMPACT TEST

UN Regulation 46 lays out the details of two impact tests, including the equipment specification and numerical values for gauging compliance. The impact test uses a rubber coated rigid sphere mounted on a pendulum of 1 m in length and reduced mass of 6.8 kg, dropped from an angle of 60° onto the mirror (including mounting and housing). Should the mounting of the mirror break during the tests, the part remaining must not project beyond the base by more than 10 mm, and the parts remaining attached that can be reached by a 165 mm diameter sphere must have a radius of curvature ≥ 2.5 mm. The reflecting surface shall not break during the tests, unless the fragments of glass still adhere to the back of the housing or to a surface firmly, with a maximum separation of 2.5 mm on either side of cracks, or the reflecting surface is made of safety glass.

The US FMVSS 111 states that the mirror and mounting shall be free of sharp points or edges that could contribute to pedestrian injury. What constitutes a sharp point or edge is not defined. No test is defined by the FMVSS or by the NHTSA laboratory test procedure (NHTSA, 1999).

4.1.1.5 MIRROR MARKINGS

The US legislation specifies that convex mirrors (which are permitted only for the external passenger side mirror) must be indelibly marked on the mirror surface with the phrase ‘‘Objects in Mirror Are Closer Than They Appear.’’

The EU legislation (UN Regulation 46) specifies that mirrors must have indelibly marked the trade name or mark of the manufacturer and E approval mark and number representing the country which has granted approval. This can be at any location on the mirror housing.

As mentioned, the EU legislation also specifies that if a manufacturer chooses to provide an additional aspherical portion on the mirror a line must mark the transition from the main regulated portion of the mirror.

4.1.1.6 COEFFICIENT OF REFLECTION

The US and EU requirements regarding the coefficients of reflection are very similar and they use the same terminology, very similar testing procedures, SAE J964-1984 and R46 Annex 6 respectively, and almost the same minimum limits. For the night setting, both define a minimum reflectivity of $\geq$ 4%. However, for the day setting, FMVSS 111 defines a 35% minimum, while UN Regulation 46 states a coefficient of reflectivity of 40%.

In addition, the US legislation specifies that the driver can control the night/day setting as well as failsafe requirements to return to the higher reflectance day mode in the event of electrical failure.

4.1.2 DISCUSSION OF REAL-WORLD IMPLICATIONS

4.1.2.1 FIELD OF VIEW AND MINIMISATION: REAL-WORLD IMPLICATIONS

In the US, cars are required to be fitted with a planar exterior mirror on the driver-side and a non-planar mirror on the passenger side. This is different to the EU, where cars are permitted to (and typically fitted with) non-planar mirrors on both sides.

Non-planar mirrors have not been adopted in the US due to concerns over whether the miniaturised image will negatively affect a driver’s ability to judge distances to other vehicles and their approach speed. However, they provide a much smaller field of view than non-planar mirrors and cause a relatively large blind spot which has been linked to be related to lane change crashes (de Vos, 2000). Several studies have been carried out to determine whether implementing non-planar mirrors on the driver’s side could be beneficial or detrimental.

Empirical investigations of the effects of mirror curvature have produced a strong consensus that convex mirrors cause overestimation of distance, but several factors can moderate or compensate for that effect. All quantitative studies of the effects of the radius of convex mirrors have demonstrated less overestimation of distance than predicted by the visual-angle model. Shorter-radius (more strongly curved) mirrors generally lead to greater overestimation of distance. Previous studies have examined the effects of mirror radius up to 2 m. There is strong evidence that 2 m mirrors still cause substantial overestimation, and little indication that reductions in overestimation have asymptoted at that radius (Flannagan *et al.*, 1997).

Luoma, Flannagan and Sivak used accident data to determine the effect of implementing non-planar driver-side mirrors on lane change crashes (Luoma, Flannagan and Sivak, 2000). Their findings support the use of non-planar driver side mirrors. The analysis was based on 1,062 crashes reported from 1987 to 1998 to Finnish insurance companies for vehicles with passenger-side spherical convex mirrors and one of three types of driver-side mirror (planar, spherical convex, or multiradius). The results showed that the mean effect of non-planar mirrors compared to planar mirrors was a statistically significant decrease of 22.9% in lane change crashes to the driver side. The non-planar mirrors were beneficial especially for the high risk driver groups, as well as for the lane change situations and environmental conditions in which most lane change crashes take place in the U.S.

A survey of European drivers found that drivers responded similarly for planar versus aspheric mirrors when asked of their ability to judge approach speed of vehicles using the mirror. Overall, the majority of drivers expressed a preference for a non-planar mirror on the driver's side of the vehicle. Drivers stated that they would choose an aspheric mirror if given the option (Rau *et al*., 2007). Some manufacturers in the US have started to voluntarily fit an FMVSS 111 compliant planar main viewing mirror with an integrated blind-spot viewing auxiliary wide-angle mirror. This delivers the extended field of view without the potential drawbacks of main mirror distance distortion/image minification that accompanies Regulation 46 aspheric mirrors (Lynam, 2009).

Figure 12: FMVSS 111 compliant planar main viewing mirror with a voluntarily fitted blind-spot viewing auxiliary wide-angle mirror (Lynam, 2009)

A study by Morgan and Blanco found that laboratory and stationary-driver testing have consistently shown that non-planar mirrors are associated with overestimations in distance and speed. However, there is less consistency in findings for on-road testing, as the magnitude and practical effect of overestimation varies. Likewise, lane-change crash rates in Europe do not appear to be affected by non-planar mirror use. The ability of drivers to detect and react to an object is aided by non-planar mirrors. This, and the interior planar rear-view mirror, may offset overestimation and the effect of smaller accepted gaps. Additional research is needed to determine the effect of non-planar rear-view mirrors on crash rates and driver acceptance, as well as the possibility of different configurations, of non-planar mirrors within the United States (Morgan and Blanco, 2010).

4.1.2.2 VIBRATION: REAL-WORLD IMPLICATIONS

EU regulations specify a test which must be conducted to ensure that vibrations do not change the field of view or cause a driver to misinterpret the nature of the image perceived. However, US regulations only specify that mountings should provide a stable support, although no definition of ‘stable’ is provided. Therefore it could be assumed that side mirrors conforming to EU regulations may be more stable and provide a better image quality at high speed. However, no accident data was found to support this theory.

OEMs who were consulted during the literature review stated that suppliers manufacture side mirrors for their vehicles in the US and EU and carry out extensive vibration tests. Tests carried out include vibration analysis in hot, cold and humid environments and simulate how mirrors operate in different environmental extremes. Samples are mounted in a fixture over a vibration table and tests are made using a laser that reflects light from the glass to a video camera. An analyser determines how much the mirror vibrates relative to the amount of vibration in the vehicle itself. Following testing, the glass must still operate, the mirror head cannot become unhinged from the pivot point, the attachments must remain intact and the studs that hold the mirror onto the door must maintain a specified mounting torque (Quality magazine, 2003).

4.1.2.3 IMPACT TESTS FOR EXTERIOR MIRRORS: REAL-WORLD IMPLICATIONS

EU tests give more specific requirements to improve pedestrian protection in the event of an impact between a pedestrian and a car side mirror. No literature has been found linking tests to lower pedestrian injury severities in such events. A comparison of EU and US data for injury severity of side mirror impacts would be required to determine whether stricter EU requirements translate to improved pedestrian safety.

Information from a limited number of manufacturers showed that, for ‘world cars’, the same side mirror housing was generally used in the US and the EU. However, different mirror surfaces must be fitted to comply with the differing field of view requirements. Therefore, it is likely that wing mirrors fitted to cars in the US and Europe are able to comply with both EU and US regulations.

In 2005, paediatric head trauma experts recommended that new technologies were introduced to vehicles in order to minimise pedestrian injuries. These include modifying vehicle exterior structures, such as wing mirrors, including size reduction and fold down designs (Mobasheri *et al*., 2005). Fold down mirrors have been mandatory for decades in Regulation 46, which may mean that pedestrians are less likely to be seriously injured by wing mirrors in the EU.

4.1.2.4 MIRROR MARKINGS: REAL-WORLD SAFETY IMPLICATIONS

In the US, non-planar passenger-side mirrors are required to be fitted with a sign stating ‘objects in the mirror may be closer than they appear'. No relevant literature was found to identify the safety implication of removing this sign.

4.1.2.5 COEFFICIENT OF REFLECTION: REAL-WORLD SAFETY IMPLICATIONS

Olson *et al.* carried out a study to evaluate the effect of various mirror reflectivities on the opinions and performance of drivers in a variety of situations. The first study required subjects to detect the presence of a following car, and indicate which lane it was in. This was conducted as a laboratory study using movies of the car and roadway and simulating a twilight condition. Reaction times, error scores, and preferences favoured mirrors of 36% reflectance or more (Olson *et al.*, 1974).

When considering to update Australian design rule 14 (rear vision mirrors) the Department of Transport and Regional Services in Australia stated that changing the minimum requirement of coefficient of reflection of rear-view mirrors from 35% to 40% should not have any impact on safety. However, accident statistics or studies to provide evidence to support this statement have not been identified during the literature search Department of Transport and Regional Services (2006).

4.2 INTERIOR REAR-VIEW MIRRORS

Interior mirrors are made mandatory by EU legislation for all M_1 vehicles apart from vehicles fitted with anything other than safety glazing material in the prescribed field of vision. US FMVSS 111 states that all passenger cars must have an inside rear-view mirror of unit magnification.

4.2.1 NOTABLE DIFFERENCES

The following sections describe the most notable and potentially influential differences. Refer to Table 49 in Annex 3 for a detailed side-by-side comparison of the legislative requirements.

The legislative requirements for interior rear-view mirrors in the EU are specified by UN Regulation 46, whereas FMVSS standard 111 specifies requirements for the US, with test procedures defined by NHTSA TP-111 (NHTSA, 1999). EU and US requirements are identical for adjustment, coefficient of reflectivity for night modes and the upper range of mirrors to extend to the horizon, in addition EU and US legislation both require impact testing and similar have similar requirements for field of view. Despite these similarities there are several differences between the EU and US requirements, most notable differences are field of view, impact testing, minimisation and the coefficient of reflectivity.

4.2.1.1 FIELD OF VIEW

One notable difference with the US (FMVSS 111) and EU legislation (UN Regulation 46) is the differing field of view requirements. This encompasses differing: areas to view, driver eye point position, vehicle configuration on test and permitted obstructions to the view.

Under the EU requirements, a 20m wide view of a level road surface starting 60m to the horizon behind the driver's ocular points must be provided. For the US the visibility limit is 61m (i.e. 200 feet) rearward, 1 metre further back than the EU requirements. Furthermore, the viewing angle is 20°, which equates to 21.5m wide area on the road surface (20m in the EU Regulation).

The driver's ocular points in UN Regulation 46 are defined in reference to the vehicle's R point, while the US legislation refers to FMVSS 104 (§ 571.104), which in turn refers to

SAE J941 and SAE J826. These standards define the eye position based on eye ellipses of 90th, 95th, and 99th percentile drivers. This means that the eye positions for the two tests are different.

In the US the vehicle is loaded with four passengers at test (68kg), while the EU specifies that the vehicle should be in running order as defined by UN R.E.3 Paragraph 2.2.5.4, including two front occupants (75kg). These differing vehicle conditions may also affect the indirect field of view.

The EU legislation permits up to 15% of the prescribed field of view to be obscured by items such as the sun visor, wipers, heating elements and stop lamp (S3). In addition, the headrests, framework and bodywork, such as window columns of rear split doors or rear window frame are excluded. Moreover, no internal rear-view mirror is required if the vehicle is fitted with anything other than safety glazing material in the field of vision. The US regulation states that the line of sight may be partially obscured by seated occupants or by head restraints, but does not quantify the obscuration that is acceptable.

4.2.1.2 MINIMISATION

The US legislation (FMVSS 111) requires a Unit magnification internal rear-view mirror i.e. it must be flat. Regulation 46 permits flat and spherically curved interior mirrors, with a radius of curvature ≥ 1,200 mm. If curved it shall be tested in three places with a spherometer, with limits both between each test point and relative to the arithmetic mean. Therefore, objects viewed in an EU interior mirror (if it is spherical) may appear smaller than in a US mirror. However, in practice, manufacturers commonly fit flat interior mirrors in both US and EU.

4.2.1.3 IMPACT TEST

Regulation 46 lays out details of two impact tests, including the equipment specification and numerical performance values for gauging compliance. The impact test uses a rubber coated rigid sphere mounted on a pendulum of 1 m length and reduced mass of 6.8 kg, dropped from an angle of 60° onto the mirror (including mounting and housing). Should the mounting of the mirror break during the tests the part remaining shall not project beyond the base by more than 10 mm, and the parts remaining attached that can be reached by a 165 mm diameter sphere have a radius of curvature ≥ 2.5 mm. The reflecting surface shall not break during the tests, unless the fragments of glass still adhere to the back of the housing or to a surface firmly, with a maximum separation of 2.5 mm on either side of cracks, or the reflecting surface is made of safety glass.

The US FMVSS 111 states that a test need only be performed if the mirror is within the head impact area (defined in FMVSS 201). If so, the mounting shall deflect, collapse or break away without leaving sharp edges when the reflective surface of the mirror is subjected to a force of 400 N. The NHTSA laboratory test procedure (NHTSA, 1999), states that seven configurations should be selected in which to test the mirror. In these tests, the mirror is mounted on a plate simulating the windscreen angle, while a leather coated wooden head form is slowly (≤5.08 mm/minute) pushed onto the mirror. What constitutes a sharp edge is not defined.

4.2.1.4 COEFFICIENT OF REFLECTIVITY

The US and EU requirements regarding the coefficients of reflection are very similar and they use the same terminology, very similar testing procedures SAE J964-1984 and UN Regulation 46 Annex 6 respectively and almost the same minimum limits. For the night setting both define a minimum reflectivity of ≥4%. However, for the day setting the US defined 35% minimum while the EU states a coefficient of reflectivity of 40%.

In addition, the US legislation specifies that the driver can control the night/day setting as well as failsafe requirements to return to the higher reflectance day mode in the event of electrical failure.

4.2.1.5 FIELD OF VIEW AND MINIMISATION: REAL-WORLD IMPLICATIONS

Convex interior mirrors are not permitted by US regulations which specify that interior mirrors must provide unit magnification. Although curved mirrors can increase the field of view, there are concerns over whether the minified image it provides negatively affects a driver's ability to judge distances to other vehicles and their approach speed. The rear-view field of view requirements of both regulations differ slightly. The required field of view in the US is slightly larger.

Information from a limited number of manufacturers showed that, for 'world cars', the same interior mirror was generally used in the US and EU. This means that there is an overlap of requirements since mirrors conform to both types of field of view test within EU and US regulations. This in turn indicates that, in reality, differences between both regulations may not have significant real-world safety implications.

Accident data for cars using different shapes of interior mirror or cars providing different rearwards fields of view were not identified during the literature search.

4.2.1.6 IMPACT TEST: REAL WORLD IMPLICATIONS

Interior mirrors fitted must undergo different impact tests depending on whether they are to be sold in the EU or the US. Occupant injury data due to impact with interior structures could not be found to compare whether one test is more effective than the other at reducing injury severity.

Information from a limited number of manufacturers showed that, for 'world cars', the same interior mirror was generally used in the US and EU. This means that there is an overlap of requirements since mirrors conform to both types of impact test within EU and US regulations. This in turn indicates that, in reality, differences between both regulations may not have significant real-world safety implications.

4.3 REAR VISIBILITY (REVERSING VISIBILITY)

Mandatory requirements for rear visibility aimed at preventing low speed reversing accidents (with vulnerable pedestrians, especially very young children) are unique to the US (see Annex 3 for test specification). The Final Rule was published in April 2014 with entry into force on 6th June 2014 (49 CFR Part 571; Docket No. NHTSA-2010-0162). This specified a phase-in schedule with full compliance by May 1st 2018.

The rule applies to passenger cars, trucks, multipurpose passenger vehicles, buses, and low-speed vehicles with a gross vehicle weight of less than 10,000 pounds (4,536 kg). The requirements specify requirements for test cylinders to be seen indirectly on test points in an area between 0.3m and 6.1m rearward of the vehicle (see Figure 13).

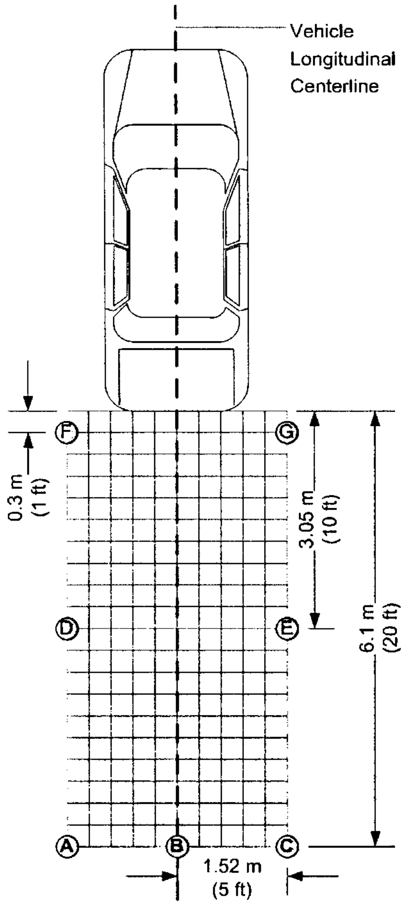

Figure 13: Test cylinder locations for rear visibility (FMVSS 111)

Improvements in structural crashworthiness and have meant that pillar thicknesses have increased over the last 10 to 15 years. This has influenced the rear visibility around the C-pillar region, although the view directly behind the vehicle may not have been influenced to the same extent.

Although accidents of this type might be typically associated with larger SUVs (which are more frequent in the US), it is also known that some smaller passenger cars have relatively poor rear visibility depending on their structural design and the driving position, so it is not only larger SUVs for which this aspect might be an issue.

It is not clear whether vehicle manufacturers selling into Europe will voluntarily equip vehicles with rear visibility systems compliant with FMVSS 111; some vehicles in Europe already offer reversing camera systems. If they are not equipped, this would constitute an area in which, going forward, US regulated vehicles offer better visibility compared to European vehicles.

The US regulation does not contain specification for screen size, image resolution or screen brightness; these aspects have the potential to influence the effectiveness of the information conveyed by the system. NHTSA have considered these aspects, but for a range of reasons have not included requirements in FMVSS 111.

Screen size is not specified because the requirements for the size of the test objects that must be visible mean that the information provided to the driver is at a minimum size. There are two issues for screen brightness; minimum level to ensure that the information can be understood in a range of lighting conditions, and the maximum level to ensure that glare is not caused. NHTSA concluded that they were not aware of any performance requirements that could objectively meet their concerns for these aspects.

4.3.1 DISCUSSION OF REAL-WORLD IMPLICATIONS

In April 2014, NHTSA issued a final rule to expand the required field of view for all passenger cars to enable the driver of a motor vehicle to detect areas behind the motor vehicle to reduce death and injury resulting from backing incidents, particularly incidents involving small children and disabled persons. These requirements are unachievable through the use of rear-view mirror alone and cars manufactured for the US market must now be fitted with rear-view cameras.

In Europe, the field of view requirements have not been expanded to include the area specified in the update to US regulations. Based on the data collected during a cost benefit analysis conducted by NHTSA, the effect of the regulation in the US is predicted to prevent 13-15 fatalities and 1,125-1,332 injuries per year (NHTSA, 2014).

5. REFERENCES

The analysis in this second Test Case has been carried out by TRL of the UK on behalf of the European Commission.

5.1 LIGHTING REFERENCES

Akashi, Y., Dee, P., Chen, J., Van Derlofske, J., & Bullough, J. (2003). Interaction between fixed roadway lighting and vehicle forward lighting. *Proceedings of the 5th International Symposium on Progress in Automobile Lighting*. Munich, Germany: Darmstädter Lichttechnik.

Akashi, Y., Van Derlofske, J., Raghavan, R., & Bullough, J. (2008). *Assessment of Headlamp Glare And Potential Countermeasures:The Effects of Headlamp Mounting Height - DOT HS 810 947*. Washington: NHTSA.

Allen, K. (2009). *The Effectiveness of Amber Rear Turn Signals for Reducing Rear Impacts - DOT HS 811 115*. Washington: NHTSA.

Bacelar, A. (2003). The contribution of vehicle lights in urban and peripheral urban environments. *Lighting Research & Technology, 36*(1), 69-78.

Bullough, J. (2013). *Headlamp Levelness and Glare: Preliminary Analyses Based on Field Data - doi:10.4271/2013-01-0749*. SAE.

Bullough, J. (2013a). *Headlamp Levelness and Glare: Preliminary Analyses Based on Field Data - doi:10.4271/2013-01-0749*. SAE.

Bullough, J. (2014). *Adaptive High Beam Systems: Visual Performance and Safety Effects - doi: 10.4271/2014-01-0431*. SAE Technical Paper 2014-01-0431.

Bullough, J. D., Donnell, E., & Rea, M. (2013b). To Illuminate or Not to Illuminate: Roadway Lighting as it Affects Traffic Safety at Intersections. *Accident Analysis and Prevention, 53*(1), 65-77.

Bullough, J., & Rea, M. S. (2001). Forward Vehicular Lighting and Inclement Weather Conditions. *PAL*. Munich, Germany.

Bullough, J., Pysar, R., & Skinner, N. (2010). *Real-World Measurement of Headlamp Illumination - doi: 10.4271/2010-01-0294*. SAE.

Bullough, J., Pysar, R., & Skinner, N. (2010). *Real-World Measurement of Headlamp Illumination - doi: 10.4271/2010-01-0294*. SAE.

Bullough, J., Skinner, N., Pysar, R., Radetsky, L., Smith, A., & Rea, M. (2008). *Nighttime Glare and Driving Performance: Research Findings*. Washington: NHTSA.

Bullough, J., Skinner, N., Pysar, R., Radetsky, L., Smith, A., & Rea, M. (2008). *Nighttime Glare and Driving Performance: Research Findings*. Washington: NHTSA.

Cavallo, V. C. (2001). Distance Perception of Vehicle Rear Lights in Fog. *The Journal of the Human Factors and Ergonomics Society*, Vol 43, No3, pp442-451.

Cavallo, V., & Pinto, M. (2012). Are car daytime running lights detrimental to motorcycle conspicuity? *Accident Analysis & Prevention*, *49*, 78-85.

Commandeur, J., Mathijssen, R., Elvik, R., Janssen, W., & Kallberg, V.-P. (2003). *Scenarios for the implementation of daytime running lights in the European Union.* Leidschendam: SWOV.

Copenhaver, M., & Jones, R. (1992). *Measurement of headlamp aim and the electrical and photometric performance characteristics of rear lighting systems.* Washington: NHTSA.

Courcier, M., Reiss, B., & Sanchez, V. (2013). Towards an Optimized Matrix Beam System. *10th International Symposium on Automotive Lighting.* Darmstadt, Germany.

Daniel Stern Lighting Consultancy. (2002). *DSLC's response to the agency's request for comments on headlamp glare and related issues.* Toronto: DSLC.

Daniel Stern Lighting Consultancy. (2002). *Where Does the Glare Come From? - A Comprehensive Discussion of Seeing and Glare in the Nighttime Roadway Environment.* Daniel Stern Lighting Consultancy.

De Boer, J. (1967). Visual perception in road traffic and the field. In J. De Boer, *Public lighting* (pp. 11–96). Eindhoven, Netherlands: Philips Technical Library.

Edwards, M. (1988). AnInvestigation of Selected Vehicle Design Characteristics Using the Crash Avoidance Datafile - DOTHS 807 223. *Eleventh International TechnicalConference on Experimental Safety Vehicles* (pp. 389-395). Washington: NHTSA.

Elvik, R. (1996). A meta-analysis of studies concerning the safety effects of daytime running lights on cars. *Accident Analysis & Prevention*, *28*(6), 685-694.

Elvik, R. (2013). Can a road safety measure be both effective and ineffective at the same time? A game-theoretic model of the effects of daytime running lights. *Accident Analysis & Prevention*, *59*, 394-398.

Elvik, R., Christensen, P., & Olsen, S. (2003). *Daytime running lights. A systematic review of effects on road safety*. Transportøkonomisk institutt.

Farmer, C., & Williams, A. (2002). Effects of daytime running lights on multiple-vehicle daylight crashes in the United States. *Accident Analysis and Prevention*, *34*, 197–203.

Flannagan, M. (2001). *The Safety Potenital of Current and Improved Front Fog Lights.* Ann Arbor, Michigan, USA: UMTRI (University of Michigan).

Flannagan, M., Sivak, M., & Schoettle, B. (2007). *Benefits of Headlamp Leveling and Cleaning for Current U.S. Low Beams.* Michigan: UMTRI.

Frieding, A. (1999). Optimized headlamps for wet road conditions. *PAL.* Munich.

Hagiwara, T., Morishita, M., Horii, Y., Miki, K., & Ohshima, I. (2007). Preferences for Headlight Swivel Angles at Curves on Rural Two-Lane Highways.

Transportation Research Record: Journal of the Transportation Research Board, 1, 47-53.

Hamm, M. (2002). *Adaptive Lighting Functions History and Future-Performance Investigations and Field Test for User's Acceptance.* SAE Technical Paper No. 2002-01-0526.

Hamm, M. (2013). Safety Improvement by New Matrix and Turn Indicator Functionality. *10th International Symposium on Automotive Lighting.* Darmstadt, Germany.

HLDI. (2011a). Mazda collision avoidance features: initial results. *Loss Bulletin, 28*(13).

HLDI. (2011b). Acura collision avoidance features: initial results. *Loss Bulletin, 28*(21).

HLDI. (2012a). Mercedes-Benz collision avoidance features: initial results. *Loss Bulletin, 29*(7).

HLDI. (2012b). Volvo collision avoidance features: initial results. *Loss Bulletin, 29*(5).

Hole, G., & Tyrrell, L. (1995). The influence of perceptual set on the detection of motorcyclists using daytime headlights. *Ergonomics, 38*, 1326-1341.

Jenssen, G., Bjørkli, C., Sakshaug, K., & Moen, T. (2007). Behavioural adaptation to adaptive front lighting systems (AFS): a six day driving simulator study. *Proceedings of the 14th World Conference on Intellegent Transport Systems (ITS).* Beijing, China.

Johansson, G., & Rumar, K. (1968). Visible distances and safe approach speeds for night driving. *Ergonomics*, 275-282.

Kahane, C. (1983). *An Evaluation of Side Marker Lamps for Cars, Trucks and Buses.* Washington: NHTSA.

Kahane, C. J. (1983). *An Evaluation of Side Marker Lamps for Cars, Trucks and Buses (DOT HS-806 430).* Washington D.C.: NHTSA.

Knight, I., Sexton, B., Bartlett, R., Barlow, T., Latham, S., & McCrae, I. (2006). *Daytime Running Lmaps (DRL): A review of the reports from the European Comission.* Crowthorne, UK: TRL Limited.

Kobayashi, S., Hayami, T., Sugimoto, A., & Uchida, H. (1999). Development of the Phase-I AFS front lighting system. *PAL, 5*, 449-464.

Koornstra, M., Bijleveld, F., & Hagenzieker, M. (1997). *The Safety Effects of Daytime Running Lights.* Leidschendam: SWOV.

Lerner, M., Albrecht, M., & Evers, C. (2005). *Das Unfallgeschehen bei Nacht - BASt-Bericht M 172.* Bergisch Gladbach: BASt.

Mace, D., Garvey, P., Porter, R., Schwab, R., & Adrian, W. (2001). *Countermeasures for Reducing the Effects of Headlight Glare.* Washington: The AAA Foundation for Traffic Safety.

Magma mirrors, Magma electronics. (2009). *49 CFR Part 571, Docket No: NHTSA-2009-0041; RIN# 2127-AK43, FMVSS; Rearview Mirrors, FR Vol 74, No 41*. Washington: NHTSA.

McLaughlin, S., Hankey, J., Green, C., & Larsen, M. (2004). *Target Detection Distances and Driver Performance with Swiveling HID Headlamps.* SAE Technical Paper 2004-01-2258.

Neuman, R. (2014). *Adaptive Driving Beam - Visibility Improvement versus Glare - doi:10.4271/2014-01-0436.* SAE TEchnical Paper 2014-01-0436.

NHTSA. (1996). *49 CFR Part 571 Denial of Petition for Rulemaking; Federal Motor Vehicle Safety Standards - FR Doc. 96–27073 Filed 10–22–96; 8:45 am.* Washington: NHTSA.

NHTSA. (1999). *Laboratory test procedure for FMVSS 111, TP111V-00.* Washington: DOT.

NHTSA. (2008). *Investigation of Safety-Based Advanced Forward-Lighting Concepts to Reduce Glare.* Washington, DC: NHTSA.

NHTSA. (2008). *Summary of Headlamp Research at NHTSA - DOT HS 811 006.* Washington: NHTSA.

Olson, P. (1985). *A survey of the condition of lighting equipment on vehicles in the United States.* Warrendale: SAE.

Peña-García, A., Lopez, R., Estrella, A., Dols, F., Poyo, F., Mesa, E., et al. (2010). Influence of daytime running lamps on visual reaction time of pedestrians when detecting turn indicators. *Journal of Safety Research, 41*, 385-389.

Rea, M., & Ouellette, M. (1991). Relative visual performance: A basis for application. *Lighting Research and Technology, 23*(3), 135-144.

Reagan, I., Brumbelow, M., & Frischmann, T. (2015). On-road experiment to assess drivers' detection of roadside targets as a function of headlight system, target placement, and target reflectance. *Accident Analysis and Prevention*, 74-82.

Rice, L. (2010). *Practical Implications of Lighting Standards and Regulations and Their History*. SAE International.

Rosenhahn. (1999). Headlamp Components for Adaptive Frontlighting - Usability of a Lighting Function for Adverse Weather Conditions. *PAL*, (pp. 677-688). Munich, Germany.

Rosenhahn, E. (2001). Adaptive Headlamp Systems Concerning Adverse Weather: Fog. *PAL, 9*.

Rumar, R. (2000). *Relative merits of the U.S. and ECE high-beam maximum intensities and of two- and four-headlamp systems.* Michigan: UMTRI.

Sivak, M., & Flannagan, M. (1995). *Evaluation of the SAE J1735 Draft Proposal for a Harmonized Low-Beam Headlighting Pattern.* Warrendale: SAE.

Sivak, M., Flannagan, M., Schoettle, B., & Nakata, Y. (2002). *Benefits of Applying Adaptive Headlighting to the Current U.S. and European Low-Beam Patterns.* Warrendale: SAE.

Sivak, M., Helmers, G., Owens, D., & Flannagan, M. (1992). *Evaluation of proposed low-beam headlighting patterns.* . Michigan: UMTRI.

Sivak, M., Schoettle, B., Flannagan, M., & Minoda, T. (2005). Optimal strategies for adaptive curve lighting. *Journal of Safety Research, 36*, 281-288.

Skinner, N., & Bullough, J. (2009). Toward Performance Specifications for Intelligent High Beam Headlamps. *8th International Symposium on Automotive Lighting.* Darmstadt, Germany.

Sullivan, J. M., & Flannagan, M. J. (2006). *Implications of Fatal and Nonfatal Crashes for Adaptive Headlighting.* Michigan: UMTRI.

Sullivan, J., & Flannagan. (2002). The role of ambient light level in fatal crashes: inferences from daylight saving time transitions. *Accident Analysis and Prevention, 34*, 487–498.

Sullivan, J., & Flannagan, M. (2007). Determining the potential safety benefit of improved lighting in three pedestrian crash scenarios. *Accident Analysis and Prevention, 39*, 638-647.

Sullivan, J., & Flannagan, M. (2008). *The Influence of Rear Turn Signal Characteristics on Crash Risk - DOT HS 811 037.* Washington: NHTSA.

Sullivan, J., & Flannagan, M. (2008). *Trends in Fatal U.S. Crashes in Darkness: 1990 to 2006.* Michigan: UMTRI.

Sullivan, J., & Flannagan, M. (2010). *Vehicle Kinematics in Turns and the Role of Cornering Lamps in Driver Vision.* Ann Arbor, MI: UMTRI.

Sullivan, J., & Flannagan, M. (2011). Differences in geometry of pedestrian crashes in daylight and darkness. *Journal of Safety Research, 42*, 33-37.

Taylor, G., & Ng, W. (1981). *Effectiveness of Rear-Turn-Signal Systems in Reducing VehicleAccidents from an Analysis of Actual Accident Data - SAE Technical Report 810192.* Detroit: SAE.

Theeuwes, J., & Alferdinck, J. (1997). The Effectiveness of side marker lamps: An experimental study. *Accident Analysis and Prevention*, 235-245.

Theeuwes, J., & Riemersma, J. (1995). Daytime running lights as a vehicle collision countermeasure: the Swedish evidence reconsidered. *Accident Analysis & Prevention, 27*(5), 633-642.

Wang, J.-S. (2008). *The Effectiveness of Daytime Running Lights for Passenger Vehicles.* Washington, DC: NHTSA.

5.2 DIRECT VISION REFERENCES

Chinn B, Knight I, Dodd M, Smith T, Shearlaw A, Cherry A, Mayo M (2002). Primary safety new car assessment programme – annual report 2001/2002. TRL Project Report PR/SE/585/2002.

Clark, B (1996). Mismatches between driver visual capabilities and road vehicle standards. Vol. 5, No. 2, June 1996, Road & Transport Research

Clark B (1996b) 15th ESV conference Melbourne, Australia paper number 96-S9-W-33.

King, S (1998). Blind to killer blind spots? Spen King & Associates, Warwickshire, UK

Leening, A (1988). Driver vision and vehicle design. Royal Automobile Club of Victoria.

Millington V, Cuerden R, Hulse S Brightman T (2006). Investigation into A pillar obscuration – s study to quantify the problem using real-world data. TRL Published project report PPR159. Available at: http://www.trl.co.uk/ Accessed: Jan 2015.

Reed M (2008). Intersection kinematics: A pilot study of driver turning behaviour with application to pedestrian obscuration by A-pillars. Retrieved from: http://deepblue.lib.umich.edu/bitstream/handle/2027.42/61347/100991.pdf?sequence=1 Accessed Jan 2015.

Sivak M, Schoettle B., Reed P, Flannagan J (2006). Influence of visibility out of the vehicle cabin on lane change crashes. Accident Analysis and Prevention, 38, 969-972.

Wade M and Hammond C (2002). Forward looking blindspots: A report of A-pillar induced field-of-view obstruction and driver performance in a simulated rural environment. Retrieved: http://www.its.umn.edu/Publications/ResearchReports/reportdetail.html?id=638 Accessed: Jan 2015.

5.3 INDIRECT VISION REFERENCES

De Vos, A.P. (2000). Non-planar driver's side rearview mirrors: A survey of mirror types and European driver experience and a driver behaviour study on the influence of experience and driver age on gap acceptance and vehicle detection. TNO Human Factors research institute. NHTSA DOT HS 809149

Department of Transport and Regional Services. (2006). Regulation Impact Statement for ADR 14 – Rear Vision Mirrors. Vehicle Safety Standards. Department of Transport and Regional Services. Retrieved 18 December 2014 from: http://www.comlaw.gov.au/Details/F2006L02663

NHTSA. (2014). Federal Register. Federal Motor Vehicle Safety Standards; Rear Visibility; Final Rule. 49 CFR Part 571. Vol. 79. No. 66.

Flannagan, M.J., Sivak, M and Traube, E. (1997). Effects of Large-Radius Convex Rearview Mirrors on Driver Perception. SAE Technical Paper 970910, doi:10.4271/970910.

Luoma, J., Flannagan, M.J. and Sivak, M. (2000). Effects of non-planar driver-side mirrors on lane change crashes. The University of Michigan. Transportation Research Institute. Report No. UMTRI-2000-26

Mobasheri, R., Chitnavis, B. and Bhattee, G. Serious paediatric head trauma caused by vehicle rear view mirrors. Emerg Med J 2005;22:455–456. doi: 10.1136/emj.2004.018150

Morgan, J. and Blanco, M. (2010). Synthesis Study of Light Vehicle Non-Planar Mirror Research. NHTSA DOT HS 811 328

Olson, PL., Jorgeson, C.M. and Mortimer, R.G. (1974). Effects of rearview mirror reflectivity on driver's comfort and performance. Highway Safety Research Institute. UM-HSRI-HF-74-22 Final Rpt.

Quality magazine. (2003). Mirror Life Reflects Testing Extremes. Retrieved 22 December 2014 from: http://www.qualitymag.com/articles/84420-mirror-life-reflects-testing-extremes.

Rau, P.S., Wierwille, W., Schaudt, W., Spaulding, J. and Hanowski, R. (2007). Study of Driver Performance/Acceptance Using Aspheric Mirrors in Light Vehicle Applications. Virginia Tech Transportation Institute. Paper Number 07-0237.

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Annex 1

COMPARISON TABLES FOR EU REGULATIONS AND US STANDARDS - LIGHTING

Table 20: Current EU regulations and US standards for main-beam (driving-beam) [upper beam] headlamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R112: UN Regulation No. 112; R98: UN Regulation No. 98)

Property	EU (UN Regulations) Specification	Reference	US (FMVSS/SAE Standards) Specification	Reference	Comparison
Applicability	Mandatory	R48, 6.1.1	Mandatory	F108, Table I-a	Identical
Number	2 or 4*	R48, 6.1.2	2 or 4*	F108, Table I-a	Identical
Colour	White	R48, 5.15	White	F108, Table I-a	Identical
Position					
Height[§]	-	-	Max: ≤1,372 mm Min: ≥559 mm	F108, Table I-a	Heights are not defined in the EU, while the US provides prescriptive height definitions
Width	-	-	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a	Heights are not defined in the EU, while the US provides subjective height definitions
Length	At the front	R48, 6.1.4.3	On the front	F108, Table I-a	Identical
Geometric Visibility	H[†]: min L/R 5° V[†]: min U/D 5°	R48, 6.1.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges
Photometric Visibility	H: L5° to R5° V: 0°	R112, 6.3.3 R98, 6.3.3	H: L12° to R12° V: D4° to U2°	F108, Table XVIII	Horizontal and vertical photometric visibility angle ranges are smaller in the EU

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima[$]	*Asymmetric Beam*: Class A: ≥27,000 cd @ H: 0°, V: 0° ≥3,400 cd @ H: L/R 5°, V: 0° Class B: ≥40,500 cd @ H: 0°, V: 0° ≥5,100 cd @ H: L/R 5°, V: 0° *Gas Discharge*: ≥43,800 cd @ H: 0°, V: 0° ≥6,250 cd @ H: L/R 5°, V: 0°	R112, 6.3.3 R98, 6.3.3 R98, 6.3.3.1	UB2: ≥40,000 cd @ H: 0°, V: 0° ≥1,000 cd @ H: L/R 12°, V: D2.5° UB5: ≥7,000 cd @ H: 0°, V: 0° ≥400 cd @ H: L/R 12°, V: D2.5°	F108, Table XVIII	EU Class B asymmetric beam requirements are similar to the greatest minimum photometric requirement in the US (UB2) along the headlamp reference axis, while EU Class A requirements are much greater than that of the lowest minimum photometric requirement in the US (UB5). EU gas discharged headlamps have a 10% greater minimum photometric requirement than all US requirements. At the largest photometric visibility angles, EU headlamps require much greater photometric minima than US headlamps. Due to the large differences in photometric visibility angle, however, these results are incomparable.
Photometric Maxima[$]	≤215,000 cd	R112, 6.3.3.2 R98, 6.3.3.2	UB2: ≤75,000 cd @ H: 0°, V: 0° ≤12,000 cd @ H: 0°, V: D4° UB5: ≤15,000 cd @ H: 0°, V: 0° ≤2,500 cd @ H: 0°, V: D4°	F108, Table XVIII	Photometric maxima in the EU are greater (300%), regardless of photometric visibility angle

* Dependent on headlamp system used

[§] US: to the centre of the lamp

[†] Origins at the perimeter of the projection of the illuminating surface on a transverse plane tangent to the foremost part of the headlamp lens

[$] UN: for both Category A and B asymmetrical beam headlamps (UN regulation 112) and gas discharge headlamps (UN regulation 98) and with photometric measurements made at ≥25 m and test voltages of 6.3 v, 6.75 v, 13.2 v and 28. 0v; US: for both the maximum and minimum photometric requirements encompassing upper beam headlighting system standards (FMVSS Standard 108, Table XVIII; Max: UB2, Min: UB5) and with photometric measurements made at ≥18.3 m and a test voltage 12.8±0.02 v.

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; Class A, Class A classified headlamp; Class B, Class B classified headlamp; UB2, upper beam system #2; UB5, upper beam system #5.

Table 21: Current EU regulations and US standards for dipped-beam (passing-beam) [lower beam] headlamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R112: UN Regulation No. 112; R98: UN Regulation No. 98)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory, can be adapted for left or right hand traffic	R48, 6.2.1	Mandatory	F108, Table I-a	Identical
Number	2	R48, 6.2.2	2 or 4*	F108, Table I-a	Two lamp dipped-beam headlamp systems to be used in the EU only
Colour	White	R48, 5.15	White	F108, Table I-a	Identical
Position					
Height§	Max: ≤1,200 mm Min: ≥500 mm	R48, 6.2.4.2	Max: ≤1,372 mm Min: ≥559 mm	F108, Table I-a	Maximum and minimum height are both lower in the EU Height range is smaller in the EU Maximum and minimum heights further affected by differences in EU and US definitions
Width	Outer: ≤400 mm	R48, 6.2.4.1	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a	Widths are more prescriptive in the EU, while the US is more subjective
Length	At the front	R48, 6.2.4.3	On the front	F108, Table I-a	Identical
Vertical Orientation					
Vertical Inclination Limit†	*h*<0.8 m: D0.5% to D2.5% 0.8<*h*<1.0 m: D0.5% to D3.0% *h*>1.0 m: D1.0% to D3.0%	R48, 6.2.6.1.2	VOL: D0.4° VOR: 0° Varied based on range of practical operating conditions and type of equipment	F108, S10.18.9.1.1 F108, S14.2.5.5.3.1 F108, S14.2.5.5.3.2 F108, S14.2.5.5.3.1 F108, S10.18.8.2.1	Vertical inclination limits for the cut-off are greater in the EU than the US apart from when mounting height <0.8 m (0.4° = 0.7% inclination) Vertical inclination limits of cut-off are related to headlamp mounting height in the EU, while US requirements fail to take this into account. The EU provides an acceptable range for vertical inclination, while the US provides a target value

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Headlamp Levelling System	Mandatory, if unable to satisfy vertical inclination limits across range of static loading scenarios	R48, 6.2.6.2.1 R48, Annex 5	Mandatory	F108, S10.18.1	EU requirements only mandatory if headlamps are unable to satisfy vertical inclination limits across the range of static loading scenarios
Automated Headlamp Levelling	Optional for lamps with luminous flux ≤2,000 lumens Mandatory for lamps with luminous flux >2,000 lumens	R48, 6.2.6.2.1 R48, 6.2.6.2.2 R48, 6.2.9	Optional	F108, S10.18.1.2	EU provides option for automated headlamp levelling systems, making this mandatory for lamps with a luminous flux >2,000 lumens, while the US provides no requirement to fit such devices
Geometric Visibility	H: I10° to O45° V: D10° to U15°	R48, 6.2.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges
Photometric Visibility	*Asymmetric Beam*: H: L9° to R9° V: D4° to U4° *Gas Discharge*: H: L20° to R20° V: D4.29° to U4°	R112, 6.2.4 R98, 6.2.5	H: L90° to R90° V: D4° to U90°	F108, Table XIX-a F108, Table XIX-b	Horizontal and vertical photometric visibility angle ranges are smaller in the EU then in the US. Gas discharged lights have a slightly lower vertical photometric visibility value, when compared to all other lamps in the EU and US
Photometric Minima[$]	*Asymmetric Beam*: ≥5,100 cd @ H: 0°, V: D0.86° ≥65 cd @ H: L8°, V: 0° *Gas Discharge*: ≥7,500 cd @ H: 0°, V: D0.86° ≥65 cd @ H: L8°, V: 0°	R112, 6.2.4 R98, 6.2.5	≥4,500 cd @ H: 0°, V: D0.86° ≥125 cd @ H: L90° to R90° V: U10° to U90°	F108, Table XIX-a F108, Table XIX-b	For the harmonised test point: EU minimum photometric requirements are greater than US requirements. EU gas discharged headlamps have a 67% greater minimum photometric requirement than in the US. For the absolute photometric minima: EU headlamps have much lower absolute photometric minima than US headlamps. Due to the large differences in photometric visibility angle, however, these results are incomparable.

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Maxima[Δ]	*Asymmetric Beam*: ≤13,200 cd @ H: L3.43°, V: D0.86° Class A: ≤17,600 cd @ H: L9° to R9° V: D1.72° to D4° Class B: ≤20,200 cd @ H: L9° to R9° V: D1.72° to D4° *Gas Discharge*: ≤18,480 cd @ H: L3.43°, V: D0.86°	R112, 6.2.4 R98, 6.2.5	≤12,000 cd @ H: L3.5°, V: D0.86° ≤12,500 cd @ H: R4°, V: D4°	F108, Table XIX-a F108, Table XIX-b	For the harmonised test point: EU maximum photometric requirements are greater than US requirements. EU gas discharged headlamps have a 54% greater minimum photometric requirement than in the US. For the absolute photometric maxima: EU headlamps have much greater absolute photometric maxima than US headlamps. Due to the large differences in photometric visibility angle, however, these results are incomparable.
Photometric Maxima for Oncoming Traffic[‡]	≤350 cd @ H: L3.43° V: U0.57°	R112, 6.2.4 R98, 6.2.5	≤700 cd @ H: L3.43°, V: U0.5°	F108, Table XIX-a F108, Table XIX-b	The EU requires lower photometric maxima (50%) to control glare for oncoming driver at 50m
Headlamp Cleaning Devices	Optional for lamps with luminous flux ≤2,000 lumens Mandatory for lamps with luminous flux >2,000 lumens	R48, 6.2.9	-	-	EU provides option for headlamp cleaning devices, making this mandatory for lamps with a luminous flux >2,000 lumens, while the US does not define the use of headlamp cleaning devices

* Dependent on headlamp system used

[§] UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

† UN: vertical inclination of the dipped-beam cut-off defined based on the mounting height (h) of the lower edge of the apparent surface of the dipped-beam headlamp, as measured on an unloaded vehicle, in the direction of the headlamp reference axis; US: vertical inclination defined based on the angle of the cut-off maximum gradient from the horizontal axis for VOL and VOR

$ Photometric minima and coordinates are defined for both the absolute photometric minima required and the photometric minima required at the harmonised test point (H: L3.43°, V: D0.86°); UN: for both Category A and B asymmetrical beam headlamps (UN regulation 112) and gas discharge headlamps (UN regulation 98), for photometric measurements made at ≥25m and test voltages of 6.3v, 6.75v, 13.2v and 28.0v; US: for the photometric requirements encompassing visually/optically aimed lower beam headlighting system standards only (FMVSS Standard 108, Table XIX; LB1V-LB4V) and with photometric measurements made at ≥18.3m and a test voltage 12.8±0.02v

Δ Photometric maxima and coordinates are defined for both the absolute photometric minima required and the photometric minima required at the harmonised test point (H: L3.43°, V: D0.86°); UN: for both Category A and B asymmetrical beam headlamps (UN regulation 112) and gas discharge headlamps (UN regulation 98), for photometric measurements made at ≥25m and test voltages of 6.3v, 6.75v, 13.2v and 28.0v; US: for the photometric requirements encompassing visually/optically aimed lower beam headlighting system standards only (FMVSS Standard 108, Table XIX; LB1V-LB4V) and with photometric measurements made at ≥18.3m and a test voltage 12.8±0.02v

‡ Location for photometric maxima for oncoming drivers at 50m abstracted from Sivak et al. (2001)

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; Class A, Class A classified headlamp; Class B, Class B classified headlamp; VOL, headlamp that is visually/optically aimed using the left side of the lower beam pattern; VOR, headlamp that is visually/optically aimed using the right side of the lower beam pattern.

Table 22: Current EU regulations and US standards for day-time running lamps [daytime running lamps] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R87: UN Regulation No. 87)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Specification	Reference	Specification	Reference	
Applicability	Mandatory	R48, 6.19.1	Optional	F108, Table I-a	EU is mandatory, while US is optional
Number	2	R48, 6.19.2	2	F108, Table I-a	Identical
Colour	White	R48, 5.15	White , white to amber, white to selective amber, selective amber or amber	F108, Table I-a	EU mandates white, while US mandates a range of colours from white to amber
Position					
Height*	Max: ≤1,500 mm Min: ≥250 mm	R48, 6.19.4.2	Max: ≤1,067 mm[§]	F108, Table I-a	Maximum height is greater in the EU No minimum heights are defined by the US Maximum and minimum heights further affected by differences in EU and US definitions
Width	Inner: ≥600 mm[†]	R48, 6.19.4.1	Symmetric about vertical centreline	F108, Table I-a	Widths are more prescriptive in the EU, while the US provides no definition apart from ensuring that they are located symmetrically about the vertical centreline
Length	At the front	R48, 6.19.4.3	On the front	F108, Table I-a	Identical
Geometric Visibility	H: I20° to O20° V: D10° to U10°	R48, 6.19.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges
Photometric Visibility	H: L20° to R20° V: D5° to U10°	R87, Annex 3	-	-	Photometric visibility ranges are prescribed in the EU, while the US does not define photometric visibility ranges
Photometric Minima[$]	≥400 cd @ H: 0°, V: 0° ≥4 cd @ H: L/R 20° V: D/U 5°	R87, 7.1 R87, 7.2 R87, Annex 3	≥500 cd @ H: 0°, V: 0°	F108, S7.10.13	EU headlamps have much lower photometric minima than US headlamps

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Maxima[$]	≤1,200 cd @	R87, 7.1 R87, 7.2 R87, Annex 3	≤3,000 cd	F108, S7.10.13	EU headlamps have much lower photometric maxima than US headlamps
Activation	Automatic activation on operation of engine Automatic deactivation when engine switched off and when either headlamps or fog lamps switched on Manual deactivation if vehicle speed ≤10 km/h & can be automatically activated at speeds ≥10 km/h or distances >100m	R48, 6.19.7	Automatic activation as determined by manufacturer Automatic deactivation when headlamp control is in the on position Automatic deactivation when signal turn lamps activated	F108, Table I-a	EU is more prescriptive with activation/deactivation scenarios

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

[§] If not combined with a pair of lamps already required by this standard or, if combined with upper beam headlamps, to a maximum mounting height of ≤864 mm

[†] May be reduced to ≥400 mm when vehicle width is <1,300 mm

[$] UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps positioned either with photometric measurements made at ≥18.3m and tested at voltage supplies of 12.8v

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp.

Table 23: Current EU regulations and US standards for cornering lamps (R48: UN Regulation No. 48; R119: UN Regulation No. 119; J852, SAE Standard No. J852)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Optional	R48, 6.20.1	Optional	J852	Identical
Number	2	R48, 6.20.2	2	J852	Identical
Colour	White	R48, 5.15	White to amber	J852, 6.1.7	EU requires white, while US provides the option of a range of colours from white to amber
Position					
Height*	Max: ≤900 mm§ Min: ≥250 mm	R48, 6.20.4.3	Max: ≤760 mm Min: ≥305 mm	J852, 7.5	Maximum height is greater in the EU Minimum height is smaller in the EU Maximum and minimum heights further affected by differences in EU and US definitions
Width	Located either side of median longitudinal plane of vehicle	R48, 6.20.4.1	-	-	The EU subjectively defines width positions, while the US provides no definition
Length	≤1,000 mm from front	R48, 6.20.4.2	-	-	Widths are prescribed in the EU, while the US provides no definition
Geometric Visibility	H: L30° to L60° V: D10° to U10°	R48, 6.20.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges
Photometric Visibility	H: L90° to R90°† V: D2.5° to U1°	R119, 6.2 R119, 6.3	H: B90° to F85° V: D2.5° to U90°	J852, 6.1.5	The EU defines the reference axis to the front of the car, while the US defines this to the side of the car Greater upward photometric visibility angles are required by the US
Photometric Minima$	≥400 cd @ H: D2.5°, V: L45°† ≥240 cd @ H: D2.5° V: L30/60°†	R119, 6.2 R119, Annex 3	≥500 cd @ H: D2.5°, V: F45° ≥300 cd @ H: D2.5° V: F30/60°	J852, 6.1.5	EU cornering lamps have lower photometric minima than US cornering lamps

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Maxima$^{\$}$	≤14,000 cd @ H: D0.57° to D2.5° V: L90° to R90°† ≤600 cd @ H: 0°, V: L45°†	R119, 6.3	≤500 cd @ H: 0° V: B90° to F85° ≤500 cd @ H: 0°, V: F45°	J852, 6.1.5	For the harmonised test point: EU maximum photometric requirements are greater than US requirements. For the absolute photometric maxima: EU cornering lamps have much greater absolute photometric maxima than US cornering lamps.
Activation	May only be activated when headlamps are activated Only activated when direction-indicators are activated and/or when steering angle is changed from straight ahead When reversing lamp is activated No activation at speeds of >40 km/h	R48, 6.20.7 R48, 6.20.9	Intended for use only when headlamps are operational Activation should coincide with turn signal activation May be activated by steering angle No activation at high vehicle speed or while stopped	J852, 7.1 J852, 7.2 J852, 7.3 J852, 7.4	EU cornering lamps may be activated when reversing lamps are activated Maximum activation cut-off speeds in the EU are more prescriptive, while the US provides a more subjective definition

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

§ No point on the apparent surface of the lamp, in the direction of the reference axis, shall be higher than the highest point on the apparent surface, in the direction of the reference axis, of the dipped-beam headlamp

† Photometric angles provided for cornering lamps mounted on the left-hand side of the vehicle only. For cornering lamps mounted on the right-hand side of the vehicle please reverse the direction designations

$ UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp.

Table 24: Current EU regulations and US standards for adaptive front-lighting systems [full adaptive forward lighting systems] (AFS) (R48: UN Regulation No. 48; R123: UN Regulation No. 123; J2838, SAE Standard No. J2838)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Specification	Reference	Specification	Reference	
Applicability	Optional	R48, 6.22.1	Prohibited	J2838, 7.7	Certain agencies in the US may prohibit the use of AFS, while the EU provides the option of installing AFS
Number	1 System	R48, 6.22.2	1 System	J2838	Identical
Colour	White	R48, 5.15	White	J2838, 6.2.1	Identical
Position					
Height*	*Main Lighting Unit*: Max: ≤1,200 mm Min: ≥500 mm *Additional Units*: Max: ≤1,200 mm Min: ≥250 mm Nearest Unit: ≤400 mm	R48, 6.22.4.1.1 R48, 6.22.4.1.2 R48, 6.22.4.1.3	-	-	Heights are prescribed in the EU, while the US does not define heights
Width	Outer: ≤400 mm	R48, 6.22.4.1.4	-	-	Widths are prescribed in the EU, while the US does not define widths
Length	At the front	R48, 6.22.4.2	-	-	Lengths are prescribed in the EU, while the US does not define lengths
Passing-Beam Vertical Orientation					

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
AFS Class C Initial Vertical Inclination Limits§	h<0.8 m: D0.5% to D2.5% 0.8<h<1.0 m: D0.5% to D3.0% h>1.0 m: D1.0% to D3.0%	R48, 6.22.6.1.2	D1%	J2838, 6.5.1.1	Greater vertical inclination limits for the cut-off are allowed in the EU when compared to the US Vertical inclination limits of cut-off are related to headlamp mounting height in the EU, but not the US The EU provides an acceptable range for vertical inclination, while the US provides a target value
AFS Vertical Alignment	Class C: D0.57° Class V: D0.57°-D1.3° Class E: D0.23°-D0.57° Class W: D0.23°-D0.57°	R123, Annex 3	Class C: D0.57° Class V: D0.57°-D1.3° Class E: D0.23°-D0.57° Class W: D0.23°-D0.57°	J2838, 6.5.1.1	Identical
Headlamp Levelling System	Required, if unable to satisfy vertical inclination limits across range of static loading scenarios	R48, 6.22.6.2.1	Required, if cannot be adjusted by other means (i.e. vehicle height)	J2838, 6.2.3	Identical; as both the EU and US require a headlamp levelling system, unless the car is able to correct for headlamp misalignment in other ways
Automated Headlamp Levelling	Required, if unable to satisfy vertical inclination limits across range of static loading scenarios		Optional	J2838, 6.5.1.3	The EU requires the headlamp levelling system to be automated while the US does not
Geometric Visibility	*Driving Beam*: H†: min L/R 5° V†: min U/D 5° *Passing Beam*: H: I10° to O45° V: D10° to U15°	R48, 6.22.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Visibility	*Driving-Beam*: H: L5° to R5° V: 0° *Passing-Beam*: H: L16° to R12° V: D6° to U6°	R123, 6.3.2 R123, 6.2.4 R123, Annex 3	*Upper Beam*: H: L5° to R5° V: 0° *Lower Beam*: H: L16° to R12° V: D6° to U6°	J2838, 6.1.1.3 J2838, 6.1.1.4	Identical
Photometric Minima[$]	*Driving-Beam*: ≥40,500 cd @ H: 0°, V: 0° ≥5,100 cd @ H: L/R 5°, V: 0° *Passing-Beam*: ≥50 cd @ H: L3.43°, V: U0.57° Class C: ≥16,900 cd @ H: L0.5° to R3° V: D1.72° Class V: ≥8,400 cd @ H: L0.5° to R3° V: D1.72° Class E: ≥16,900 cd @ H: L0.5° to R3° V: D1.72° Class W: ≥29,530 cd @ H: L0.5° to R3° V: D1.72°	R123, 6.3.2 R123, Annex 3	*Driving-Beam*: ≥40,500 cd @ H: 0°, V: 0° ≥5,100 cd @ H: L/R 5°, V: 0° *Passing-Beam*: ≥50 cd @ H: L3.43°, V: U0.57° Class C: ≥16,900 cd @ H: L0.5° to R3° V: D1.72° Class V: ≥8,400 cd @ H: L0.5° to R3° V: D1.72° Class E: ≥16,900 cd @ H: L0.5° to R3° V: D1.72° Class W: ≥29,530 cd @ H: L0.5° to R3° V: D1.72°	J2838, 6.1.1.3 J2838, 6.1.1.4	Identical

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Maxima$^{\Delta}$	*Driving-Beam*: ≥215,000 cd *Passing-Beam*: Class C: ≥44,100 cd @ H: L0.5° to R3° V: D1.72° ≥350 cd @ H: L3.43°, V: U0.57° Class V: ≥44,100 cd @ H: L0.5° to R3° V: D1.72° ≥350 cd @ H: L3.43°, V: U0.57° Class E: ≥79,300 cd @ H: L0.5° to R3° V: D1.72° ≥625 cd @ H: L3.43°, V: U0.57° Class W: ≥70,500 cd @ H: L0.5° to R3° V: D1.72° ≥625 cd @ H: L3.43°, V: U0.57°	R123, 6.3.2 R123, Annex 3	*Driving-Beam*: ≥215,000 cd *Passing-Beam*: Class C: ≥44,100 cd @ H: L0.5° to R3° V: D1.72° ≥350 cd @ H: L3.43°, V: U0.57° Class V: ≥44,100 cd @ H: L0.5° to R3° V: D1.72° ≥350 cd @ H: L3.43°, V: U0.57° Class E: ≥79,300 cd @ H: L0.5° to R3° V: D1.72° ≥625 cd @ H: L3.43°, V: U0.57° Class W: ≥70,500 cd @ H: L0.5° to R3° V: D1.72° ≥625 cd @ H: L3.43°, V: U0.57°	J2838, 6.1.1.3 J2838, 6.1.1.4.1.2	Identical

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Driving-Beam AFS Activation	Adaptive activation based on: Ambient conditions Light emitted by front light-signalling devices of oncoming vehicles Light emitted by rear light-signalling devices of preceding vehicles Additional functions are allowed	R48, 6.22.7.1.2	-	-	The activation of the driving beam is prescribed in the EU, while the US does not define the activation of the driving beam
Class C (Basic) Passing-Beam AFS Activation	Basic passing-beam class, activated if no other class is activated May be activated and/or deactivated based on ambient light conditions Without prejudice to the above, additional functions are allowed	R48, 6.22.7.3 R48, 6.22.7.4.1	-	-	The activation of the Class C passing beam is prescribed in the EU, while the US does not define the activation of the Class C passing beam

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Class V Passing-Beam AFS Activation	Shall be activated if one or more of the following are detected: Roads in built-up areas and speed ≤60 km/h Fixed road illumination and speed ≤60 km/h Speed ≤50 km/h	R48, 6.22.7.4.2	Intended for use when sufficient ambient light is present and speed is <60 km/h	J2838, 7.4	Class V passing beam activation is always activated at speeds of ≤50 km/h in the EU, while in the US there has to be sufficient ambient light present too Identical for activation at speeds of ≤60 km/h and roads in built up areas/ambient lighting/fixed road illuminations
Class E Passing-Beam AFS Activation	Shall be activated if speed >70km/h and one or more of the following are detected: Road characteristics correspond to motorway conditions Speed >80 km/h, >90 km/h, >100 km/h and >110 km/h, with each increasing speed increasing the intensity of light	R48, 6.22.7.4.3	Intended for use when speed >80 km/h, >90 km/h, >100 km/h and >110 km/h, with each increasing speed increasing the intensity of light	J2838, 7.5	Class E passing beam activation is activated at at speeds of >70 km/h when the road characteristics correspond with highway conditions, while the US activates only at speed of >80 km/h

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Class W Passing-Beam AFS Activation	Shall be activated if front fog lamps are off and one or more of the following are detected: Road wetness has been detected Windshield wiper continuously operated for ≥2 minutes	R48, 6.22.7.4.4	Intended for use in adverse weather that is detected automatically or signified by activation of windshield wipers	J2838, 7.6	EU requires front fog lamps to be off prior to activation, while the US does not The EU requires windshield wipers to have been activated for ≥2 minutes prior to the activation of the Class W passing beam, while the US can activate this on windshield wiper activation
Bend Lighting Mode AFS Activation	Shall only be activated based on evaluation of the angle of steering lock or the trajectory of the centre of gravity of the vehicle	R48, 6.22.7.4.5	-	-	The activation of the bend lighting mode is prescribed in the EU, while the US does not define the activation of the bend lighting mode
Headlamp Cleaning Devices	Mandatory for lamps that contribute to Class C passing-beams and that have a luminous flux >2,000 lumens	R48, 6.2.9.1	-	-	EU provides option for headlamp cleaning devices, making this mandatory for lamps with a luminous flux >2,000 lumens, while the US does not define the use of headlamp cleaning devices

* UN: maximum is to the highest point, minimum is to the lowest point of the lamp and nearest unit is the distance between the main lighting unit and the nearest additional lighting unit

§ UN: vertical inclination of the dipped-beam cut-off defined based on the mounting height (h) of the lower edge of the apparent surface of the dipped-beam headlamp, as measured on an unloaded vehicle, in the direction of the headlamp reference axis; US: vertical inclination defined based on the angle of the cut-off maximum gradient from the horizontal axis

† Origins at the perimeter of the projection of the illuminating surface on a transverse plane tangent to the foremost part of the headlamp lens

[$] Photometric minima and coordinates are defined for both the absolute minimum and maximum photometric minima required for driving-beam, Class C passing-beam, Class V passing-beam, Class E passing-beam, Class W passing-beam and bend lighting modes with photometric measurements made at 10 m or 25 m and test voltages of 6.3v, 13.2v or 28.0v

[Δ] Photometric maxima and coordinates are defined for both the absolute minimum and maximum photometric maxima required for driving-beam, Class C passing-beam, Class V passing-beam, Class E passing-beam, Class W passing-beam and bend lighting modes with photometric measurements made at 10 m or 25 m and test voltages of 6.3v, 13.2v or 28.0v

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; AFS, adaptive front-lighting systems (full adaptive forward lighting systems); Class C, unmodified (basic) passing-beam pattern for AFS; Class V, modified (town mode) passing-beam pattern for AFS which minimises glare for oncoming vehicles and increases illumination of road delineators; Class E, modified (highway mode) passing-beam pattern which increases illumination further down the road; Class W, modified (adverse weather) passing-beam pattern which increases the illumination of road delineators, increases illumination further down the road and decreases illumination in front of the vehicle; Bend Lighting Mode, modified beam pattern to increase illumination for curves, bends or intersections.

Table 25: Current EU regulations and US standards for front direction-indicator [front turn signal] lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R6: UN Regulation No. 6)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Specification	Reference	Specification	Reference	
Applicability	Mandatory	R48, 6.5.1	Mandatory	F108, Table I-a	Identical
Number	2	R48, 6.5.3	2	F108, Table I-a	Identical
Colour	Amber	R48, 5.15	Amber	F108, Table I-a	Identical
Position					
Height*	Max: ≤1,500 mm[§] Min: ≥350 mm	R48, 6.5.4.2.2	Max: ≤2,108 mm Min: ≥381 mm	F108, Table I-a	Maximum and minimum height are both lower in the EU Height range is smaller in the EU, unless vehicle structure affects the maximum achievable lamp height Maximum and minimum heights further affected by differences in EU and US definitions
Width	Outer: ≤400 mm Inner: ≥600 mm[†]	R48, 6.5.4.1	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a	Widths are more prescriptive in the EU, while the US is more subjective
Length	-	-	At or near the front	F108, Table I-a	Lengths are not defined in the EU, while the US provides subjective length definitions
Geometric Visibility	H: I45° to O80° V: D15°[$] to U15°	R48, 6.5.5	*Lens Area*: H[Δ]: I45° to O45° V[Δ]: D15°[$] to U15° *Luminous Intensity*: H: I45° to O80° V: D15°[$] to U15°	F108, Table V-b F108, Table V-c	Geometric visibility and luminous intensity angles identical US provides an additional option to use a minimum effective luminous lens area as a visibility requirement
Photometric Visibility	H: I20° to O20° V: D10°[$] to U10°	R6, Annex 4	H: I20° to O20° V: D10°[$] to U10°	F108, Table VI-a	Identical

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima[‡]	*Class 1*: ≥175 cd @ H: 0°, V: 0° ≥17.5 cd @ H: I/O 20° V: U/D 5° *Class 1b:* ≥400 cd @ H: 0°, V: 0° ≥40 cd @ H: I/O 20° V: U/D 5°	R6, 6.1 R6, Annex 4	*Base*: ≥200 cd @ H: 0°, V: 0° ≥25 cd @ H: I/O 20° V: U/D 5° *Base x2.5:* ≥500 cd @ H: 0°, V: 0° ≥62.5 cd @ H: I/O 20° V: U/D 5°	F108, Table VI-a	EU Class 1 and 1b requirements are lower than equivalent requirements (Base and Base x2.5) in the US, regardless of lamp location or photometric visibility angle
Photometric Maxima[‡]	*Class 1*: ≤1000 cd @ H: 0°, V: 0° ≤100 cd @ H: I/O 20° V: U/D 5° *Class 1b:* ≤1200 cd @ H: 0°, V: 0° ≤120 cd @ H: I/O 20° V: U/D 5°	R6, 6.1 R6, Annex 4	-	-	Photometric maxima are prescribed in the EU, while the US does not define photometric maxima
Flashing	Required, to flash 90±30 times per min in phase with others	R48, 6.5.7	Required	F108, Table I-a	Flashing must be in phase with all other direction-indicator lamps on the same side and flash 90±30 times per minute in the EU, while the US is more subjective in its requirements

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

[§] May be increased to ≤2,100 mm if structure of vehicle does not permit upper limits

† May be reduced to ≥400 mm when vehicle width is <1,300 mm

$ May be reduced to D5° when lamp is mounted below 750 mm

Δ For unobstructed minimum effective projected luminous lens area of 2,200 mm2

‡ UN: for single function lamps positioned either ≥40 mm (Class 1) or ≤20 mm (Class 1b) from a dipped-beam headlamp and tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps positioned either ≥100 mm (Base) or <100 mm (Base x2.5) from lower beam headlamp and with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; Class 1, lamps positioned ≥40 mm from a dipped-beam headlamp; Class 1b, lamps positioned ≤20 mm from a dipped-beam headlamp; Base, lamps positioned ≥100 mm from a lower beam headlamp; Base x2.5, lamps positioned <100 mm from a lower beam headlamp.

Table 26: Current EU regulations and US standards for rear direction-indicator [rear turn signal] lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R6: UN Regulation No. 6)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory, option of Class 2a/2b lamps	R48, 6.5.1	Mandatory, Class 2a only	F108, Table I-a	Identical
Number	2	R48, 6.5.3	2	F108, Table I-a	Identical
Colour	Amber	R48, 5.15	Amber or red	F108, Table I-a	Amber colour only mandated in the EU, while the US permits either amber or red
Position					
Height*	Max: ≤1,500 mm§ Min: ≥350 mm	R48, 6.5.4.2.2	Max: ≤2,108 mm Min: ≥381 mm	F108, Table I-a	Maximum and minimum height are both lower in the EU Height range is smaller in the EU, unless vehicle structure affects the maximum achievable lamp height Maximum and minimum heights further affected by differences in EU and US definitions
Width	Outer: ≤400 mm Inner: ≥600 mm†	R48, 6.5.4.1	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a	Widths are more prescriptive in the EU, while the US is more subjective
Length	-	-	On the rear	F108, Table I-a	Lengths are not defined in the EU, while the US provides subjective length definitions
Geometric Visibility	H: I45° to O80° V: D15°$ to U15°	R48, 6.5.5	*Lens Area*: HΔ: I45° to O45° VΔ: D15°$ to U15° *Luminous Intensity*: H: I45° to O80° V: D15°$ to U15°	F108, Table V-b F108, Table V-c	Geometric visibility and luminous intensity angles identical US provides an additional option to use a minimum effective luminous lens area as a visibility requirement
Photometric Visibility	H: I20° to O20° V: D10°$ to U10°	R6, Annex 4	H: I20° to O20° V: D10°$ to U10°	F108, Table VII	Identical

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima‡	≥50 cd @ H: 0°, V: 0° ≥5 cd @ H: I/O 20° V: U/D 5°	R6, 6.1 R6, Annex 4	Amber: ≥130 cd @ Red: ≥80 cd @ H: 0°, V: 0° Amber: ≥15 cd @ Red: ≥10 cd @ H: I/O 20° V: U/D 5°	F108, Table VII	Photometric minima are lower across all colours in the EU, regardless of photometric visibility angle
Photometric Maxima‡	*Class 2a*: ≤500 cd @ H: 0°, V: 0° ≤50 cd @ H: I/O 20° V: U/D 5° *Class 2b*: ≤1000 cd @ H: 0°, V: 0° ≤100 cd @ H: I/O 20° V: U/D 5°	R6, 6.1 R6, Annex 4	Amber: ≤750 cd Red: ≤300 cd	F108, Table VII	EU Class 2a photometric maxima are lower when compared to amber lamps, and greater when compared to red lamps, in the US EU Class 2b photometric maxima are greater, regardless of colour or photometric visibility angle EU Class 2a photometric ranges are lower when compared to amber lamps and greater when compared to red lamps in the US EU Class 2b photometric ranges are greater, regardless of colour or photometric visibility angle
Flashing	Required, to flash 90±30 times per min in phase with others	R48, 6.5.7	Required	F108, Table I-a	Flashing must be in phase with all other direction-indicator lamps on the same side and flash 90±30 times per minute in the EU, while the US is more subjective in its requirements

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

§ May be increased to ≤2,100 mm if structure of vehicle does not permit upper limits

† May be reduced to ≥400 mm when vehicle width is <1,300 mm

$ May be reduced to D5° when lamp is mounted below 750 mm

Δ For unobstructed minimum effective projected luminous lens area of 5,000 mm^2

‡ UN: for single function steady illumination lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; Class 2a, steady burning rear direction-indicator lamp; Class 2b, variable intensity rear direction-indicator lamp.

Table 27: Current EU regulations and US standards for side direction-indicator lamps (R48: UN Regulation No. 48; J914: SAE Standard J914; R6: UN Regulation No. 6)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)*		Comparison
	Specification	Reference	Specification	Reference	
Applicability	Mandatory	R48, 6.5.1	Optional	J914, 3.1	EU is mandatory, while US is optional
Number	2	R48, 6.5.3	2	J914	Identical
Colour	Amber	R48, 5.15	Amber	J914, 6.2.1.1; F108, 6.1.2	Identical
Position					
Height[§]	Max: ≤1,500 mm[†] Min: ≥350 mm	R48, 6.5.4.2.1	Max: ≤1,650 mm Min: ≥500 mm	J914, 7.1.1	Maximum and minimum height are both lower in the EU Height ranges are similar, unless vehicle structure affects the maximum achievable lamp height Maximum and minimum heights further affected by differences in EU and US definitions
Width	-	-	-	-	-
Length	≤2,500 mm	R48, 6.5.4.3	As close to front as practicable	J914, 7.1.1	Lengths are prescriptive but flexible in the EU, while the US provides subjective length definitions
Geometric Visibility	H: O5° to O60° V: D15°[$] to U15°	R48, 6.5.5	H: O5° to O60° V: D5° to U30°	J914, 6.1.5.4	Vertical visibility angles are lower and vertical visibility angle ranges are smaller in the EU
Photometric Visibility	-	-	H: O5° to O60° V: D5° to U30°	J914, 6.1.5.4	-
Photometric Minima[Δ]	≥0.6 cd @ H: 0°, V: 0° ≥0.12 cd @ H: O60°, V: U30°	R6, 6.1 R6, Annex 4	≥0.6 cd @ H: 0°, V: 0° ≥0.12 cd @ H: O60°, V: U30°	J914, 6.1.5.4	Identical
Photometric Maxima[Δ]	≤280 cd	R6, 6.1 R6, Annex 4	≤280 cd	J914, 6.1.5.4	Identical
Flashing	Required, to flash 90±30 times per min in phase with others	R48, 6.5.7	Required, flash in phase with others	J914, 6.4.2	Flashing must be in phase with all other direction-indicator lamps on the same side for both and flash 90±30 times per minute in the EU

* Applicable for vehicles that are <12m in length

[§] UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

[†] May be increased to ≤2,300 mm if structure of vehicle does not permit upper limits

[$] May be reduced to D5° when lamp is mounted below 750 mm

[Δ] UN: for category 5 lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: US: for side turn signal lamps homologated with UN Regulation 6 Category 5 requirements and with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp.

Table 28: Current EU regulations and US standards for side-marker [side marker] lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R91: UN Regulation No. 91)

Property	EU (UN Regulations)* Specification	EU (UN Regulations)* Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Optional	R48, 6.18.1	Mandatory	F108	EU is optional, while US is mandatory
Number	2-4	R48, 6.18.2; R48, 6.18.4.3	2x Front 2x Rear	F108, Table I-a	Number of side marker lamps can range from 2-4 in the EU, but must be 4 (2x rear and 2x front) in the US
Colour	Amber or red (if grouped with rear position lamps)	R48, 5.15	Front: Amber Rear: Red	F108, Table I-a	Colour must be amber in the EU, unless grouping with the rear position lamps, while the colour must be amber at the front and red at the rear in the US
Position					
Height[§]	Max: ≤1,500 mm[†] Min: ≥250 mm	R48, 6.18.4.2	Min: ≥381 mm	F108, Table I-a	Minimum height is lower in the EU, while the US does not define a maximum height Maximum and minimum heights further affected by differences in EU and US definitions
Width	-	-	-	-	-
Length	One lamp fitted within the first third and/or last third of the vehicle length	R48, 6.18.4.3	Front: As far to the front as practicable Rear: As far to the rear as practicable	F108, Table I-a	Length definitions are subjective for both the EU and the US, however, the US definition is more restrictive
Geometric Visibility	*SM1*: H: B30° to F30° V: D10°[$] to U10° *SM2*: H: B45° to F45° V: D10°$ to U10°	R48, 6.18.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges

Property	EU (UN Regulations)*		US (FMVSS/SAE Standards)		Comparison
Photometric Visibility	*SM1*: H: B30° to F30° V: D10°[$] to U10° *SM2*: H: B45° to F45° V: D10°$ to U10°	R91, Annex 4	H: L45° to R45° V: D10°[$] to U10°	F108, Table X	Horizontal photometric visibility angle ranges are smaller for SM1 lamps in the EU, but identical for SM2 lamps
Photometric Minima[Δ]	*SM1*: ≥4 cd @ H: 0°, V: 0° ≥0.6 cd @ H: B/F 45° V: D/U 10° *SM2*: ≥0.6 cd	R91, 7.1.1	Front: ≥0.62 cd Rear: ≥0.25 cd	F108, Table X	Photometric minima are greater in the reference axis for SM1 lamps in the EU Photometric minima for SM2 lamps in the EU are smaller for front side marker lamps and greater for rear side marker lamps
Photometric Maxima[Δ]	≤25 cd	R91, 7.1.2	-	-	Photometric maxima are prescribed in the EU, while the US does not define photometric maxima
Flashing	Optional, to flash 90±30 times per minute in phase with others	R48, 6.5.7	Optional	F108, Table I-a	Flashing must be in phase with all other direction-indicator lamps on the same side in the EU, optional in the US

* Applicable for vehicles that are ≤6m in length

[§] UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

[†] May be increased to ≤2,100 mm if structure of vehicle does not permit upper limits

[$] May be reduced to D5° when lamp is mounted below 750 mm

[Δ] UN: for SM2 category lamps tested at voltage supplies of 6.75v and 13.5v; US: for non-reflecting single function lamps with photometric measurements made at ≥1.2m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; Category SM1, high performance side marker lamp; Category SM2, low performance side marker lamp.

Table 29: Current EU regulations and US standards for S1/S2 category stop-lamps [stop lamps] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R7: UN Regulation No. 7)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory, option of S1/S2 category stop lamps	R48, 6.7.1	Mandatory, S1 category lamps only	F108	The EU permits the use of variable intensity stop lamps, while the US prohibits their use
Number	2	R48, 6.7.2	2	F108, Table I-a	Identical
Colour	Red	R48, 5.15	Red	F108, Table I-a	Identical
Position					
Height*	Max: ≤1,500 mm§ Min: ≥350 mm	R48, 6.7.4.2.1	Max: ≤1,829 mm Min: ≥381 mm	F108, Table I-a	Maximum and minimum height are both lower in the EU Height range is smaller in the EU, unless vehicle structure affects the maximum achievable lamp height Maximum and minimum heights further affected by differences in EU and US definitions
Width	Outer: ≤400 mm	R48, 6.7.4.1	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a	Widths are more prescriptive in the EU, while the US is more subjective
Length	At the rear of the vehicle	R48, 6.7.4.4	On the rear	F108, Table I-a	Identical
Geometric Visibility	H: I45°† to O45° V: D15°$ to U15°	R48, 6.7.5	*Lens Area*: HΔ: I45° to O45° VΔ: D15°$ to U15° *Luminous Intensity*: H: I45° to O45° V: D15°$ to U15°	F108, Table V-b F108, Table V-c	Geometric visibility and luminous intensity angles identical US provides an additional option to use a minimum effective luminous lens area as a visibility requirement
Photometric Visibility	H: I20° to O20° V: D10°$ to U10°	R7, Annex 4	H: L20° to R20° V: D10°$ to U10°	F108, Table IX	Identical

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima‡	≥60 cd @ H: 0°, V: 0° ≥6 cd @ H: I/O 20° V: U/D 5°	R7, 6.1.4.1 R7, Annex 4	≥80 cd @ H: 0°, V: 0° ≥10 cd @ H: I/O 20° V: U/D 5°	F108, Table IX	Photometric minima are lower in the EU, regardless of photometric visibility angle
Photometric Maxima‡	*Category S1*: ≤260 cd @ H: 0°, V: 0° ≤26 cd @ H: I/O 20° V: U/D 5° *Category S2*: ≤730 cd @ H: 0°, V: 0° ≤73 cd @ H: I/O 20° V: U/D 5°	R7, 6.1.4.2 R7, Annex 4	≤300 cd	F108, Table IX	Photometric maxima are lower in the EU for S1 category stop lamps Photometric maxima are greater in the EU for S2 category stop lamps Photometric range is lower in the EU for S1 category stop lamps Photometric range is greater in the EU for S2 category stop lamps

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

§ May be increased to ≤2,100 mm if structure of vehicle does not permit upper limits

† May be reduced to I20° when lamp is mounted below 750 mm

$ May be reduced to D5° when lamp is mounted below 750 mm

Δ For unobstructed minimum effective projected luminous lens area of 5,000 mm^2

‡ UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; Category S1, steady burning stop lamp; Category S2, variable intensity stop lamp.

Table 30: Current EU regulations and US standards for S3/S4 category stop-lamps [high-mounted stop lamps] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R7: UN Regulation No. 7)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory, option of S3/S4 category stop lamps	R48, 6.7.1	Mandatory, S3 category lamps only	F108	The EU permits the use of variable intensity high-mounted stop lamps, while the US prohibits their use
Number	1	R48, 6.7.2	1	F108, Table I-a	Identical
Colour	Red	R48, 5.15	Red	F108, Table I-a	Identical
Position					
Height*	Lower edge shall be: Above upper edge of S1/S2 lamps <u>and either</u> ≤150 mm below lower edge of rear window <u>or</u> ≥850 mm from the ground	R48, 6.7.4.2.2	≤153 mm below lower edge of rear window of convertibles <u>or</u> ≤77 mm below lower edge of rear window of other passenger cars	F108, S6.1.4.1.1	EU requires S3/S4 category stop lamps to be located above S1/S2 category stop lamps, while the US provides no such mounting height restriction. EU allow lower mounting height positions in passenger cars when the lower edge of the rear window is used as a reference EU allow marginally greater mounting height positions in convertible cars when the lower edge of the rear window is used as a reference
Width	On median longitudinal plane	R48, 6.7.4.1	Centred on the vertical centreline	F108, Table I-a	Identical
Length	-	-	On the rear, including mounting on glazing	F108, Table I-a	Lengths are not defined in the EU, while the US provides subjective length definitions
Geometric Visibility	H: L10° to R10° V: D5° to U10°	R48, 6.7.5	H§: L45° to R45°	F108, Table V-b F108, Table V-c	Left and right horizontal visibility angles and horizontal visibility angle ranges are smaller in the EU Vertical visibility angles are prescribed in the EU, while the US does not define vertical visibility ranges

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Visibility	H: L10° to R10° V: D5° to U10°	R7, Annex 4	H: L10° to R10° V: D5° to U10°	F108, Table XV	Identical
Photometric Minima†	≥25 cd @ H: 0°, V: 0° ≥8 cd @ H: L/R 10° V: U10°	R7, 6.1.4.3 R7, Annex 4	≥25 cd @ H: 0°, V: 0° ≥8 cd @ H: L/R 10° V: U10°	F108, Table XV	Identical
Photometric Maxima†	*Category S3*: ≤110 cd @ H: 0°, V: 0° ≤35.2 cd @ H: I/O 10° V: U10° *Category S4*: ≤160 cd @ H: 0°, V: 0° ≤51.2 cd @ H: I/O 10° V: U10°	R7, 6.1.4.4 R7, Annex 4	≤160 cd	F108, Table XV	Photometric maxima are lower in the EU for S3 category stop lamps Photometric maxima are identical for S4 category stop lamps in the reference axis Photometric ranges are lower in the EU for S3 category stop lamps Photometric ranges are identical for S4 category stop lamps in the reference axis

* UN: all measurements are to the lower edge of the lamp, unless otherwise stated; US: all measurements are made to ensure that no portion of the lamp achieves these values

§ For unobstructed minimum effective projected luminous lens area of 2,903 mm^2

† UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; Category S3, steady burning high-mounted stop lamp; Category S4, variable intensity high-mounted stop lamp.

Table 31: Current EU regulations and US standards for front position lamps [front position (parking) lamps] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R7: UN Regulation No. 7; J222: SAE Standard No. J222)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory	R48, 6.9.1 R48, 5.12	Mandatory	F108, Table I-a J222	Identical Front position lamps in both the US and EU have dual functionality with parking lamps
Number	2	R48, 6.9.2	2	F108, Table I-a J222, 3.1	Identical
Colour	White	R48, 5.15	White or Amber	F108, Table I-a J222, 6.2	White colour only mandated in the EU, while the US permits either white or amber
Position					
Height*	Max: ≤1,500 mm§ Min: ≥250 mm	R48, 6.9.4.2	Max: ≤1,829 mm Min: ≥381 mm	F108, Table I-a	Maximum and minimum height are both lower in the EU Height range is smaller in the EU, unless vehicle structure affects the maximum achievable lamp height Maximum and minimum heights further affected by differences in EU and US definitions
Width	Outer: ≤400 mm	R48, 6.9.4.1	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a J222, 7.1.1	Widths are more prescriptive in the EU, while the US is more subjective
Length	-	-	On the front	F108, Table I-a J222, 3.1	Lengths are not defined in the EU, while the US provides subjective length definitions
Geometric Visibility	H: I45°† to O80°$ V: D15°Δ to U15°	R48, 6.9.5	*Lens Area*: H‡: I45° to O45° V‡: D15°$ to U15° *Luminous Intensity*: H: I45° to O80° V: D15°Δ to U15°	F108, Table V-b F108, Table V-c J222, 6.5.1 J222, 6.5.2.3	Geometric visibility and luminous intensity angles similar, but can vary in the EU in respect to certain scenarios US provides an additional option to use a minimum effective luminous lens area as a visibility requirement
Photometric Visibility	H: I20° to O20° V: D10°Δ to U10°	R7, Annex 4	H: I20° to O20° V: D10°Δ to U10°	F108, Table XIV J222, 6.1.5	Identical

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima[₸]	≥4 cd @ H: 0°, V: 0° ≥0.4 cd @ H: I/O 20° V: U/D 5°	R7, 6.1.1 R7, Annex 4	≥4 cd @ H: 0°, V: 0° ≥0.4 cd @ H: I/O 20° V: U/D 5°	F108, Table XIV J222, 6.1.5	Identical
Photometric Maxima[₸]	≤140 cd @ H: 0°, V: 0° ≤14 cd @ H: I/O 20° V: U/D 5°	R7, 6.1.1 R7, Annex 4	≤125 cd @ V >0° ≤250 cd @ V <0°	F108, Table XIV J222, 6.1.5	Photometric maxima, below the horizontal axis, are greater in the US than the EU Photometric maxima, above the horizontal axis and at large photometric angles, are greater in the US than in the EU

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

§ May be increased to ≤2,100 mm if structure of vehicle does not permit upper limits

† May be reduced to I20° when lamp is mounted below 750 mm

$ May be reduced to O45° at the discretion of the manufacturer when side-marker lamp is installed on vehicle

Δ May be reduced to D5° when lamp is mounted below 750 mm

‡ For unobstructed minimum effective projected luminous lens area of 1,300 mm2

₸ UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp.

Table 32: Current EU regulations and US standards for rear position lamps [taillamps] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R7: UN Regulation No. 7)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory, option of R/R1/R2 category lamps	R48, 6.10.1	Mandatory, R/R1 category lamps only	F108, Table I-a	The EU permits the use of variable intensity rear position lamps, while the US prohibits their use
Number	2	R48, 6.10.2	2	F108, Table I-a	Identical
Colour	Red	R48, 5.15	Red	F108, Table I-a	Identical
Position					
Height*	Max: ≤1,500 mm§ Min: ≥350 mm	R48, 6.10.4.2	Max: ≤1,829 mm Min: ≥381 mm	F108, Table I-a	Maximum and minimum height are both lower in the EU Height range is smaller in the EU, unless vehicle structure affects the maximum achievable lamp height Maximum and minimum heights further affected by differences in EU and US definitions
Width	Outer: ≤400 mm	R48, 6.10.4.1	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a	Widths are more prescriptive in the EU, while the US is more subjective
Length	The rear of the vehicle	R48, 6.10.4.3	On the rear	F108, Table I-a	Identical
Geometric Visibility	H: I45°† to O80°$ V: D15°Δ to U15°	R48, 6.10.5	*Lens Area*: H‡: I45° to O45° V‡: D15°Δ to U15° *Luminous Intensity*: H: I45° to O80° V: D15°Δ to U15°	F108, Table V-b F108, Table V-c	Geometric visibility and luminous intensity angles identical, although in certain circumstances the inboard and outboard geometric visibility angles can be reduced US provides an additional option to use a minimum effective luminous lens area as a visibility requirement
Photometric Visibility	H: I20° to O20° V: D10°Δ to U10°	R7, Annex 4	H: L20° to R20° V: D10°Δ to U10°	F108, Table VIII	Identical

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima[₸]	≥4 cd @ H: 0°, V: 0° ≥0.4 cd @ H: I/O 20° V: U/D 5°	R7, 6.1.3 R7, Annex 4	≥2 cd @ H: 0°, V: 0° ≥0.3 cd @ H: I/O 20° V: U/D 5°	F108, Table VIII	Photometric minima are greater in the EU, regardless of photometric visibility angle
Photometric Maxima[₸]	*Category R/R1*: ≤17 cd @ H: 0°, V: 0° ≤1.7 cd @ H: I/O 20° V: U/D 5° *Category R2*: ≤42 cd @ H: 0°, V: 0° ≤4.2 cd @ H: I/O 20° V: U/D 5°	R7, 6.1.3 R7, Annex 4	≤18 cd	F108, Table VIII	Photometric maxima are lower in the EU for R/R1 category stop lamps Photometric maxima are greater in the EU for R2 category stop lamps Photometric range is lower in the EU for R/R1 category stop lamps Photometric range is greater in the EU for R2 category stop lamps

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

§ May be increased to ≤2,100 mm if structure of vehicle does not permit upper limits

† May be reduced to I20° when lamp is mounted below 750 mm

$ May be reduced to O45° at the discretion of the manufacturer when side-marker lamp is installed on vehicle

Δ May be reduced to D5° when lamp is mounted below 750 mm

‡ For unobstructed minimum effective projected luminous lens area of 1,250 mm2

₸ UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; R/R1, steady burning rear position lamp; R2, variable intensity rear position lamp.

Table 33: Current EU regulations and US standards for end-outline marker lamps [clearance lamps] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R7: UN Regulation No. 7; SAE Standard No. J2042)

Property	EU (UN Regulations)* Specification	EU (UN Regulations)* Reference	US (FMVSS/SAE Standards)§ Specification	US (FMVSS/SAE Standards)§ Reference	Comparison
Applicability	Optional, option of AM/RM1/RM2 category lamps	R48, 6.13.1	Optional	J2042	Identical for applicability The EU permits the use of variable intensity rear end-outline marker lamps, while the US prohibits their use
Number	4-8	R48, 6.13.2	2x Front 2x Rear	F108, Table I-a	Number of side marker lamps can range from 4-8 in the EU, but must be 4 (2x rear and 2x front) in the US
Colour	Front: White Rear: Red	R48, 5.15	Front: Amber Rear: Red	F108, Table I-a	Colour must be white at the front and red at the rear in the EU, while the colour must be amber at the front and red at the rear in the US
Position					
Height	Front: Upper edge not lower than upper edge of wind-screen Rear: At maximum height possible	R48, 6.13.4.2	As near the top as practicable	F108, Table I-a	Minimum height at front is lower in the EU Identical for the rear
Width	Outer: ≤400 mm and as close as possible to the extreme outer edge of the vehicle	R48, 6.13.4.1	Indicate the overall width of the vehicle and symmetric about the vertical centreline	F108, Table I-a	Widths are more prescriptive in the EU, while the US is more subjective

Property	EU (UN Regulations)*		US (FMVSS/SAE Standards)[§]		Comparison
Length	-	-	Front: On the front Rear: On the rear Other: Any other location to ensure that overall width of vehicle is indicated	F108, Table I-a	Lengths are not defined in the EU, while the US provides subjective length definitions
Other	Distances must be ≥200 mm vertically from position lamps	R48, 6.13.9	-	-	Minimum vertical distance from position lamps are prescribed in the EU, while the US does not define these minimum distances
Geometric Visibility	H: O80° V: D20° to U5°	R48, 6.13.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges
Photometric Visibility	H: 0° to O20° V: D10° to U5°	R7, Annex 4	H: I45° to O45°[†] V: D10°[$] to U10°	F108, Table XI	Smaller horizontal and upward photometric visibility angles required in the EU
Photometric Minima[Δ]	≥4 cd @ H: 0°, V: 0° ≥0.4 cd @ H: O20°, V: D/U 5°	R7, 6.1.1 R7, 6.1.3	Front: ≥0.62 cd Rear: ≥0.25 cd	F108, Table XI	Photometric minima are greater in the reference axis for all lamps in the EU Absolute photometric minima for all lamps in the EU are smaller than photometric minima for front end-outline marker lamps and greater than photometric minima for rear end-outline marker lamps

Property	EU (UN Regulations)*		US (FMVSS/SAE Standards)[§]		Comparison
Photometric Maxima[Δ]	*AM*: ≥140 cd @ H: 0°, V: 0° ≥14 cd @ H: O20°, V: D/U 5° *RM1*: ≥17 cd @ H: 0°, V: 0° ≥1.7 cd @ H: O20°, V: D/U 5° *RM2*: ≥42 cd @ H: 0°, V: 0° ≥4.2 cd @ H: O20°, V: D/U 5°	R7, 6.1.1 R7, 6.1.3	Front: - Rear: ≥15 cd	F108, Table XI	Front photometric maxima are prescribed in the EU, while the US does not define front photometric maxima Rear photometric maxima are greater in the reference axis for all lamps in the EU Absolute rear photometric minima for all lamps in the EU are smaller than photometric minima for rear end-outline marker lamps

* Applicable for vehicles that are between 1.8-2.1 m in length

[§] Applicable for vehicles that are ≤2302 mm in width

[†] May be reduced to D0° when lamp is mounted at locations other than the front or rear

[$] May be reduced to D5° when lamp is mounted below 750 mm

[Δ] UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28v; US: for non-reflecting single function lamps with photometric measurements made at ≥1.2m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; AM, front end-outline marker lamp; RM1, steady burning rear end-outline marker lamp; RM2, variable intensity rear end-outline marker lamp.

Table 34: Current EU regulations and US standards for parking lamps (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R7: UN Regulation No. 7)

Property	EU (UN Regulations)* Specification	EU (UN Regulations)* Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Optional, for either front and rear lamps or side mounted lamps only	R48, 6.12.1	Mandatory, for front mounted lamps only	F108, Table I-a J222	US mandate the installation of front mounted parking lamps only, while the EU provides the option of installing either front and rear parking lamps, side mounted parking lamps or no parking lamps Difference in philosophy may be due to the mandatory requirements for side marker lamps in the US, which can potentially perform the function of front, rear and side mounted parking lamps
Number	*Front*: 2 *Rear*: 2 *Side*: 2	R48, 6.12.2 R48, 6.12.3	2	F108, Table I-a J222, 3.1	Front: Identical Side and rear: Cannot compare due to differing philosophies
Colour	*Front*: White *Rear*: Red *Side*: Amber	R48, 5.15	White or Amber	F108, Table I-a J222, 6.2	Front: EU require white coloured lamps only, while the US allows either white or amber Side and rear: Cannot compare due to differing philosophies
Position					
Height§	-	-	Max: ≤1,829 mm Min: ≥381 mm	F108, Table I-a	Heights are not defined in the EU, while the US provides prescriptive height definitions
Width	*Front and Rear*: Outer ≤400 mm *Side*: On the sides	R48, 6.12.4.1	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a J222, 7.1.1	Front: Widths are more prescriptive in the EU, while the US is more subjective Side and rear: Cannot compare due to differing philosophies
Length	-	-	On the front	F108, Table I-a J222, 3.1	Lengths are not defined in the EU, while the US provides subjective length definitions

Property	EU (UN Regulations)*		US (FMVSS/SAE Standards)		Comparison
Geometric Visibility	*Forward and Rearward Facing*: H: 0° to O45° V: D15°[†] to U15°	R48, 6.12.5	*Lens Area*: H[$]: I45° to O45° V[$]: D15°[†] to U15° *Luminous Intensity*: H: I45° to O80° V: D15°[†] to U15°	F108, Table V-b F108, Table V-c J222, 6.5.1 J222, 6.5.2.3	The EU requires forward and rearward facing geometric visibility angles, regardless of lamp location, while the US requires forward facing angles only Greater inboard geometric visibility angles are required in the US The US provides an additional option to use a minimum effective luminous lens area as a visibility requirement
Photometric Visibility	H: I20° to O20° V: D10°[†] to U10°	R77, Annex 4	H: L20° to R20° V: D10°[†] to U10°	F108, Table XIV J222, 6.1.5	Identical
Photometric Minima[Δ]	≥2 cd @ H: 0°, V: 0° ≥0.2 cd @ H: O20°, V: U/D 5°	R77, 7.1 R77, Annex 4	≥4 cd @ H: 0°, V: 0° ≥0.4 cd @ H: L/R 20° V: U/D 5°	F108, Table XIV J222, 6.1.5	US requires greater photometric minima, regardless of photometric visibility angle
Photometric Maxima[Δ]	*Forward Facing*: ≤60 cd @ H: 0°, V: 0° ≤6 cd @ H: O20°, V: U/D 5° *Rearward Facing:* ≤30 cd @ H: 0°, V: 0° ≤3 cd @ H: O20°, V: U/D 5°	R77, 7.1 R77, Annex 4	≤125 cd @ V >0° ≤250 cd @ V <0°	F108, Table XIV J222, 6.1.5	Photometric maxima are much greater (2.1-83 times larger) in the US than the EU
Combination with Position Lamps	Lamps that meet the requirements of front or rear position lamps are permitted	R48, 6.12.9	Front position lamps and parking lamps considered equivalent	J222	Parking lamp function allowed to be provided by lamps that meet the requirements of front and rear position lamps in the EU, while the US considers that front position and parking lamps are equivalent

* Applicable to vehicles ≤6m in length and ≤2m in width only

§ US: to the centre of the lamp

† May be reduced to D5° when lamp is mounted below 750 mm

$ For unobstructed minimum effective projected luminous lens area of 1,250 mm2

Δ UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥1.2m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp.

Table 35: Current EU regulations and US standards for front fog lamps (R48: UN Regulation No. 48; R19: UN Regulation No. 19; J583: SAE Standard No. J583)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Optional	R48, 6.3.1	Optional	J583	Identical
Number	2	R48, 6.3.2	2	J583	Identical
Colour	White or Selective Yellow	R48, 5.15	White or Selective Yellow	J583, 6.4	Identical
Position					
Height*	Max: $\leq$800 mm§ Min: $\geq$250 mm	R48, 6.3.4.2	Top edge no higher than top edge of the low beam headlamp	J583, 7.1	Heights are more prescriptive in the EU, while the US is more subjective
Width	Outer: $\leq$400 mm	R48, 6.3.4.1	-	-	Widths are not defined in the US, while the EU provides prescriptive width definitions
Length	At the front	R48, 6.3.4.3	-	-	Lengths are not defined in the US, while the EU provides subjective length definitions
Vertical Orientation					
Vertical Inclination Limit†	*Class B*: D0% to D1.5% *Class F3*: $\phi\leq$2000 lm: D0% to D1% $\phi>$2000 lm & $h<$0.8 m: D1.0% to D3.0% $\phi>$2000 lm & $h>$0.8 m: D1.5% to D3.5%	R48, 6.3.6.1	*Class F*: $h\leq$0.65 m: D0.75° $h>$0.65 m: D1° *Class F3*: D1°	J583, 5.2.5.2 J583, 7.3.1	No discernible differences between EU and US vertical inclination limits for the cut-off, apart from EU Class F3 lamps with a luminous flux of <2000 lm (0.75° = 1.31% inclination; 1° = 1.75% inclination) The EU provides an acceptable range for vertical inclination, while the US provides a target value

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Headlamp Levelling System	Mandatory, if unable to satisfy vertical inclination limits across range of static loading scenarios Optional, to account for prevailing ambient conditions	R48, 6.3.6.2 R48, Annex 5 R48, 6.3.9	-	-	EU requirements only mandatory if headlamps are unable to satisfy vertical inclination limits across the range of static loading scenarios Headlamp levelling system requirements are not specified in the US
Automated Headlamp Levelling	Mandatory for lamps with luminous flux >2,000 lumens	R48, 6.3.6.1.2.2.1 R48, 6.3.6.2.1	-	-	Mandatory requirement for automated headlamp levelling systems in the EU for lamps with a luminous flux >2,000 lumens Automated headlamp levelling system requirements are not specified in the US
Geometric Visibility	H: I10° to O45° V: D5° to U5°	R48, 6.3.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges
Photometric Visibility	*Class B*: H: L26° to R26° V: D3.5° to U15° *Class F3*: H: L60° to R60° V: D6° to U60°	R19, 6.3.5 R19, 6.4.3 R19, Annex 4	*Class F*: H: L15° to R15° V: D3° to U60° *Class F3*: H: L60° to R60° V: D6° to U60°	J583, 6.2.5.2 J583, 6.2.5.3	Horizontal and vertical photometric visibility angle ranges are identical for Class F3 lamps EU Class B lamps have greater horizontal and downward photometric visibility angles when compared to US Class F lamps, while Class F lamps have a greater upward photometric visibility angle

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima[$]	*Class B*: ≥1,700 cd @ H: L/R 3°, V: D2.5° ≥85 cd @ H: L5° to R5° V: 0° to U1.75° *Class F3*: ≥2,700 cd @ H: L/R 3°, V: D2.5° ≥450 cd @ H: L/R 35° V: D1.5° to D4.5°	R19, 6.3.5 R19, 6.4.3	*Class F*: ≥2,400 cd @ H: L/R 3°, V: D1.5° ≥1,200 cd @ H: L/R 9° & L/R 15° V: D1.5° & D3° *Class F3*: ≥2,160 cd @ H: L/R 3°, V: D2.5° ≥360 cd @ H: L/R 35° V: D1.5° to D4.5°	J583, 6.2.5.2 J583, 6.2.5.3	For the harmonised test point: EU Class F3 minimum photometric requirements are greater than all US requirements. EU Class B minimum photometric requirements are smaller than all US requirements For the absolute photometric minima: US Class F minimum photometric requirements are greater than all EU requirements. EU Class B minimum photometric requirements are smaller than all US requirements. Due to the large differences in photometric visibility angle, however, these results are incomparable.
Photometric Maxima[Δ]	*Class B*: ≤570 cd @ H: 0°, V: U2° ≤11,500 cd @ H: L22° to R22° V: D1.75° to D3.5° *Class F3*: ≤245 cd @ H: 0°, V: U2° ≤12,000 cd @ H: L10° to R10° V: D1.5° to D3.5°	R19, 6.3.5 R19, 6.4.3	≤295 cd @ H: 0°, V: U2° *Class F*: ≤12,000 cd @ H: L3° to R3° V: D1.5° *Class F3*: ≤14,400 cd @ H: L10° to R10° V: D1.5° to D3.5°	J583, 6.2.5.2 J583, 6.2.5.3	For the harmonised test point: EU Class B maximum photometric requirements are greater than US requirements. EU Class F3 maximum photometric requirements are smaller than US requirements. For the absolute photometric maxima: US requirements are greater than or equivalent to EU requirements. Due to the large differences in photometric visibility angle, however, these results are incomparable.

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Maxima for Oncoming Traffic	*Class B*: ≤570 cd @ H: L3°, V: U1° *Class F3*: ≤360 cd @ H: L3°, V: U1°	R19, 6.3.5 R19, 6.4.3	≤435 cd @ H: L3°, V: U1°	J583, 6.2.5.2 J583, 6.2.5.3	EU Class B maximum photometric requirements for oncoming traffic is greater than US requirements EU Class F3 maximum photometric requirements for oncoming traffic is lower than US requirements

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp

§ No point on the apparent surface in the direction of the reference axis must be higher than the highest point on the apparent surface in the direction of the reference axis of the dipped-beam headlamp

† UN: vertical inclination of the dipped-beam cut-off defined based on the mounting height (h) of the lower edge of the apparent surface of the dipped-beam headlamp, as measured on an unloaded vehicle with one person in the driver's seat, in the direction of the headlamp reference axis; US: vertical inclination defined based on the angle of the cut-off maximum gradient from the horizontal axis

$ Photometric minima and coordinates are defined for both the absolute photometric minima required and the photometric minima required at the harmonised test point (H: L/R 3°, V: D2.5/1.5°); UN: for both Class B and Class F3 front fog lamps (UN regulation 19), for photometric measurements made at ≥25m and test voltages of 6.3v, 13.2v and 28.0v; US: for both Class F and Class F3 front fog lamps (SAE standard J583), for photometric measurements made at ≥10m and a test voltage 12.8v

Δ Photometric maxima and coordinates are defined for both the absolute photometric maxima required and the photometric maxima required at the harmonised test point (H: 0°, V: D2°); UN: for both Class B and Class F3 front fog lamps (UN regulation 19), for photometric measurements made at ≥25m and test voltages of 6.3v, 13.2v and 28.0v; US: for both Class F and Class F3 front fog lamps (SAE standard J583), for photometric measurements made at ≥10m and a test voltage 12.8v

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; Class B/F, low performance front fog lamp; Class F3, high performance front fog lamp.

Table 36: Current EU regulations and US standards for rear fog lamps [rear fog lamp systems] (R48: UN Regulation No. 48; R38: UN Regulation No. 38; J1319: SAE Standard No. J1319)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Specification	Reference	Specification	Reference	
Applicability	Mandatory, option of F/F1/F2 category lamps	R48, 6.11.1	Optional, F/F1 category lamps only	J1319	The EU mandates the use of rear fog lamps, while it is an optional requirement in the US The EU permits the use of variable intensity rear position lamps
Number	1 or 2	R48, 6.11.2	1 or 2	J1319, 3.2	Identical
Colour	Red	R48, 5.15	Red	J1319, 3.1	Identical
Position					
Height*	Max: ≤1,000 mm Min: ≥250 mm	R48, 6.11.4.2	-	-	Heights are not defined in the US, while the EU provides prescriptive height definitions
Width	One lamp: on the opposite side to traffic direction or on longitudinal plane Two lamps: -	R48, 6.11.4.1	One lamp: on or to the left of centreline Two lamps: symmetrically located about centreline	J1319, 7.1.2	Identical for one lamp systems Two lamp system widths are not defined in the EU, while the US provides subjective width definitions
Length	At the rear	R48, 6.11.4.3	-	-	Lengths are not defined in the US, while the EU provides subjective length definitions
Other	Distance must be >100 mm from stop lamps	R48, 6.11.9	Distance must be >100 mm from stop lamps	J1319, 7.1.1	Identical
Geometric Visibility	H: L25° to R25° V: D5° to U5°	R48, 6.11.5	H: L45° to R45° V: D5° to U5°	J1319, 7.1.4	Horizontal visibility angles are lower and horizontal visibility angle ranges are smaller in the EU
Photometric Visibility	H: L10° to R10° V: D5° to U5°	R38, Annex 3	H: L10° to R10° V: D5° to U5°	J1319, 6.1.5.1	Identical

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima[₸]	≥150 cd @ H: 0°, V: 0° ≥75 cd @ H: L/R 5° V: U/D 2.5°	R38, 6.2 R38, Annex 3	≥125 cd @ H: 0°, V: 0° ≥62.5 cd @ H: L/R 5° V: U/D 2.5°	J1319, 6.1.5.1	Photometric minima are greater in the EU, regardless of photometric visibility angle

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

§ May be increased to ≤2,100 mm if structure of vehicle does not permit upper limits

† May be reduced to I20° when lamp is mounted below 750 mm

$ May be reduced to O45° at the discretion of the manufacturer when side-marker lamp is installed on vehicle

Δ May be reduced to D5° when lamp is mounted below 750 mm

‡ For unobstructed minimum effective projected luminous lens area of 1,250 mm2

₸ UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; F/F1, steady burning rear fog lamp; F2, variable intensity rear fog lamp.

Table 37: Current EU regulations and US standards for rear non-triangular retro-reflectors [rear reflex reflectors] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R23: UN Regulation No. 3)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory	R48, 6.14.1	Mandatory	F108, Table I-a	Identical
Number	Minimum of 2	R48, 6.14.2	2	F108, Table I-a	More than 2 reflectors may be used in the EU
Colour	Red	R48, 5.15	Red	F108, Table I-a	Identical
Position					
Height*	Max: ≤900 mm[§] Min: ≥250 mm	R48, 6.14.4.2	Max: ≤1,524 mm Min: ≥381 mm	F108, Table I-a	Maximum and minimum height are both lower in the EU Height range is smaller in the EU, unless vehicle structure affects the maximum achievable reflector height Maximum and minimum heights further affected by differences in EU and US definitions
Width	Outer: ≤400 mm	R48, 6.14.4.1	As far apart as practicable and symmetric about vertical centreline	F108, Table I-a	Widths are more prescriptive in the EU, while the US is more subjective
Length	At the rear	R48, 6.14.4.3	On the rear	F108, Table I-a	Identical
Geometric Visibility	H: I30° to O30° V: D10°[†] to U10°	R48, 6.14.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges
Photometric Visibility					

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Illumination **Angle**	*Position 1*: H: 0°, V: 0° *Position 2*: H: 0°, V: D/U 10°[†] *Position 3*: H: L/R 5° V: D/U 20°	R3, Annex 7	*Position 1*: H: 0°, V: 0° *Position 2*: H: 0°, V: U10° *Position 3*: H: 0°, V: D10°[†] *Position 4*: H: L20°, V: 0° *Position 5*: H: R20°, V: 0°	F108, Table XVI-a	Horizontal illumination angles are smaller in the EU, while vertical angles are smaller in the US
Angle of Divergence	Minimum: 20' Maximum: 1°30'	R3, Annex 7	Minimum: 0.2° Maximum: 1.5°	F108, Table XVI-a	The minimum angle of divergence is smaller in the EU (20' = 0.033°), while the maximum angles of divergence are identical
CIL Minima[$]	*Position 1*: 20': 300 mcd/lux 1°30': 5 mcd/lux *Position 2*: 20': 200 mcd/lux 1°30': 2.8 mcd/lux *Position 3*: 20': 100 mcd/lux 1°30': 2.5 mcd/lux	R3, Annex 7	*Position 1*: 0.2°: 420 mcd/lux 1.5°: 6 mcd/lux *Position 2 & 3*: 0.2°: 280 mcd/lux 1.5°: 5 mcd/lux *Position 4 & 5*: 0.2°: 140 mcd/lux 1.5°: 3 mcd/lux	F108, Table XVI-a	Greater CIL minima are required in the US, regardless of illumination angle or angle of divergence
CIL Maxima	-	-	-	-	N/A
Shape	Triangular shaped retro-reflectors prohibited	R3, Annex 5	-	-	EU regulations prohibit the use of triangular shaped retro-reflectors, while US standards have no shape restrictions

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp; US: to the centre of the lamp

§ May be increased to ≤1,200 mm if grouped with any rear lamp(s) or increased to ≤1,500 mm if structure of vehicle does not permit upper limits

† May be reduced to D5° when lamp is mounted below 750 mm

$ US: for photometric measurements made at ≥30.5m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; CIL, coefficient of luminous intensity.

Table 38: Current EU regulations and US standards for front non-triangular retro-reflectors (R48: UN Regulation No. 48; R23: UN Regulation No. 3)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory, for all vehicles with forward facing concealable lamp reflectors Optional, on all other vehicles	R48, 6.16.1	-	-	N/A
Number	Minimum of 2	R48, 6.16.2	-	-	N/A
Colour	Colourless	R48, 5.15	-	-	N/A
Position					
Height*	Max: ≤900 mm§ Min: ≥250 mm	R48, 6.16.4.2	-	-	N/A
Width	Outer: ≤400 mm	R48, 6.16.4.1	-	-	N/A
Length	At the front	R48, 6.16.4.3	-	-	N/A
Geometric Visibility	H: I30° to O30° V: D10°† to U10°	R48, 6.16.5	-	-	N/A
Photometric Visibility					
Illumination Angle	*Position 1*: H: 0°, V: 0° *Position 2*: H: 0°, V: D/U 10°† *Position 3*: H: L/R 5° V: D/U 20°	R3, Annex 7	-	-	N/A
Angle of Divergence	Minimum: 20' Maximum: 1°30'	R3, Annex 7	-	-	N/A

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
CIL Minima	*Position 1*: 20': 1200 mcd/lux 1°30': 20 mcd/lux *Position 2*: 20': 800 mcd/lux 1°30': 11.2 mcd/lux *Position 3*: 20': 400 mcd/lux 1°30': 10 mcd/lux	R3, Annex 7	-	-	N/A
CIL Maxima	-	-	-	-	N/A
Shape	Triangular shaped retro-reflectors prohibited	R3, Annex 5	-	-	N/A

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp

§ May be increased to ≤1,500 mm if structure of vehicle does not permit upper limits

† May be reduced to D5° when lamp is mounted below 750 mm

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; CIL, coefficient of luminous intensity.

Table 39: Current EU regulations and US standards for side non-triangular retro-reflectors [side reflex reflectors] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R23: UN Regulation No. 3)

Property	EU (UN Regulations)* Specification	Reference	US (FMVSS/SAE Standards) Specification	Reference	Comparison
Applicability	Optional	R48, 6.17.1	Mandatory	F108, Table I-a	Identical
Number	Minimum of 4	R48, 6.17.2 R48, 6.17.4.3	2x Front 2x Rear	F108, Table I-a	The US requires four retro reflectors only, while the EU requires a minimum of four retro-reflectors
Colour	Amber, or red (if grouped with rear position lamps)	R48, 5.15	Front: Amber Rear: Red	F108, Table I-a	Identical
Position					
Height[§]	Max: ≤1500 mm Min: ≥250 mm	R48, 6.17.4.2	Max: ≤1,524 mm Min: ≥381 mm	F108, Table I-a	Maximum and minimum height are both lower in the EU Height range is greater in the EU Maximum and minimum heights further affected by differences in EU and US definitions
Width	-	-	On each side	F108, Table I-a	Widths are prescribed in the US, while the EU does not define widths
Length	One lamp fitted within the first third and/or last third of the vehicle length	R48, 6.17.4.3	Front: As far to the front as practicable Rear: As far to the rear as practicable	F108, Table I-a	Length definitions are subjective for both the EU and the US, however, the US definition is more restrictive
Geometric Visibility	H: F45° to R45° V: D10°[†] to U10°	R48, 6.17.5	-	-	Geometric visibility ranges are prescribed in the EU, while the US does not define geometric visibility ranges
Photometric Visibility					

Property	EU (UN Regulations)*		US (FMVSS/SAE Standards)		Comparison
Illumination Angle	*Position 1*: H: 0°, V: 0° *Position 2*: H: 0°, V: D/U 10°† *Position 3*: H: L/R 5° V: D/U 20°	R3, Annex 7	*Position 1*: H: 0°, V: 0° *Position 2*: H: 0°, V: U10° *Position 3*: H: 0°, V: D10°† *Position 4*: H: L20°, V: 0° *Position 5*: H: R20°, V: 0°	F108, Table XVI-a	Horizontal illumination angles are smaller in the EU, while vertical angles are smaller in the US
Angle of Divergence	Minimum: 20' Maximum: 1°30'	R3, Annex 7	Minimum: 0.2° Maximum: 1.5°	F108, Table XVI-a	The minimum angle of divergence is smaller in the EU (20' = 0.033°), while the maximum angles of divergence are identical
CIL Minima$	*Position 1*: 20': 750 mcd/lux 1°30': 12.5 mcd/lux *Position 2*: 20': 500 mcd/lux 1°30': 7 mcd/lux *Position 3*: 20': 250 mcd/lux 1°30': 6.25 mcd/lux	R3, Annex 7	*Position 1*: 0.2°: 1050 mcd/lux 1.5°: 15 mcd/lux *Position 2 & 3*: 0.2°: 700 mcd/lux 1.5°: 12.5 mcd/lux *Position 4 & 5*: 0.2°: 350 mcd/lux 1.5°: 7.5 mcd/lux	F108, Table XVI-a	Greater CIL minima are required in the US, regardless of illumination angle or angle of divergence
CIL Maxima	-	-	-	-	N/A
Shape	Triangular shaped retro-reflectors prohibited	R3, Annex 5	-	-	EU regulations prohibit the use of triangular shaped retro-reflectors, while US standards have no shape restrictions

* Applicable for vehicles that are ≤6m in length

§ UN: maximum is to the highest point and minimum is to the lowest point of the lamp

† May be reduced to D5° when lamp is mounted below 750 mm

$ For amber coloured retro-reflectors only, for red retro-reflector CIL requirements see Table 37; US: for photometric measurements made at ≥30.5m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; CIL, coefficient of luminous intensity.

Table 40: Current EU regulations and US standards for reversing lamps [back up lamps] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R23: UN Regulation No. 23)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Mandatory	R48, 6.4.1	Mandatory	F108, Table I-a	Identical
Number	Mandatory: 1 Optional: 2	R48, 6.4.2.1	Mandatory: 1 Additional lamps permitted to meet requirements	F108, Table I-a	Identical, but could be interpreted that more than 2 lamps can be used in the US
Colour	White	R48, 5.15	White	F108, Table I-a	Identical
Position					
Height*	Max: ≤1,200 mm Min: ≥250 mm	R48, 6.4.4.2	-	-	Heights are not defined in the US, while the EU provides prescriptive height definitions
Width	-	-	-	-	N/A
Length	At the rear	R48, 6.4.4.3	On the rear	F108, Table I-a	Identical
Geometric Visibility	*One Lamp*: H: L45° to R45° V: D5° to U15° *Two Lamps*: H: I30° to O45° V: D5° to U15°	R48, 6.4.5	Visible in zone: U: 610mm to 1828mm B: ≥914mm L/R: ≤914mm beyond the end of each side of the vehicle	F108, Table V-a	Different geometric visibility angle philosophies
Photometric Visibility	*One Lamp*: H: L45° to R45° V: D5° to U10° *Two Lamps*: H: I30° to O45° V: D5° to U10°	R23, Annex 3	H: L45° to R45° V: D5° to U10°	F108, Table XII	Identical for one lamp systems Smaller inboard geometric visibility angles required for two lamp systems in the EU

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima[§]	≥80 cd @ H: 0°, V: 0° *One Lamp*: ≥15 cd @ H: L/R 45° V: D5° to U5° *Two Lamps:* ≥15 cd @ H: O 45° V: D5° to U5°	R23, 6.1.2 R23, Annex 3	*One Lamp*: ≥160 cd @ H: 0°, V: 0° ≥30 cd @ H: L/R 45° V: U5° to D5° *Two Lamps:* ≥80 cd @ H: 0°, V: 0° ≥15 cd @ H: L/R 45° V: U5° to D5°	F108, Table XII	Identical photometric minima required for two lamp systems Greater photometric minima required for one lamp systems in the US
Photometric Maxima[§]	≤300 cd @ V: >0° ≤600 cd @ V: 0° to D5° ≤8,000 cd @ V: >D5°	R23, 6.1.3	*One Lamp*: ≤600 cd *Two Lamps:* ≤300 cd	F108, Table XII	Different photometric maxima philosophies Photometric maxima are more prescriptive in the EU Greater photometric maxima allowed for angles below D5° in the EU Greater photometric maxima allowed for two lamp systems at angles below 0° in the EU Greater photometric maxima allowed for one lamp systems at angles above 0° in the US

* UN: maximum is to the highest point and minimum is to the lowest point of the lamp

[§] UN: for single function lamps tested at voltage supplies of 6.75v, 13.5v and 28.0v; US: for non-reflecting single function lamps with photometric measurements made at ≥3m

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; V, vertical (latitudinal) plane perpendicular to a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp; One Lamp, a one reverse/back up lamp system; Two Lamps, a two reverse/back up lamp system.

Table 41: Current EU regulations and US standards for hazard warning signals (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108)

Property	EU (UN Regulations) Specification	Reference	US (FMVSS/SAE Standards) Specification	Reference	Comparison
Applicability	Mandatory: for all direction-indicators Optional: for side-marker lamps	R48, 6.6.1 R48, 6.6.7.3	Mandatory: for turn signal lamps as a minimum	F108, S6.1.5.1	The EU requires the use of side direction-indicator lamps and permits the use of side-marker lamps for the hazard warning signal, while the US requires the use of the turn signal lamps as a minimum
Number	6-10	R48, 6.6.2	Minimum of 4	F108, Table I-a	Due to the range of mandatory and optional requirements between regulations, the EU specifies between 6-10 lamps and the US requires a minimum of 4 lamps
Colour	Amber	R48, 5.15	As specified in Table 25 to Table 28	F108, Table I-a	Amber colour only mandated in the EU, while the US may permit either amber or red
Position					
Height	As specified in Table 25 to Table 28	R48, 6.6.4.2	As specified in Table 25 to Table 28	F108, Table I-a	Please see differences in Table 25 to Table 28
Width	As specified in Table 25 to Table 28	R48, 6.6.4.1	As specified in Table 25 to Table 28	F108, Table I-a	Please see differences in Table 25 to Table 28
Length	As specified in Table 25 to Table 28	R48, 6.6.4.3	As specified in Table 25 to Table 28	F108, Table I-a	Please see differences in Table 25 to Table 28
Geometric Visibility	As specified in Table 25 to Table 28	R48, 6.6.5	As specified in Table 25 to Table 28	F108, Table V-b F108, Table V-c	Please see differences in Table 25 to Table 28
Photometric Visibility	As specified in Table 25 to Table 28	R6, Annex 4	As specified in Table 25 to Table 28	F108, Table VI-a F108, Table VII	Please see differences in Table 25 to Table 28

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima	As specified in Table 25 to Table 28	R6, 6.1 R6, Annex 4	As specified in Table 25 to Table 28	F108, Table VI-a F108, Table VII	Please see differences in Table 25 to Table 28
Photometric Maxima	As specified in Table 25 to Table 28	R6, 6.1 R6, Annex 4	As specified in Table 25 to Table 28	F108, Table VII	Please see differences in Table 25 to Table 28
Flashing	Must flash in phase	R48, 6.6.7.1	Must flash in phase	F108, S6.1.5.1	Identical
Activation	Manual control Optional automatic activation on collision or after emergency stop signal	R48, 6.6.7.2	-	-	Activation requirements are not defined in the US, while the EU requires manual activation and provides the option of automatic activation strategies

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers.

Table 42: Current EU regulations and US standards for emergency stop signals (R48: UN Regulation No. 48)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Optional, for either all stop or all direction-indicator lamps	R48, 6.23.1	Prohibited for all stop lamps	F108, Table I-a	EU provides the option to install an Emergency Stop Signal option using either the stop or direction-indicator lamps, while the US limits the use of flashing stop lamps to turn signal indicators only and provides no requirements for Emergency Stop Signal systems
Number	3-10	R48, 6.23.2	-	-	N/A
Colour	Amber or red	R48, 5.15	-	-	N/A
Position					
Height	As specified in Table 25 to Table 30	R48, 6.23.4	-	-	N/A
Width	As specified in Table 25 to Table 30	R48, 6.23.4	-	-	N/A
Length	As specified in Table 25 to Table 30	R48, 6.23.4	-	-	N/A
Geometric Visibility	As specified in Table 25 to Table 30	R48, 6.23.5	-	-	N/A
Photometric Visibility	As specified in Table 25 to Table 30	R7, Annex 4 R6, Annex 4	-	-	N/A
Photometric Minima	As specified in Table 25 to Table 30	R7, 6.1.4 R7, Annex 4 R6, 6.1 R6, Annex 4	-	-	N/A

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Maxima	As specified in Table 25 to Table 30	R7, 6.1.4 R7, Annex 4 R6, 6.1 R6, Annex 4	-	-	N/A
Flashing	Must flash in phase at a frequency of 4±1 Hz	R48, 6.23.7.1	-	-	N/A
Activation	Automatic activation and deactivation Activation: At speeds >50 km/h and on emergency braking logic signal Deactivation: Deactivation of emergency braking logic signal or hazard warning signal activation	R48, 6.23.7.3	-	-	N/A

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; H, horizontal (longitudinal) plane about a polar axis in a spherical coordinate system centred on the illuminating surface of the lamp.

Table 43: Current EU regulations and US standards for rear-end collision alert signals (R48: UN Regulation No. 48)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Optional, for all direction-indicator lamps	R48, 6.25.1	-	-	N/A
Number	6-10	R48, 6.25.2	-	-	N/A
Colour	Amber	R48, 5.15	-	-	N/A
Position					
Height	As specified in Table 25 to Table 30	R48, 6.25.4	-	-	N/A
Width	As specified in Table 25 to Table 30	R48, 6.25.4	-	-	N/A
Length	As specified in Table 25 to Table 30	R48, 6.25.4	-	-	N/A
Geometric Visibility	As specified in Table 25 to Table 30	R48, 6.25.5	-	-	N/A
Photometric Visibility	As specified in Table 25 to Table 30	R6, Annex 4	-	-	N/A
Photometric Minima	As specified in Table 25 to Table 30	R6, 6.1 R6, Annex 4	-	-	N/A
Photometric Maxima	As specified in Table 25 to Table 30	R6, 6.1 R6, Annex 4	-	-	N/A

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Flashing	Must flash in phase at a frequency of 4±1 Hz	R48, 6.25.7.1	-	-	N/A
Activation	Automatic activation and deactivation Activation: At v_r ≥30 km/h and when time to collision ≤1.4 secs At v_r ≤30 km/h and when time to collision ≤0.0467*v_r secs Deactivation: After 3 seconds	R48, 6.25.7.3 R48, 6.25.7.5 R48, 6.25.7.6	-	-	N/A

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers; v_r, relative velocity.

Table 44: Current EU regulations and US standards for rear registration plate lamps [licence plate lamps] (R48: UN Regulation No. 48; F108: FMVSS Standard No. 108; R23: UN Regulation No. 23)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Specification	Reference	Specification	Reference	
Applicability	Mandatory	R48, 6.8.1	Mandatory	F108, Table I-a	Identical
Number	Such that the device illuminates the site of the registration plate	R48, 6.8.2	Mandatory: 1 Additional lamps permitted to meet requirements	F108, Table I-a	Similar
Colour	White	R48, 5.15	White	F108, Table I-a	Identical
Position					
Height	Such that the device illuminates the site of the registration plate	R48, 6.8.4.2	-	-	Heights are not defined in the US, while the EU provides very subjective requirements
Width	Such that the device illuminates the site of the registration plate	R48, 6.8.4.1	-	-	Widths are not defined in the US, while the EU provides very subjective requirements
Length	Such that the device illuminates the site of the registration plate	R48, 6.8.4.3	On the rear	F108, Table I-a	Lengths are subjectively defined by both the EU and US
Geometric Visibility	Such that the device illuminates the site of the registration plate	R48, 6.8.5	-	-	Geometric visibility ranges are very subjectively defined in the EU, while the US does not define geometric visibility ranges
Incidence of Light*	Maximum angle: ≤82°	R4, 7	Minimum angle: ≥8°	F108, S7.7.15.4	The EU regulate maximum incidence angles, while the US regulate minimum incidence angles

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Photometric Minima§	≥2.5 cd/m^2	R4, 9	≥8 lx	F108, S7.7.13.2	Difference in units make this difficult to compare (assuming a perfect diffuse reflecting surface, 2.5 cd/m2 = 7.85 lx)
Photometric Maxima	-	-	-	-	N/A

* Incidence angle measured between the plane of the licence plate surface and a plane bounded by the furthest point on the licence plate surface to the edge of the light emitting surface farthest from the licence plate

§ Minima must be met at all test station target locations

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers.

Table 45: Current EU regulations and US standards for exterior courtesy lamps (R48: UN Regulation No. 48)

Property	EU (UN Regulations) Specification	EU (UN Regulations) Reference	US (FMVSS/SAE Standards) Specification	US (FMVSS/SAE Standards) Reference	Comparison
Applicability	Optional	R48, 6.24.1	-	-	N/A
Number	Minimum 2 and no more than 1 lamp per function	R48, 6.24.2	-	-	N/A
Colour	White	R48, 5.15	-	-	N/A
Position					
Height	-	-	-	-	N/A
Width	-	-	-	-	N/A
Length	-	-	-	-	N/A
Geometric Visibility	Not visible in zone: U: 1 m to 3 m F/B: 10 m beyond the ends of the vehicle L/R: 10 m beyond the sides of the vehicle	R48, 6.24.9 R48, Annex 14	-	-	N/A
Photometric Visibility	-	-	-	-	N/A
Photometric Minima	-	-	-	-	N/A
Photometric Maxima	-	-	-	-	N/A

Directional nomenclature: I, inboard; O, outboard; D, downward; U, upward; B, backward; F, forward; L, left; R, right. Applicable for right hand traffic lamps only, reverse left and right directions for left hand traffic lamps.

EU, European Union; UN, United Nations; US, United States of America; FMVSS, Federal Motor Vehicle Safety Standards; SAE, Society of Automotive Engineers.

Annex 2

COMPARISON TABLES FOR EU REGULATIONS AND US STANDARDS – DIRECT VISION

Table 46: Comparison of legislative requirements in Europe (UN Regulation 43), USA (FMVSS 205)and Global Technical Regulation No. 6. Current differences between FMVSS 205 and GTR 6 highlighted because GTR 6 not transposed into US legislation yet. Note that transposition is ongoing which will resolve these differences.

Property **(Test)**	**EUROPE** **(UN Regulation No.43)**	**USA** **(FMVSS 205; ANSI Z26.1-1977; ANSI Z26.1a-1980)**	**GLOBAL TECHNICAL REGULATION** **(GTR 6)**	**Current differences between FMVSS 205 and GTR 6. Note that these will be resolved once transposition process complete.**
LAMINATED WINDSCREENS				
Windscreen optics	Tests on windscreens • using defined vision areas • at the installation angle • Test method ISO 3538	Test of 12" squares which may be cut from the most curved part of the windscreen • no defined vision area • not tested at the installation angle • test method not as ISO 3538	As UN Regulation No. 43	Tests on windscreens • no defined vision area • not tested at the installation angle • test method not as ISO 3538
Light transmission	TL ≥ 70 per cent Test method ISO 3538	TL ≥ 70 per cent Test method ISO 3538	TL ≥ 70 per cent Test method ISO 3538	No significant difference.

Property (Test)	EUROPE (UN Regulation No.43)	USA (FMVSS 205; ANSI Z26.1-1977; ANSI Z26.1a-1980)	GLOBAL TECHNICAL REGULATION (GTR 6)	Current differences between FMVSS 205 and GTR 6. Note that these will be resolved once transposition process complete.
Light stability **High temperature** **Humidity** **Fire resistance**	Test method as ISO 3917 Burning rate <250 mm/min	Test method as ISO 3917 but The evaluation for high temperature and humidity tests not as Europe and Japan Burning rate < 88.8 mm/min	Test method as ISO 3917 Evaluation as Europe (and Japan) Burning rate < 90 mm/min	Test method not completely to ISO 3917
Impact 227g Ball	Test method ISO 3537 Tests at + 40°C and – 20°C Varying drop heights according to thickness	Test method ISO 3537 Test at 25°C Standard drop height	Test method ISO 3537 Test at + 40°C and -20°C One standard drop height at each temperature	Difference in test temperatures
Impact 198g Dart	No test	Test at 25°C. No ISO test.	No test	Requirement for test, will be rescinded (dropped) once transposition process completed..
Penetration Resistance 2.26 kg ball	Test method: ISO 3537 Drop height 4.0 m	Test method: ISO 3537 Drop height 3.66 m	As UN Regulation No. 43	Difference in drop height
Abrasion Resistance	Test method: ISO 3537	As UN Regulation No. 43	As UN Regulation No. 43	No difference

Property (Test)	EUROPE (UN Regulation No.43)	USA (FMVSS 205; ANSI Z26.1-1977; ANSI Z26.1a-1980)	GLOBAL TECHNICAL REGULATION (GTR 6)	Current differences between FMVSS 205 and GTR 6. Note that these will be resolved once transposition process complete.
Headform Impact Test	Test method: ISO 3537 Evaluation of penetration resistance and breaking pattern 4 m drop test on flat test pieces. 1.5 m drop test on windscreens	No test	The headform 1.5 m drop test on windscreens is included. (The ECE R43 and Japanese test at 4.0 m on flat test pieces is not included)	No requirement for headform impact test
Colour Identification	General type requirement that traffic light colors can be recognized, but no specific test	No test	No Test	No significant difference
TOUGHENED BODYGLASS				
Impact test 227 g Ball	• Test method: ISO 3537 • Standard drop height: 2.0 m	• Test method: ISO 3537 • Drop height: 3.05m Flat 305 x 305 mm test pieces	As UNECE Regulation No. 43 Standard drop height: 2.0 m	Difference in drop height
Impact test 4.99 kg shot bag	No test	No ISO test. Drop height: 2.40 m Flat 305x305mm test pieces.	No test	Requirement for test

Property **(Test)**	**EUROPE** **(UN Regulation No.43)**	**USA** **(FMVSS 205; ANSI Z26.1-1977; ANSI Z26.1a-1980)**	**GLOBAL TECHNICAL REGULATION** **(GTR 6)**	**Current differences between FMVSS 205 and GTR 6. Note that these will be resolved once transposition process complete.**
Abrasion test	No test for the glass surface If plastic coated, then: test method: ISO 3537	• Test method: ISO 3537 Carried out on bodyglass requisite for driving visibility	As UN Regulation No. 43	No significant difference
Light transmission	• Test method: ISO 3538 • In areas requisite for driving visibility: • $T_L \geq 70$ per cent In areas not requisite for driving visibility: TL no lower limit	• Test method: ISO 3538 • For passenger cars the TL limit is ≥ 70 per cent , except for rooflights For other vehicles the limits are as UN Regulation No. 43	As UN Regulation No. 43	No significant difference
Optical quality	No test	No test	No test	No difference.

Property (Test)	EUROPE (UN Regulation No.43)	USA (FMVSS 205; ANSI Z26.1-1977; ANSI Z26.1a-1980)	GLOBAL TECHNICAL REGULATION (GTR 6)	Current differences between FMVSS 205 and GTR 6. Note that these will be resolved once transposition process complete.

Fragmentation	Test procedure ISO 3537
	
	• Production parts are broken using a spring loaded centre punch or pointed hammer from one defined breaking point
	• The minimum particle count allowed is 40 (in any 5x5 cm sided square)
	• No elongated particles (splines) in excess of 10.0 cm are permitted
	• The maximum particle size allowed is 3 cm^2
		Fragmentation test as ISO 3537, with only one defined break position (25 mm inboard of the mid-point of the longest edge)
		
		The interpretation of results is based on the weight of the largest fragment, which shall not exceed 4.25 g. This equates to the following maximum particle sizes:
		
		3 mm thickness: 5.6 cm^2
		4 mm thickness: 4.2 cm^2
		5 mm thickness: 3.4 cm^2
		
		No evaluation of the length of fragments.
			As UN Regulation No. 43 except:
			
			• Determination of the largest particle weight rather than of the area, e.g. for glass up to 4.5 mm thickness the weight shall not exceed 3.0 g. This equates to:
			  • 3.9 cm^2 for glass 3 mm
			  • 3.0 cm^2 for glass 4 mm
			
			.
				Larger particle size allowed for fragmentation test.

Table 47: Comparison of EU regulations and US standards for windshield wipers and washers.

Property	**EU (UN Regulations)**[Δ]		**US (FMVSS/SAE Standards)**		**Comparison**
	Specification	Reference	Specification	Reference	
Wiped area		EU 1008/2010, Annex 3, 1.1		F104	Difficult to compare because of different definitions of driver eye origin. However, angles of some sight planes are similar (left) although in general larger for US, in particular 'up' one. Also additional medium clearance area required for US.
Vision area (small)	Cover at least 98%	EU 1008/2010, Annex 3, 1.1	Cover 99%	F104	
Origin	ISO defined 'V' points	R43 Annex 18	SAE defined 95% eyellipsoids	J903a, 941	
Sight planes	Left 13 deg	R43 Annex 18	Left 7-10 deg (car width)	F104	
	Right 20 deg	R43 Annex 18	Right 15 deg	F104	
	Up 3 deg thro V1	R43 Annex 18	Up 3-5 deg (car width)	F104	
	Down 1 deg thro V2	R43 Annex 18	Down 1 deg	F104	

Property	EU (UN Regulations)[Δ]		US (FMVSS/SAE Standards)		Comparison
Vision area (large)	Cover at least 80%	EU 1008/2010, Annex 3, 1.1	Cover at least 80%	F104	
Origin	ISO defined 'V' points	R43 Annex 18	SAE defined 95% eyellipsoids	J903a, 941	
Sight planes	Left 17 deg	R43 Annex 18	Left 16-18 deg (depending on car width)	F104	
	Right (left reflected)	R43 Annex 18	Right 49-56 deg	F104	
	Up 7 deg thro V1	R43 Annex 18	Up 7-10 deg (depending on car width)	F104	
	Down 5 deg thro V2	R43 Annex 18	Down 5 deg	F104	
Vision area (medium)			Cover at least 94%	F104	
Origin			SAE defined eyellipsoids	J903a, 941	
Sightlines			Left 13-14 deg (car width)	F104	

Property	EU (UN Regulations)[Δ]		US (FMVSS/SAE Standards)		Comparison
			Right 46-53 deg	F104	
			Up 3-5 deg (car width)	F104	
			Down 1 deg	F104	Virtually identical
Number	more than 2	EU 1008/2010, Annex 3, 1.1	more than 2	F104	
Low	10<F per min< 55	EU 1008/2010, Annex 3, 1.1	20< F per min	F104	
high	45< F per min	EU 1008/2010, Annex 3, 1.1	45< F per min	F104	
Difference	15< F per min	EU 1008/2010, Annex 3, 1.1	15< F per min	F104	
Stall system strength	restrained for 15 sec	EU 1008/2010, Annex 3, 1.1	None (restrained for 15 sec)	(J903a only, not referenced by F104)	No mandatory stall test for US

Property	EU (UN Regulations)[Δ]		US (FMVSS/SAE Standards)		Comparison
Low temp performance	2 mins on dry windscreen @ -18 C	EU 1008/2010, Annex 3, 1.1	None		No low temperature performance test for US
Operation at high vehicle speed	lower of 80% max speed or 160 km/h	EU 1008/2010, Annex 3, 1.1	None		No operation at high vehicle speed test for US
Durability	None		None (1.5 million cycles)	(J903a only, not referenced by F104)	No durability test for Europe
Test conditions					
Electric wipers power source	Perform test with defrost and headlight load	EU 1008/2010, Annex 3, 2.1	None		No power system test for US
Ambient temperature	5 - 40 C	EU 1008/2010, Annex 3, 2.1	10 - 38 C	J903a 4.1.2	Virtually identical
WINDSCREEN WASHER SYSTEM	Mandatory	EU 1008/2010, Annex 3, 1.2	Mandatory	F104	Identical

Property	EU (UN Regulations)[Δ]		US (FMVSS/SAE Standards)		Comparison
Low temperature exposure	Perform after at -18 C, min 4hrs, thawed, repeat 6 times	EU 1008/2010, Annex 3, 2.2.3	Perform after at -18 C, min 4hrs, thawed, repeat 6 times	J942, 3.3.2	Identical
High temperature exposure	Perform after 80 C for 8 hrs	EU 1008/2010, Annex 3, 2.2.4	Perform after 79.4 C for 8 hrs	J942, 3.3.1	Identical
Clearance (fluid delivery)	Clear 60% of small area within 10 wipe cycles; Reservoir capacity > 1.0l	EU 1008/2010, Annex 3, 1.2	Clear 75% of small area within 10 wipe cycles	J942,	Slightly higher clearance area for US
System strength	Plug nozzles, actuate 3 times in 1 minute	EU 1008/2010, Annex 3, 2.2.1.1	Plug nozzles, actuate repeatably in 1 minute	J942, 4.2	Virtually identical
Durability	None		8000 cycles	J942, 4.4	No durability test for Europe
Aging	None		Ozone exposure test of flexible tubing	J942, 4.5	No aging test for Europe

Table 48: Comparison of EU regulations and US standards for windshield defrosting and demisting (defogging) systems.

Property	**EU (UN Regulations)**[Δ]		**US (FMVSS/SAE Standards)**		**Comparison**
	Specification	Reference	Specification	Reference	
WINDSCREEN DEFROSTING	Mandatory	EU 672/2010, Annex 2, 1.1	Mandatory except for non-continental USA (i.e. Hawaii)	F103	Identical
Cleared Area					Difficult to compare because of different definitions of driver eye origin. However, angles of some sight planes are similar (left) although in general larger for US, in particular 'up' one.
Vision area (small)					
Origin	ISO defined 'V' points	R43 Annex 18	SAE defined 95% eyellipsoids	J903a, 941	
Sight planes	Left 13 deg	R43 Annex 18	Left 7-10 deg (depending on car width)	F103, F104	
	Right (left reflected)	R43 Annex 18	Right 15 deg	F103, F104	

Property	EU (UN Regulations)[Δ]		US (FMVSS/SAE Standards)		Comparison
	Up 3 deg thro V1	R43 Annex 18	Up 3-5 deg (depending on car width)	F103, F104	
	Down 1 deg thro V2	R43 Annex 18	Down 1 deg	F103, F104	
Vision area (large)					
Origin	ISO defined 'V' points	R43 Annex 18	SAE defined 95% eyellipsoids	J903a, 941	
Sight planes	Left 17 deg	R43 Annex 18	Left 16-18 deg (depending on car width)	F103, F104	
	Right (left reflected)	R43 Annex 18	Right 49-56 deg	F103, F104	
	Up 7 deg thro V1	R43 Annex 18	Up 7-10 deg (depending on car width)	F103, F104	
	Down 5 deg thro V2	R43 Annex 18	Down 5 deg	F103, F104	
After 20 mins	80% of small area defrosted	EU 672/2010, Annex 2, 1.1	80% of small area	F103, J902	Identical

Property	EU (UN Regulations)[Δ]		US (FMVSS/SAE Standards)		Comparison
After 25 mins	Passenger side comparable to driver side	EU 672/2010, Annex 2, 1.1	Passenger side comparable to driver side after 20 mins	F103, J902	Virtually identical
After 40 mins	95% of large area defrosted	EU 672/2010, Annex 2, 1.1	95% of large area defrosted	F103, J902	Identical
Test conditions					Virtually identical
Vehicle soak period	>10 hrs at -8 or -18 C (manfacturer chosen)	EU 672/2010, Annex 2, 2.1.1	>10 hrs at -18 C	J902	
Ice application	0.044 g/cm2 plus soak > 30 mins < 40 mins	EU 672/2010, Annex 2, 2.1.5	0.046 ml/cm2 plus soak > 30 mins < 40 mins	J902	
Running engine	At speed corresponding to less than 50% of speed of max power output	EU 672/2010, Annex 2, 2.1.5	At speed less than 1500 rpm or less than speed and load at 40 km/h in recommended gear	F103	

Property	EU (UN Regulations)[Δ]		US (FMVSS/SAE Standards)		Comparison
WINDSCREEN DEMISTING (Defogging)	Mandatory	EU 672/2010, Annex 2, 1.1	Mandatory	F103	No performance requirements for the US
In 10 mins	Small area 90% demisted, large area 80% demisted	EU 672/2010, Annex 2, 1.2	NONE		
Test conditions					
Temperature	-3 °C throughout test	EU 672/2010, Annex 2, 2.2	NONE		
Steam	70 g /h for each seating position	EU 672/2010, Annex 2, 2.2	NONE		
Running engine	at speed corresponding to less than 50% of speed of max power output	EU 672/2010, Annex 2, 2.2	NONE		

Annex 3

COMPARISON TABLES FOR EU REGULATIONS AND US STANDARDS – INDIRECT VISION

Table 49: Current EU regulations and US standards for Class I mirrors (UN Regulation No. 46; FMVSS Standard No. 111)

Property	**EU (UN Regulations)**		**US (FMVSS/SAE Standards)**		**Comparison**
	Specification	Reference	Specification	Reference	
Applicability	Mandatory	15.2.1.1.1.	Mandatory	S5.1	Identical
Location	Internal, centre	15.2.4.1.	Internal	S5.1	US does not specify central location
Alternative	No mirror, if rear window not safety glazing material	15.2.1.1.1.	-	-	Interior mirror always required in US
Mirror definition					
Mirror definition	Give a clear view to the rear, side or front of the vehicle Excludes devices such as periscopes,	2.1.1.	Effective mirror surface means the portions of a mirror that reflect images, excluding the mirror rim or mounting brackets.	S4	EU more explicit in exclusions
Spherical surface definition	Has a constant and equal radius in all directions	2.1.1.8.	-	-	US not applicable for interior mirror

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Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Flat surface definition	-	-	Unit magnification mirror means a plane or flat mirror Includes day/night mirrors with at least one flat position	S5.1	
Manufacturing tolerances	Must meet type approved requirements, no additional tolerances	8.2.	Except for flaws that do not exceed normal manufacturing tolerances.	S5.1	EU does not mention tolerances, beyond those within the testing
Marking					
Trade mark	Trade name or mark of the manufacturer marking shall be clearly legible and be indelible.	4.1 - 4.2.	-	-	
Design					
Adjustment	All mirrors shall be adjustable	6.1.1.1.	... and shall provide for mirror adjustment by tilting in both the horizontal and vertical directions.	S5.1.2	Identical
Adjustment	The interior mirror shall be capable of being adjusted by the driver from his driving position	15.2.3.1.	-	-	Adjustment from seat not defined in US

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Projections					
Housing or exposed mirror	Perimeter, c >= 2.5 mm all points and in all directions	6.1.1.2. (b)	-	-	US sharpness of mirror not tested, however sharp edges constitute a fail if present after impact test. Could presume covers any inherent sharp edges in the design
Exposed parts	Other projections must be less than 5mm, projection's edges blunted unless	6.1.1.4.	-	-	
Exposed parts	Exempt if less than Shore A 60	6.1.1.7.	-	-	
Impact Test					
Requirement	Shall be subjected to the tests described in paragraphs 6.1.3.2.1 and 6.1.3.2.2 6.1.3.2 - impact tests	6.1.3.1.	If the mirror is in the head impact area, the mounting shall deflect, collapse or break away without leaving sharp edges	S5.1.1	Test only required in US if within impact area US force test, EU impact test
Test	Pendulum, 165mm diameter ball, rubber coating 5mm thick, 60° drop angle	6.1.3.2.1.1. 6.1.3.2.2.5.	… when the reflective surface of the mirror is subjected to a force of 400 N	S5.1.1	

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Number of tests	Two tests; Test 1 reflective side, Test 2, edge of housing, 45° to reflective surface plane	6.1.3.2.2.6.1. (a) 6.1.3.2.2.6.1. (b)	Any forward direction not more than 45° from the forward longitudinal direction.	S5.1.2	US require more testing, but includes same range
			NHTSA test procedure specifies 7 tests, with differing mirror angles	TP-111	
Results, mounting	Results, if mounting brakes, remaining mounting ≤10mm	6.1.3.3.2.	… mounting shall deflect, collapse or break away without leaving sharp edges	S5.1.1	
Results, glass	Results, the mirror shall not brake, however if the mirror brakes one of the following applies: * Glass stuck to mounting, separation from backing max 2.5mm, OR * The mirror made from safety glass	6.1.3.3.3. 6.1.3.3.3.1 6.1.3.3.3.2.			

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Dimensions					
Width	Minimum width 40mm	6.1.2.1.1	-	-	US mirror must meet field of view requirements with a flat mirror, this will define the minimum mirror size
Length	Minimum length a in mm $a = 150 \times \frac{1}{1 + \frac{1000}{r}} mm$	6.1.2.1.1	-	-	
Radius of curvature					
Curvature	reflecting surface of a mirror shall be either flat or spherically convex	6.1.2.2.1	Mirror of unit magnification [flat]	S5.1	Convex not permitted for interior mirror in US
radii	"r" average of the radii of curvature, measured over reflecting surface	2.1.1.5. Annex 7	-	-	

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Radius of curvature (spherical)	rp = arithmetical average of principal radii of curvature ri and r'I $r_p = \frac{r_i + r_i'}{2}$	2.1.1.7.	-	-	
Limit	r shall not be less than 1,200 mm	6.1.2.2.4.1.	-	-	
Calculations	If r < 3000mm	6.1.2.2.2.3.	-	-	
	Diff ri and r'I and rp at each ref point <= 0.15 r	6.1.2.2.2.1.	-	-	
	Diff (ri, r'i, rp) and r <= 0.15 r	6.1.2.2.2.2.	-	-	
	If r >= 3000mm	6.1.2.2.2.3.	-	-	
	Diff ri and r'I and rp at each ref point <= 0.25 r	6.1.2.2.2.1.	-	-	
	Diff (ri, r'i, rp) and r <= 0.25 r	6.1.2.2.2.2.	-	-	
Radius of curvature test	r measured in 3 points 1 3rd, half, 2 3rd	A7. 1.2.1.	-	-	

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Coefficient of reflection					
	Day setting >= 40%	6.1.2.2.5.	Average reflectance of at least 35 percent	S11	EU 40%, US 35%
	Day setting shall allow colours of signals to be seen	6.1.2.2.5.	-	-	EU specifies colour accuracy
	Night setting >=4%	6.1.2.2.5.	At least 4 percent	S11	Identical
	-		If electrically control failure, manual override or default to day setting	S11	US specifies action in case of electrical failure
	Must retain characteristics with prolonged adverse weather conditions	6.1.2.2.5.	-	-	EU requires durability of mirror
Reflectivity test					
Geometrical Conditions:	… diameter of not less than 13 mm (0.5 inch.). …	A6. 2.3.	… diameter of not less than 19 mm (0.75 in). ...	SAE Standard J964 OCT85. 2.3	UN Reg 46, Annex 6 and SAE J964 are very similar however different equipment specification could cause a difference in results

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Non-flat (convex) mirror measurement	If the instrument-indicating meter indicates ne divisions with a standard mirror of E per cent reflectance, then, with a mirror of unknown reflectance, nx divisions will correspond to a reflectance of X%, in accordance with the formula: $$X = E\frac{n_x}{n_e}$$	A6. 3.4.	The reflectance value is read directly from the instrument indicating meter.	SAE Standard J964 OCT85. 3.4	EU required further calculation required on result from convex mirror
View					
fitting	Does not move so as significantly to change the field of vision or vibrate to cause driver to misinterpret image	15.1.2.	-	-	EU
test	shall be maintained when the vehicle is moving at speeds of up to 80 per cent of its maximum design speed, but not exceeding 150 km/h	15.1.3.	-	-	EU
view: plan					
width	20m	15.2.4.1.	-	-	(Tan(20°/2)*61)*2

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
angle	-	-	20°	S5.1	~≥ 21.5m, US ~1.5 meter wider
extends from	60m	15.2.4.1.	61m	S5.1	US 1 meter further (as 200' ~= 61m)
height	To horizon	15.2.4.2.1.	To horizon	S5.1.1	Identical
Vehicle configuration at test	Fields of vision shall be determined ... vehicle is in running order, plus one front seat passenger (75 kg): (R.E.3) (ECE/TRANS/WP.29/78/Rev. 2, para. 2.2.5.4)	15.1.4.	Occupied by the driver and four passengers or if less the designated occupant capacity (68kg each)	S5.1.1	US car heavier on test. May change viewing angles at test (exept 2 seater)
Alternative	-	-	Area required can exclude view provided by passenger side mirror	S5.1	No derogation for this in EU
Glazing	No mirror, if rear window not safety glazing material	15.2.1.1.1.	-	-	No alternative provision for rear visibility in EU if no interior mirror
Position/ Obstructions					

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
View	Driver has clear view of road to the rear, side(s) or front of the vehicle	15.2.2.1	-	-	
Obstructions	Items SUCH AS sun visor, wipers, heating elements, stop lamp (s3) together do not obscure >15 % prescribed field	15.2.4.9.1	-	-	
Obstructions	excluded: Headrests, framework, bodywork, such as window columns of rear split doors, rear window frame	15.2.4.9.1	The line of sight may be partially obscured by seated occupants or by head restraints.	S5.1.1	US only permits partial obscuration, without further derogations
Obstruction test	powerful light sources, via mirror to vertical monitoring screen	15.2.4.10.	Fix a viewing instrument into vehicle	TP 111, 12.	

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Ocular points	"The driver's ocular points" means two points 65 mm apart and 635 mm vertically above point R of the driver's seat, Annex 8.	12.1.	Driver's eye reference points: * FMVSS 104 (§ 571.104), -> SAE, J941 [99, 95, 90%] OR * a nominal location appropriate for any 95th percentile male driver	S5.1.1	Different eye position on test will change the visible field of view

Table 50: Current EU regulations and US standards for Class III mirrors (UN Regulation No. 46; FMVSS Standard No. 111)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Specification	Reference	Specification	Reference	
Applicability	Mandatory	15.2.1.1.1	Driver side Mandatory, Passenger side conditional	S5.2 S5.3	US does not mandate passenger side mirror
location	1 on the driver's side 1 on the passenger's side	15.2.1.1.1	1 on the driver's side – FLAT IF interior mirror does not fully meet required field of view: 1 on the passenger's side - FLAT or CONVEX	S5.2.1 S5.3	EU permits convex mirror on both sides
Alternative	Class II mirrors may be fitted as an alternative.	15.2.1.1.1	Only driver mirror and interior mirror mandatory	S5.3	
Mirror definition					
Mirror definition	Give a clear view to the rear, side or front of the vehicle Excludes devices such as periscopes,	2.1.1.	Effective mirror surface means the portions of a mirror that reflect images, excluding the mirror rim or mounting brackets.	S4	EU more explicit in exclusions

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Spherical surface definition	Has a constant and equal radius in all directions	2.1.1.8.	Convex mirror means a mirror having a curved reflective surface whose shape is the same as that of the exterior surface of a section of a sphere.	S4	Identical
Flat surface definition	-	-	Unit magnification mirror means a plane or flat mirror ... For the purposes of this regulation a prismatic day/night adjustment rear-view mirror one of whose positions provides unit magnification is considered a unit magnification mirror.	S5.1	EU doesn't define a flat mirror
Manufacturing tolerances	Must meet type approved requirements, no additional tolerances	8.2.	Except for flaws that do not exceed normal manufacturing tolerances.	S5.1	EU does not mention tolerances, beyond those within the testing
Marking					
Trade mark	Trade name or mark of the manufacturer marking shall be clearly legible and be indelible.	4.1-4.2.	-	-	No mark in US

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
			PASSENGER: convex mirrors require "Objects in Mirror Are Closer Than They Appear."	S5.4.2	No declaimer in EU
Design					
Adjustment	All mirrors shall be adjustable	6.1.1.1.	… and shall be adjustable by tilting in both horizontal and vertical directions …	S5.1.2	Identical
Adjustment	DRIVER: Shall be capable of being adjusted from inside vehicle while door closed, window may be open. PASSENGER: none	15.2.3.2.	DRIVER: … from the driver's seated position PASSENGER: mirror need not be adjustable from the driver's seat	S5.2.2 S5.3	DRIVER: Identical PASSENGER: US specifies passenger side requirements, EU excludes them
Adjustment	...The mirror may, however, be locked in position from the outside.	15.2.3.2.	-	-	
Projections					
Housing	The edge of the reflecting surface shall be enclosed in a protective housing	6.1.1.2. (a)	-	-	In US housing not required

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Housing or exposed mirror	perimeter, c >= 2.5 mm all points and in all directions	6.1.1.2. (a)	The mirror and mounting shall be free of sharp points or edges that could contribute to pedestrian injury.	S5.2.2	In US sharpness of mirror not tested, however it is after test, this presumably would cover any inherent sharp edges in the design
Exposed mirror	mirror projects from housing shall return into the protective housing under a force of 50 N applied to the point of greatest projection	6.1.1.2. (a)	-	-	
Exposed parts	Other projections must be less than 5mm, projection's edges blunted unless	6.1.1.4.	-	-	
Exposed parts	Exempt if less than Shore A 60	6.1.1.7.	-	-	
Location					

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Bonnet or door	-	-	The mirror shall not be obscured by the unwiped portion of the windshield	S5.2.2	US permit mirror fitment to bonnet rather than door EU not explicitly defined
Width	Shall not project beyond the external bodywork of the vehicle substantially more than is necessary …	15.2.2.5	... neither the mirror nor mounting shall protrude farther than the widest part of the vehicle body except to the extent necessary to produce a field of view meeting or exceeding the requirements …	S5.2.2.	Identical
Impact Test					
Requirement	Shall be subjected to the tests described in paragraphs 6.1.3.2.1 and 6.1.3.2.2 6.1.3.2 - impact tests	6.1.3.1.	The mirror and mounting shall be free of sharp points or edges that could contribute to pedestrian injury	S5.2.2	EU impact test. US no test, force or limits defined. UN GTR 9: section 4.34 states no requirements currently, 9.39 states no pedestrian safety test in US, but are working on it

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)	Comparison
Test	Pendulum, 165mm diameter ball, rubber coating 5mm thick, 60° drop angle	6.1.3.2.1.1. 6.1.3.2.2.5.	-	-
Number of tests	Two tests; Test 1… through the centre of the reflecting surface … Test 2… on the side opposite to the reflecting surface ...	6.1.3.2.2.6.2. (a) 6.1.3.2.2.3. 6.1.3.2.2.6.1. (b)	-	-
Results, impactor	Result, continue 20° to vertical	6.1.3.3.1	-	-
Results, mounting	Results, if mounting brakes, remaining mounting <=10mm	6.1.3.3.3.1	-	-
Results, glass	Results, the mirror shall not brake, however if the mirror brakes one of the following applies: * Glass stuck to mounting, separation from backing max 2.5mm, OR * The mirror made from safety glass	6.1.3.3.3. 6.1.3.3.3.1 6.1.3.3.3.2	-	-

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Dimensions (exterior mirror)					
Height	Minimum height 40mm	6.1.2.1.2.	-	-	US mirror must meet field of view requirements with a flat mirror, this will define the minimum mirror size
Length a	min length a in mm $\frac{130}{1+\frac{1000}{r}}$	6.1.2.1.2.2.	-	-	
Length b	A segment which is parallel to the height of the rectangle and the length of which, expressed in millimetres, has the value 'b' 200 mm	6.1.2.1.2.1.	-	-	
Radius of curvature					
Curvature	reflecting surface of a mirror shall be either flat or spherically convex	6.1.2.2.1	DRIVER: mirror of unit magnification [flat] PASSENGER: unit magnification or a convex mirror	S5.2 S5.3	
Aspherical surface definition	A surface, which has only in one plane a constant radius.	2.1.1.9.	-	-	

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
radii	"r" average of the radii of curvature, measured over reflecting surface	2.1.1.5. Annex 7	-	-	
radius of curvature (spherical)	rp = arithmetical average of principal radii of curvature ri and r'I	2.1.1.7	-	-	
Limit	r shall not be less then 1,200 mm	6.1.2.2.4.2.	PASSENGER: The average radius of curvature must be 889 < r < 1651 mm	S5.4.3	US has a min-max range, UN has lower limit. Lower limits differ
Calculations	If r < 3000mm	6.1.2.2.2.3	-	-	
	Diff ri and r'I and rp at each ref point <= 0.15 r	6.1.2.2.2.1	-	-	US has no requirement for the value of individual points
	Diff (ri, r'i, rp) and r <= 0.15 r	6.1.2.2.2.2.	PASSENGER: none of the radii of curvature readings shall deviate from the average radius of curvature by more than plus or minus 12.5 percent	S5.4.1	US in percentage of difference, UN in r mm
	If r >= 3000mm	6.1.2.2.2.3	-	-	

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Diff ri and r'I and rp at each ref point <= 0.25 r	6.1.2.2.2.1	-	-	
	Diff (ri, r'i, rp) and r <= 0.25 r	6.1.2.2.2.2.	-	-	
Radius of curvature test					
Minimisation	r measured in 3 points 1 3rd, half, 2 3rd	A7. 1.2.1	PASSENGER: 10 test positions, value averaged	S12.1	US test procedure more complex
Aspherical					
Size	must be useful to driver, i.e. ~> 30 mm wide		DRIVER: Each passenger car shall have an outside mirror of unit magnification PASSENGER: Outside required area other mirror design possible	S5.2 S12	Identical
Marking	Mark with a line at transition	2.1.1.10	-		US legislation does not specify line marking transition
Coefficient of reflection					
	Day setting ≥ 40%	6.1.2.2.5.	Average reflectance of at least 35 percent	S11	EU 40%, US 35%

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Day setting shall allow colours of signals to be seen	6.1.2.2.5.	-	-	EU specifies colour accuracy
	Night setting ≥ 4%	6.1.2.2.5.	At least 4 percent	S11	Identical
	-		If electrically control failure, manual override or default to day setting	S11	US specifies action in case of electrical failure
	Must retain characteristics with prolonged adverse weather conditions	6.1.2.2.5.	-	-	EU requires durability of mirror
Reflectivity test					
Geometrical Conditions:	… diameter of not less than 13 mm (0.5 inch.). …	A6. 2.3.	… diameter of not less than 19 mm (0.75 in). ...	SAE Standard J964 OCT85. 2.3	UN Reg 46, Annex 6 and SAE J964 are very similar however different equipment specification could cause a difference in results

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Non-flat (convex) mirror measurement	If the instrument-indicating meter indicates ne divisions with a standard mirror of E per cent reflectance, then, with a mirror of unknown reflectance, nx divisions will correspond to a reflectance of X%, in accordance with the formula: $$x = E\frac{n_x}{n_e}$$	A6. 3.4.	The reflectance value is read directly from the instrument indicating meter.	SAE Standard J964 OCT85. 3.4	EU required further calculation required on result from convex mirror
View					
Fitting	Does not move so as significantly to change the field of vision or vibrate to cause driver to misinterpret image	15.1.2.	DRIVER: The mirror mounting shall provide a stable support for the mirror, PASSENGER: The mirror mounting shall provide a stable support …	S5.2.2 S5.3	EU defines stability and includes a test
Test	shall be maintained when the vehicle is moving at speeds of up to 80 per cent of its maximum design speed, but not exceeding 150 km/h	15.1.3.			
View: plan					

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Width	1m - 4m		DRIVER: 2.4m PASSENGER: only area that is not already covered by Interior mirror		DRIVER: US excludes beginning trapezoid view of ground. May not be possible with flat mirror. End rectangle could be comparable to EU depending on driver and mirror position, or US area wider PASSENGER: only area that is not already covered by Interior mirror need be in field of view, possible to not have mirror?
Extends from	4m - 20m		DRIVER: 10.7m PASSENGER: only area that is not already covered by Interior mirror		
Height	To horizon	15.2.4.2.1.	To horizon	S5.1.1	Identical
Vehicle configuration at test	fields of vision shall be determined ... vehicle is in running order, plus one front seat passenger (75 kg): (R.E.3) (ECE/TRANS/WP.29/78/Rev. 2, para. 2.2.5.4)	15.1.4.	Occupied by the driver and four passengers or if less the designated occupant capacity (68kg each)	S5.1.1	US car heavier on test. May change viewing angles at test (except 2 seater)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Alternative	-	-	area required for interior may need to include view provided by passenger side mirror	S5.1	US could require further increase in viewing area
Position/ Obstructions					
View	driver has clear view of road to the rear, side(s) or front of the vehicle	15.2.2.1	-	-	
Obstructions	the inner edge of the test area is defined by the side of the vehicle	15.2.4.3.1. 15.2.4.3.2.	The line of sight may be partially obscured by rear body or fender contours	S5.2.1	Identical
Obstructions	items SUCH AS sun visor, wipers, heating elements, stop lamp (s3) together do not obscure >15 % prescribed field	15.2.4.9.1	-	-	
Obstructions	excluded: Headrests, framework, bodywork, such as window columns of rear split doors, rear window frame	15.2.4.9.1	The line of sight may be partially obscured by seated occupants or by head restraints.	S5.1.1	US only permits partial obscuration, without further derogations
Obstruction test	powerful light sources, via mirror to vertical monitoring screen	15.2.4.10.	Fix a viewing instrument into vehicle	TP 111, 12.	

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Ocular points	"The driver's ocular points" means two points 65 mm apart and 635 mm vertically above point R of the driver's seat, Annex 8.	12.1.	Driver’s eye reference points: * FMVSS 104 (§ 571.104), -> SAE, J941 [99, 95, 90%] OR * a nominal location appropriate for any 95th percentile male driver	S5.1.1	Different eye position on test will change the visible field of view
Seat position	...centre of the driver's designated seating position, as specified by the vehicle manufacturer	12.1.	… with the seat in the rearmost position.	S5.2.1	US specified rear most, EU allows manufacturers choice, these could be the same

Table 51: Current EU regulations and US standards for Class II mirrors, only differences from Class III mirrors included (UN Regulation No. 46; FMVSS Standard No. 111)

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
	Specification	Reference	Specification	Reference	
Applicability	Optional	15.2.1.1.1	Driver side Mandatory, Passenger side conditional	S5.2 S5.3	US does not mandate passenger side mirror
Location	left and right external	15.2.1.1.1	1 on the driver's side - FLAT IF interior mirror does not fully meet required field of view: 1 on the passenger's side - FLAT or CONVEX	S5.2.1 S5.3	EU permits convex mirror on both sides
Alternative	Class III	15.2.1.1.1	Only driver mirror and interior mirror mandatory	S5.3	
Dimensions (exterior mirror)					
Height	Minimum height 40mm	6.1.2.1.2.	-	-	US mirror must meet field of view requirements with a flat mirror, this will define the minimum mirror size
Length a	min length a in mm $\frac{170}{1+\frac{1000}{r}}$	6.1.2.1.2.2.	-	-	

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Length b	A segment which is parallel to the height of the rectangle and the length of which, expressed in millimetres, has the value 'b' 70 mm	6.1.2.1.2.1.	-	-	
View					
Fitting	Does not move so as significantly to change the field of vision or vibrate to cause driver to misinterpret image	15.1.2.	DRIVER: The mirror mounting shall provide a stable support for the mirror, PASSENGER: The mirror mounting shall provide a stable support …	S5.2.2 S5.3	EU defines stability and includes a test
Test	shall be maintained when the vehicle is moving at speeds of up to 80 per cent of its maximum design speed, but not exceeding 150 km/h	15.1.3.			
View: plan					
Width	1m-5m		DRIVER: 2.4m PASSENGER: only area that is not already covered by Interior mirror		DRIVER: US excludes beginning trapezoid view of ground. May not be possible with flat mirror. End rectangle

Property	EU (UN Regulations)		US (FMVSS/SAE Standards)		Comparison
Extends from	4m-30m		DRIVER: 10.7m PASSENGER: only area that is not already covered by Interior mirror		could be comparable to EU depending on driver and mirror position, or US area wider PASSENGER: only area that is not already covered by Interior mirror need be in field of view, possible to not have mirror?
Height	To horizon	15.2.4.2.1.	To horizon	S5.1.1	Identical
Vehicle configuration at test	fields of vision shall be determined ... vehicle is in running order, plus one front seat passenger (75 kg): (R.E.3) (ECE/TRANS/WP.29/78/Rev. 2, para. 2.2.5.4)	15.1.4.	Occupied by the driver and four passengers or if less the designated occupant capacity (68kg each)	S5.1.1	US car heavier on test. May change viewing angles at test (except 2 seater)
Alternative	-	-	area required for interior may need to include view provided by passenger side mirror	S5.1	US could require further increase in viewing area

Table 52: Current EU regulations and US standards for indirect visibility [rear visibility]: FMVSS Standard No. 111)

Property	EU (UN Regulations)		US (FMVSS Standards)		Comparison
	Specification	Reference	Specification	Reference	
Applicability	-	-	Mandatory performance requirement	49 CFR Part 471.111	No matching EU standard
Reversing event			Starts when vehicle in reverse. Ends at manufacturers choice: 10 mile/h, 10m travelled, or continuous 10s duration	Part 571.111, S4	No matching EU standard
Test area	-	-	7 test points (A-G). Relative to point on rear of vehicle on centre longitudinal line, test points are at: A (-1.52m,-6.1m), B (0m,-6.1m), C (1.52m,-6.1m), D (-1.52m,-3.05m), E (1.52m, -3.05m), D (-1.52m, -3.05m), E (1.52m, -3.05m), F (-1.52m, -0.3m), G (1.52m, -0.3m)	S14.4	No matching EU standard
Test object	-	-	Circular cylinder 0.8m high and 0.3m external diameter	S14.3	No matching EU standard

Property	EU (UN Regulations)		US (FMVSS Standards)		Comparison
Field of view	-	-	Min of 150mm portion along circumference of each test object at positions F and G and the full width at positions A-E	S5.5.1	No matching EU standard
Size	-	-	When rear-view image measured in accordance with S14.1, calculated visual angle subtended by the horizontal width of: 3 test objects at A,B,C shall average not less than 5 minutes of arc and each shall exceed 3 minutes of arc	S5.5.2	No matching EU standard
Response time	-	-	Rear-view image shall be displayed with 2 seconds of start of reversing event	S5.5.3	No matching EU standard
Linger time	-	-	Rear-view image shall not be displayed after reversing event has ended	S5.5.4	No matching EU standard