

## AGRICULTURAL TRACTOR DRIVER'S LIMITATIONS OF VISUAL TRANSMISSION IN ASPECT OF ROAD SAFETY IN POLAND

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**Summary.** The report presents results and solutions of problems concerning visibility and agricultural tractor driver's limitations of visual transmission. It specifies the variance of results received by limitations measurements by the research circle method and the calculating method. It evaluates the adequacy of a tractors' rear-view mirrors requirements and dimensions and location of visual fields visible in it to the usage conditions in Poland (according to the mirrors' class range and location). It discusses the legal acts, which are the basis of research and requirement, and the rules of acceptance of the results of research in other countries. It mentions types of research concerning visibility verification, conducted within the framework of an agricultural tractors type-approval research. It presents examples of requirements, results of research and road traffic limitations of visual transmission, which may involve potential hazards. It also gives examples of construction solutions with reduced direct and indirect visibility limitations.

**Key words:** wheel agricultural tractors, visibility, safety

### INTRODUCTION

The agricultural tractor is a vehicle whose driver has to receive information from his environment to drive consciously and safely for himself and the other participants of road traffic. Visual transmission received by others from the environment should be perceived by the eyes of a tractor driver. It should be perceived in such a way as to provide him with information about possibility to move his vehicle and participate in road traffic. This information is necessary to use a vehicle consciously and safely – for both the driver and his environment.

Visual transmission limitations and safety are strictly connected. A driver receives over 90% of the most important, critical information from outside of his vehicle. By upgrading the quality of this visual information, we can also give the driver a better chance to avoid a collision or an accident. It is the most important area to car makers, who tend to ensure safety to users of their cars. The observed data about accidents indicate that a vehicle – agricultural tractor can be a dangerous instrument.

Visibility with an appropriate advance of necessary vehicle environment zones decides about the possibility of making a decision about counteracting the threat early enough. The factors of influence to the facilitation of receiving information and the factors determining the comfort of a driver's seat and his environment will reduce an accident threat level. The cause of the poor situation in this area is a lack of accommodation of environment configuration according to road traffic, due to limitations coming from the limitations of tractor's cabin construction.

In the report there are presented three scientific problems concerning the visual transmission necessary for a safe driving of an agricultural tractor:

- if the European requirements are adequate and if it is sufficiently accommodated to the Polish conditions,
- if there is sufficient correspondence of the research on visibility results given:
- by measurements on a research circle,
- by calculation method,
- if the obligatory requirements in Poland sufficiently eliminate threats of causing an accident.

In Poland there are in force the following juristic acts, which are the basis of requirements concerning visual transmission:

- front visibility – 180°, Regulation n° 71 ECE UN:
- front visibility in vision semicircle,
- limitations of vision and its location,
- cleaned field of windscreen,
- rear visibility – 180°, Regulation of Infrastructure Minister, Book of Acts n° 32/03, position 262:
- mirror requirements,
- visual fields requirements.

Poland, being a part of Geneva Agreement from 1958 concerning unification of regulations, had accepted Regulation n° 71 ECE UN (Uniform regulations concerning conformity of agricultural wheel tractors in the aspect of a driver's visual field). The parts of agreement are obliged to mutual acceptance of type approval given on the basis of performance requirements of the accepted regulations.

## REQUIREMENTS CONCERNING VISIBILITY LIMITATIONS

In Figure 1 there are illustrated the above-mentioned requirements according to the Regulation n° 71 ECE UN – conforming to EU Directive n° 74/346 EEC UE. The acceptable size, distribution and the range of vision limitations is specified in items from 5.2.1.3. to 5.2.1.6. of the Regulation n° 71 ECE UN.

## VISION LIMITATION DETERMINATION METHOD

On the level of a *reference point* (concepts defined in Regulation n° 71 ECE UN are designated by *Italic*) there are installed two pointed lights, 2 x 75 W, 12 V, located symmetrically by reference point in the distance of 65 mm from each other. To measure vision limitations, the two pointed lights have been installed so as to straighten the line connecting the covering part with the reference point. For testing, the tractor was equipped with the most disadvantageous tire set.

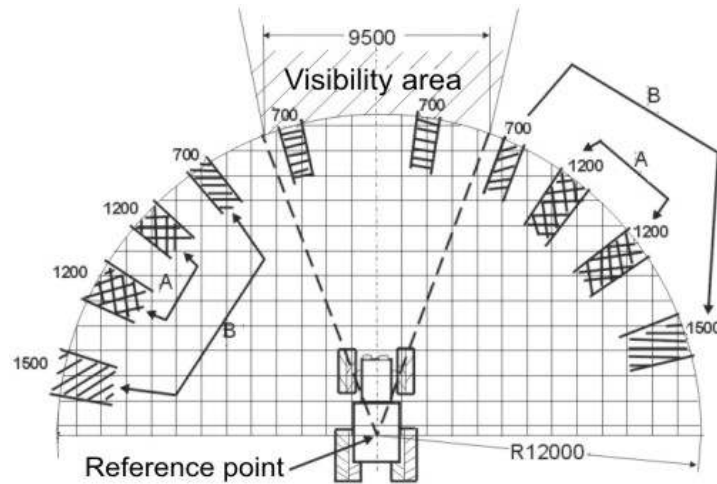


Fig. 1. Agricultural tractor, requirements – dimensions [mm], visibility semicircle, vision limitation – option A or B [Regulation N° 71 ECE UN]

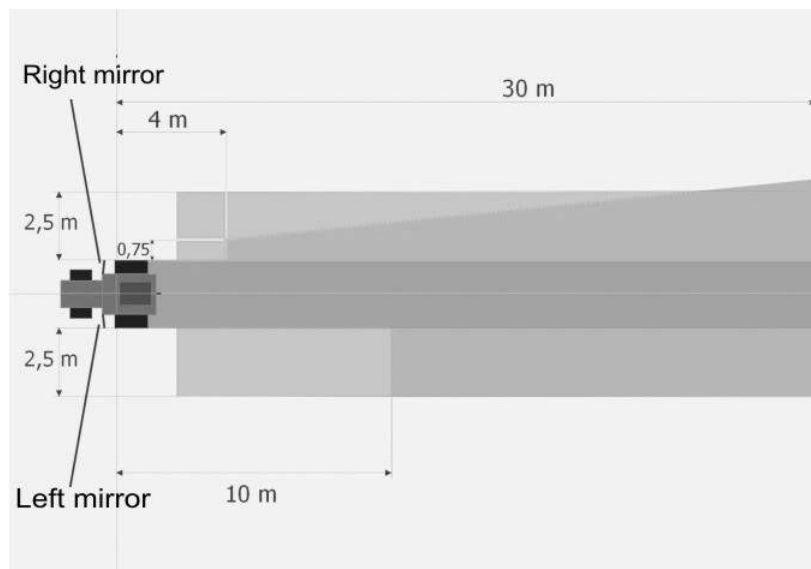


Fig. 2. Visual fields in mirrors according to [Directive EU 74/346/EEC, Infrastructure Minister Regulation]

There were measured, according to point 2.7 Reg. n° 71 ECE UN, after the simultaneous and next separate turning on the light, values of dimensions of shadows (deep shadows) covering each other, parts covering on vision semicircle.

### CALCULATION OF BINOCULAR VISION LIMITATIONS

Correspondence of different vision limitations can be verified by the mathematical calculation method instead of the above-described method. Vision limitation in [mm] can be, according to binocular vision principle and making an assumption of eye spacing  $s = 65$  mm,  $c = 12000$  mm, calculated from the formula:

$$(x/2 - s/2)/c = (b/2 - s/2)/a \quad (1)$$

$$x = 65 + (b - 65) \cdot 12000/a \quad (2)$$

where,

- a – distance in mm between a covering part and a reference point, measured along the straight line of vision connecting reference point, the center of this part and a vision semicircle,
- b – width in mm of a covering part, measured horizontally, perpendicularly to the vision straight line.

The draft with symbol indications contained in the formulas (1 and 2) is presented in Figure 3.

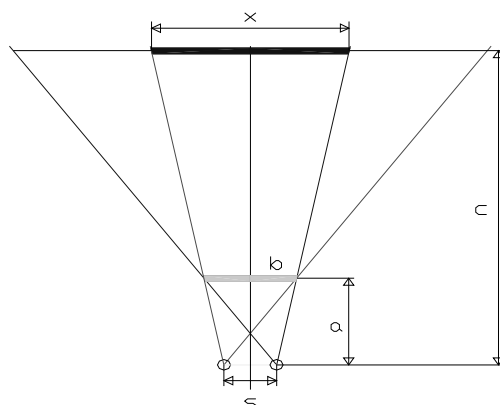


Fig. 3. A draft to calculate vision limitations by the calculating method

The above-described methods of verification can be substituted by other methods, on condition that are equivalent.

### MIRROR'S VISIBILITY DETERMINATION METHOD

In eye points, as above, are installed pointed lights. The light reflected in the mirrors should cover the required fields up to horizon.

On Figure 2 are illustrated the requirements concerning the extensiveness and location of the fields which should be visible in the mirrors according to Regulation MI [Infrastructure Minister Regulation and Directive EU 74/346/EEC].

On Photograph 1 there is illustrated a machine measuring vision limitations through cabin pillars, field cleaned by windscreen wiper and mirrors' visibility in an agriculture tractor, which are equipment of ITS Ergonomics and Visibility Research Laboratory, made according to its author's idea.

On Photograph 2 and 3 are illustrated examples of installation of research equipment in an agricultural tractor.



Phot. 1. The machine measuring visibility in an agricultural tractor

On Figure 4 are illustrated examples of results obtained in the tested agricultural tractor [Olejnik 1999].

There is number, distribution and mutual distances of vision limitations on vision semicircle for a reference point.

In Table 1 are illustrated examples of front visibility results obtained by a circle measurement method and calculation method and also extensiveness of areas on both sides behind, visible through the mirrors installed in a tractor [Olejnik 1999].



Phot. 2. Halogen head in a tractor  
– left side view



Phot. 3. Measuring machine installed in a tractor  
– rear view

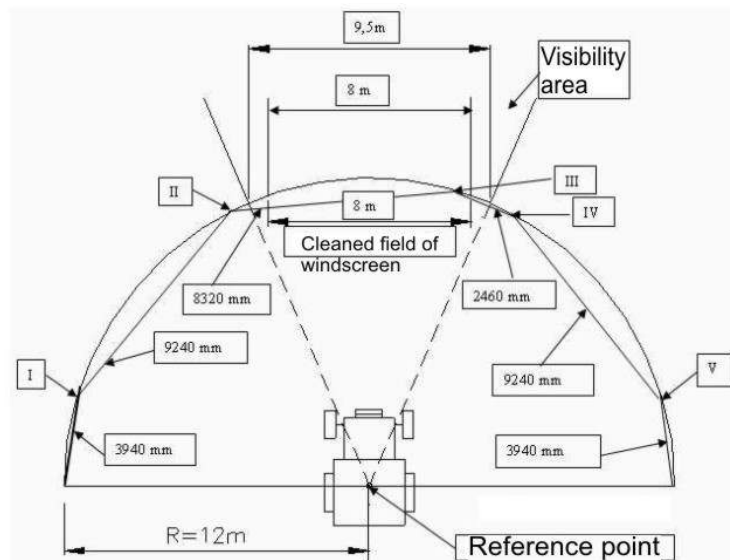


Fig. 4. Distribution and number of vision limitations on a vision circle and a field of windscreen wiper work [Olejnik 1999]

The variance between the results obtained by vision limitations measured during the research by the circle method and the calculation method are illustrated in Table 2. Calculations were carried out according to the formulas (3, 4, 5):

$$\Delta = |L_{\text{MEASURED}} - L_{\text{CALCULATED}}| \text{ mm} \quad (3)$$

$$\Delta_{\text{RELATIVE}} = \Delta / L_{\text{MEASURED}} \quad (4)$$

$$\Delta_{\%} = \Delta_{\text{RELATIVE}} \cdot 100 \% \quad (5)$$

Table 1. Research results

Measured			Criteria	Evaluation +/-
- part of every front wheel is visible from the driver's seat			should be visible	+
- on the whole vision semicircle is: 5 vision limitations			max. 6	+
- vision limitations on visual field are:				
	Measured on a circle- $L_{MEASURED}$	Calculated- $L_{CAL.}$		
I	990 mm	973 mm	max. 1200 mm	+
II	490 mm	458 mm	max. 1200 mm	+
III	395 mm	361 mm	max. 700 mm	+
IV	490 mm	451 mm	max. 1200 mm	+
V	995 mm	962 mm	max. 1200 mm	+
- chord on a vision semicircle for a field cleaned by windscreen wiper is:				
VI	8190 mm	8493 mm	min. 8000 mm	+
visual area			include	+
windscreen wiper work frequency is: 30 cycles / min			min. 20 cycles/min	+
number and distribution of vision limitations				
- in a visual area – 1			max. 2	+
- in a visual field (out of visual area):				
- on the left – 2			max. 2	+
- on the right – 2			max. 2	+
mutual distances of vision limitations – the lowest: 2460 mm			min. 2200 mm	+

Visibility in mirrors	Results	Criteria	Evaluation
left mirror			
- distance 10 m	4100 mm	min. 2500 mm	+
right mirror with simultaneous visibility keeping			
- distance 30 m	5850 mm	min. 3500 mm	+
- distance 4 m	900 mm	min. 750 mm	+

Table 2. Results variance evaluation

$\Delta$ [mm]	$\Delta_{RELATIVE}$	$\Delta_{\%}$ [%]
17	0,017	1,7
32	0,065	6,5
34	0,086	8,6
39	0,080	8,0
33	0,033	3,3
303	0,037	3,7

Accuracy of results in a calculation method depends on the accuracy of width value determination and distance of cabin elements causing vision limitations – width of covering element and distance from eye-points of this element causing vision limitation. The value of vision limitation should be determined on the level of road on a circle of diameter 24 m. The centre of a circle is on the road in an intersection of vertical line and road and cross by centre of section joining eye-points of driver in normal driving position.

Measure of distance between eye-points and obstruction and its width in a place of vision limitation calculating on a circle, is a complex operation. These places are in a three-dimensional space and most of all decide about the accuracy of vision limitation width calculation.

EU Directive concerning of visibility in mirrors [Directive EU 74/346/EEC] determines the requirements which are softer than the Polish requirements because of the assumption that a tractor will not take part in road traffic as a transport vehicle and pull a trailer. In Polish conditions, tractors are used not only to work in the fields, but also to road transport (pulling loaded trailers on public roads). The width of the pulled trailers is considerably larger than that of the tractors. An importer or a foreign manufacturer usually has a certificate of visibility in mirrors fulfilling the requirements of the EU Directives. They are really surprised that in Poland visibility requirements are different.

In this aspect the Polish specific conditions of a tractor's operational use is very different from those present in EU countries. Among other things, due to the above-mentioned factors, Polish requirements concerning mirrors arrangement and provision of appropriate visibility in them, are „sharper”. Polish regulation is supported by an analogical requirement for trucks (Regulation n° 46 ECE UN). But in this juristic act, mirror parameters such as dimension, radius and class – are not defined.

As in tractors' technical requirements it is not determined, the observed practice demonstrates assembling also class III mirrors, which have larger mirror curvature so can be smaller. For tractors, in effect of a large distance between mirrors and driver's eyes in comparison with passenger cars, observation of particulars from environment is strongly disturbed and time necessary to understand the received information is increasing. For areas very distant from a tractor, recognizing of particulars through the mirrors becomes impossible.

The tractor should be equipped with two main class II mirrors, ensuring the same visual fields as are required in trucks with a vehicle's total weight over 2 tons. Moreover, their distribution should take into account a possibility of their displacement to a usually enlarged trailer's width – in relation to the tractor's width. Permitting the situation while a tractor, fulfilling the EU Directive requirement in the aspect of rear visibility, pulls a considerably wider trailer, is a threat for the participants of road traffic. In Figure 5 there are presented zones, which cannot be perceived by the driver in the discussed situation. Some parts of the required visibility areas are covered by the trailer.

An agricultural tractor, in accordance with the regulations, can pull an agricultural machine with the maximal width of 3000 mm. A tractor's width, in accordance with the regulations, cannot be larger than 2550 mm. The manufactured on a mass scale tractors mostly have smaller width dimensions than the maximal acceptable width. Agricultural tractors permitted to Polish road traffic fulfil the requirements concerning the provision of sufficient front and rear visibility.

In case of connecting a tractor with a considerably wider trailer, the mirrors at the tractor do not ensure the required visual fields for such a complete tractor-trailer unit. Essential vision limitations caused by a trailer considerably limit the driver's possibility to observe the environment and create accident or collision threats. Polish regulations are not sensitive to such a situation.



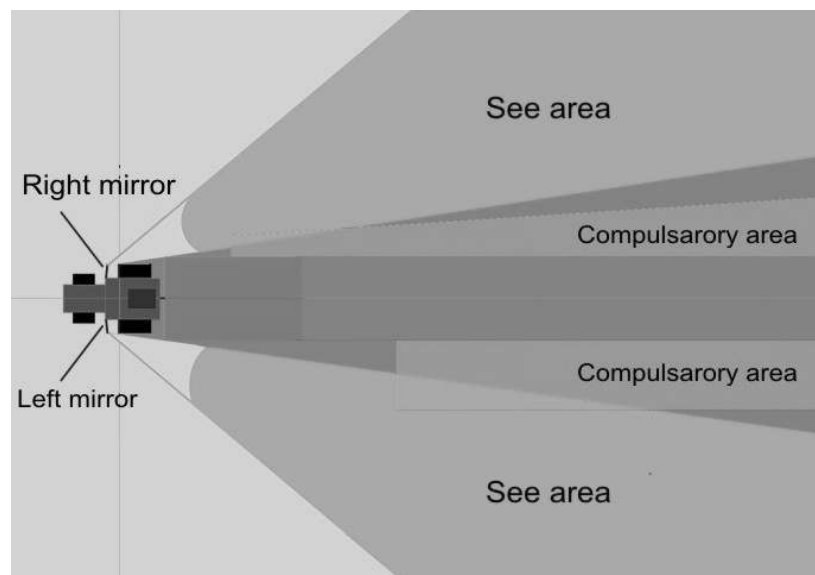


Fig. 5. Visibility in mirrors – a tractor and trailer set

## CONCLUSION

The reasons of an influence of extension changes and the development of agricultural tractors' cabin constructions requirements:

- an agricultural tractor without a safe cabin or protective frame – „survive zone” not guaranteed,
- an agricultural tractor without rear mirrors – a big threat and also no possibilities to move safely in a road traffic,
- an agricultural tractor with excessive vision limitations caused by the exhaust pipe and intake manifold limiting visual transmission from the environment,
- mirrors spacing in relation to cabin do not accommodate to trailer width, which limits the possibility of rear observation.

Driver crush accidents, while the tractor turns over, have happened since the year 1994, which brought an implementation of the regulation requiring a protective frame or a safe cabin in newly produced vehicles. The constructor has to solve a contradictory targets conflict: on one hand the pursuit to create a resistant construction (solid, thick pillars), to guarantee a driver's passive safety (survival zone), on the other hand an assurance of the maximal visibility (best without pillars), to guarantee a driver's active safety. In tractors manufactured presently there is a tendency to put intake manifold and exhaust pipe in the shadow of cabin pillars, reducing the value of vision limitations number, and at the same time reducing visual transmission limitations. The presented consideration of road traffic participants' safety in an aspect of visibility from the vehicle driver's seat allow for the following observations and conclusions:

- problems with visibility from a vehicle, in spite of a significant increase in their importance and the constantly growing formal – legal requirements, are still distant from solutions which would eliminate hazard for road traffic participants,
- Polish regulations standards concerning visibility matters require a complex analysis and modification,
- the lack of regulations comes mainly from a lack of complex research on the system Driver – Vehicle – Environment,
- visibility aspects are weakly exposed and marginally treated in automobile literature,
- the project of Regulation n° 46 ECE UN with a series of corrections 02 provide a more extensive range of areas, which a driver should perceive through mirrors. The pursuit of the regulations authors to reduce the presently existing limitations in the visual transmission from a vehicle's environment is evident. This tendency should be continued also in Poland.

It is necessary to cause changes in the certification regulations requirements concerning the tractors construction and equipment with the purpose of ensuring a sufficient visibility to a driver at the wheel.

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