AGRICULTURAL EQUIPMENT

Agriculture has continuously been listed as one of the most hazardous industries. Obtaining statistics as to exactly how dangerous it is are not easily found but statements by various governmental agencies shed some light on the subject. For instance, the University Centers Response to the Proposed Termination of the NIOSH Agriculture, Forestry, and Fishing Program (2012) page 1, and in the National Agriculture, Forestry and Fishing Agenda-December 2008 at page 6, provide the following information;

> In a typical year, 551 workers die while doing farm work.
> 93,000 non-fatal OSHA recordable injuries occur on U.S. farms each year.
> Estimated direct and indirect costs of these fatalities and injuries range from $4.5 to $13.9 billion annually.

Even a search of the internet for "tractor accidents" produces 7,370,000 hits.

Obviously, there are many accidents and causes of accidents on the farm. This paper will focus on the tractor (and all other types of self-propelled equipment), and in particular 3 types of accidents mentioned in almost every research paper on the topic;

the roll-over
the blind run-over
the highway collision involving farm equipment,

all of which we contend are accidents that can be reduced by providing the operator with exterior mirrors and/or video cameras on the equipment that provide the operator with a necessary view of the proximity area surrounding the equipment and does so with clear images.

1. The roll-over accident.

The major problem with these types of vehicles is that they have a high center of gravity because they are usually working over growing crops and when this center of gravity is dislocated abruptly the equipment turns over. As stated in University of Florida IFAS Extension paper Safer Tractor Operations for Home and Acreage Owners by Carol J. Lehtola and Charles M. Brown;

> "Tractor overturns in canals, ditches, and washouts are common. The steep slopes and loose soils in these environments are serious hazards. Other hazards are found on public roads, blind corners, narrow bridges, culverts, sharp turns, steep terrain and slippery surfaces."

When the tractor wheels hit such an obstacle or drives over the edge of a road, the operator makes a sharp correction in the opposite direction, the center of gravity keeps the vehicle going the direction dictated by the obstacle and the result is as stated in LSU AgCenter paper 2012:

> "A side overturn is the most common type of rollover, and it usually happens when traveling on local roads.*** Simply put rollover accidents happen when the tractor is in an unstable situation."

The exterior mirrors on the vehicle should be of aid to the operator in avoiding obstacles that could cause the roll-over.

2. The blind run-over accident.

This type of accident is very common and explained well by J. Miller and L. Fragar in Farm Machinery Injury-Injury Involving Tractor Run-Over, RIRD Publication No. 06/033 (2006) page 16.

> "Blind run-overs occur when the victim approaches or is in the vicinity of the tractor unseen by the operator. The victims are frequently young children who because of their small size may not be seen by the operator. Included in this category for the purpose of this project are cases where workers assisting the tractor operator have been run over while attaching an implement to the tractor or carrying out maintenance on the implement. The victim may be unnoticed by the operator because of an area in the vicinity of the tractor that is not visible from the tractor operators' position due to tractor design, or from the victim moving into the path of the tractor from behind another object."

Exterior mirrors that provide a view of the proximity areas surrounding the vehicle to view areas not seen by the operator from the driver's seat would aid in this type of accident prevention.

3. The Highway collision.

Farms are getting larger and contain more non-contiguous fields, equipment is getting larger and travel on roadways that are getting more and more congested becomes a necessity. One of the more common highway collisions is the left turn maneuver by the farm equipment operator. As explained in the National Farm Safety and Health Week Brochure (March 2012) by the National Ag Safety Database;

> "There is a crucial time for an operator to know his/her surroundings,

especially when a left turn needs to be initiated. Turning at roadway speeds is not advisable, therefore speeds must be reduced. An operator of a large machine that plans to turn left must first move the machine to the right to clear any driveways and gates that would be encountered by trailing equipment during the left turn. Any motorist traveling behind the farm machinery may think that you are letting them pass (even if it a no-passing zone). If the machine operator is not aware of the situation and completes the left turn—a collision may result."

The operator of the farm machine must have the opportunity of being able to see clearly traffic to the rear and along the side of the machine in such a situation and the only way that this can be done is with the exterior mirrors.

AGRICULTURAL EQUIPMENT AND EXTERIOR MIRRORS

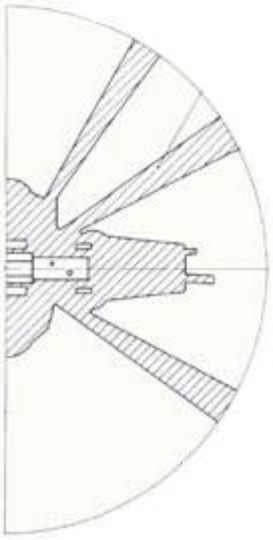
An article in Farm Industry News by Jodie Wehrspann titled: New Tractor Cabs: The latest in Creature Comforts, states:

"Tractor cabs have reached a whole new level of comfort. New models for 2012 incorporate the best features from home to your glass palace in the field. You'll see redesigned control arms that move with the seat. Touch-screen display consoles capable of streaming live video. Heated seats that swivel. Remote vehicle-monitoring systems. Automatic climate control. Wireless Internet. Intellligent cab suspension. Hookups for MP3s. USB ports and Bluetooth technology. Even a refrigerator under the seat to keep your drinks cold."

Always missing in the discussion of the cabs amenities in brochures is a mention of the necessity of the exterior mirrors and what aid they provide operator in avoiding roll-overs, blind run-overs and highway collisions.
Every vehicle has areas surrounding the vehicle that cannot be seen directly by the operator. These areas are referred to as "blind zones" i.e. they cannot be seen by the operator and aids are necessary to allow the operator to indirectly view these areas. Explaining the blind zones on a tractor can best be done with an illustration.

In the following figure we see an example of a test done on a tractor pursuant to ISO Standard 5721 (1989)

Figure 1



ISO (International Standards Organization) Standard 5721 (1989) requires in summary, a light source being used to replace the operator's eyes. From the position of the eye location of the operator in the driver's seat the areas not shown by the light are diagramed, and this is illustrated by the shaded area in Figure 1 showing the lack of visibility around the area of the tractor.

Source More Security for Kids Around Moving Vehicles on theFarm by E. Quendler, P.Veith, A. Pohl and J. Boxberger A. Published in Agricultural Engineering International: the CIGR Ejournal (2005)

How well do mirror configurations presently being offered by manufacturers show the critical areas?
Exterior mirrors are usually placed on the side of the cab and provide the view seen in the following 3 illustrations:

Figure 2

Figure 3

Figure 4

Looking at Figures 2, 3, and 4, and the images presented in the mirrors clearly shows the mirrors are not showing the critical area surrounding the vehicle. When mirrors are placed on the vehicle that do not cover the entire "blind zones" on the vehicle, the remaining areas not seen by the operator are referred to as "blind spots". The operator is left with trying to look into these areas physically to make certain that nothing is in those areas before maneuvering the vehicle or working in that area, and the cab structure itself provides a hindrance to the operator being able to take such action.

The "blind spot" areas can also be illustrated by sitting in the operator's seat and marking the spot where the ground can first be seen behind the vehicle. A line from this spot to the location of the mirror on the vehicle provides a limit on the downward view provided by the mirror. Following are a photo of a tractor (Figure 5) and a combine (Figure 6) where the lines have been superimposed on the photos to show the actual field of view and the blind area on the vehicle.

Figure 5

Figure 6

The photos also illustrate the problem of proper location of the mirrors on the vehicle. The mirrors should be located if possible to the front of the operator so they can be checked by a glance while maintaining the eyes to the front area of the vehicle.

LAWS AND STANDARDS REGARDING THE EXTERIOR MIRRORS ON AGRICULTURAL EQUIPMENT

Agricultural equipment is generally included in a category called "off-road" equipment so there is no governmental agency in the U.S. that sets rules for this equipment specifying mirror requirements, and importantly, what is the scope of the indirect view that these mirrors must provide for operators.

There are some organizations that put together "voluntary standards" that can be used by manufacturers, if they choose, and there are some worldwide organizations that put together "required standards" that must be followed to allow manufacturers to sell their products to member countries. A review of these standards does illustrate that there is a growing concern to require some sort of performance standards for the exterior mirrors placed upon agricultural equipment.

VOLUNTARY STANDARDS

The American Society of Agricultural and Biological Engineers (ASABE) provides in Section 318.16 paragraph 13 section 2 as follows:

That tractors and other self-propelled equipment with cabs must contain at least one rear view mirror to see the highway behind the machine.

The International Standards Association (ISO) provides in 4254-1 section 5.1.7.1 added to the requirement as follows:

The design and position of the operator's workplace shall be such that has adequate visibility to drive the machine and view the work area of the machine. Aids such as mirrors or TV devices shall be provided to remedy inadequate direct view.

The ISO Standard is of more aid but again, since there is no requirement that these standards be followed in the U.S. manufacturers are free to provide such mirrors as they choose.

With the growing global economy and organizations such as the European Union, and the wish of American manufacturers seeking to participate in such markets, we see the development of "performance standards" for exterior mirrors that manufacturers have to comply with to compete in such markets.

The most recent development here has been consideration of a new ISO Standard 5721 parts 1, 2, and 3 for tractors and other self-propelled equipment. The Standard is still in the development stage but more than likely the vision requirements set forth in the working draft of the Standard will remain in the final draft.

The rear vision requirements for mirrors are summarized in the following diagram:

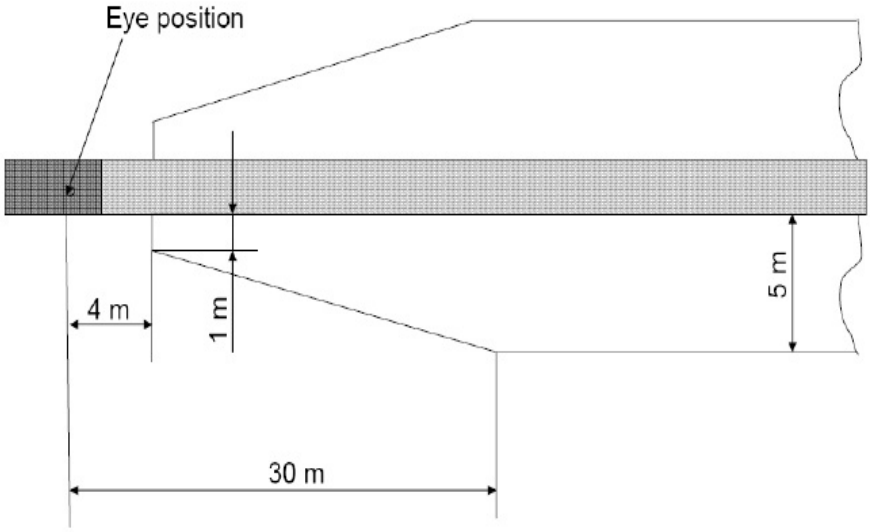


Figure 1-Field of vision laterally behind the vehicle (ISO 5721-2)

A view of the road to the rear is not required until 13.1 feet (4 meters) behind the eye location of the operator which begins with a width of 3.3 feet (1 meter) and increases on an angle to 16.4 feet (5 meters) starting at a point 98.4 feet (30 meters) behind the eye location of the operator and continue on to the horizon.

The view to the operator in the exterior mirrors commences behind the vehicle so obviously there is no aid to the operator in seeing any blind areas immediately surrounding the vehicle. A second vision requirement is then presented which can be illustrated by the following diagram.

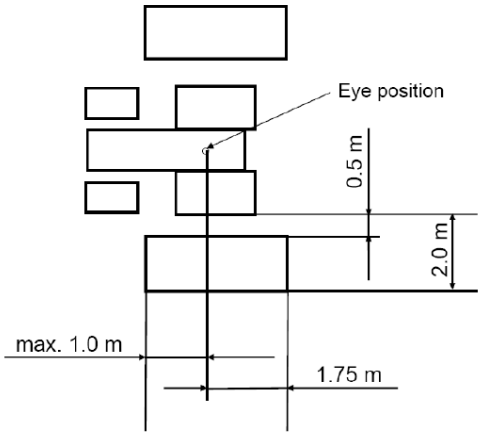


Figure 2 Field of vision beside the vehicle in 1m height above the ground

Here we see two rectangles beside the rear wheels of the equipment measuring 9 feet (2.75 meters) in length and 4.9 feet (1.5 meters) in width. The rectangles contain approximately 44 square feet and must be located 1.6 feet out from the rear tractor wheel. The standard continues that this area may be viewed by Camera/Monitor Systems.

At least we see here some attempt to alleviate the problem of blind areas around the proximity area of the machine. Tractor manufacturers selling products where the new standard is considered required will have to address the problem of complying with the standard and farmer/operators in the U.S. will have to (a.) hope that manufacturers will simply use the new mirror systems on all their vehicles so the benefits will also accrue to them or (b.) have the knowledge as to what is being done for others so when they start to look at machines they will have the information as to what they should be demanding.

The Standard would appear to offer two solutions for compliance:

1. The incorporation of two exterior rear view mirrors to view the area to the rear of the tractor along with the placement of two video cameras on the side of the cab to view the areas on the side of the rear wheel. or
2. Two mirrors on the vehicle that show the operator both the rearview requirement and provide at the same time a view of the areas in the second requirement.

Resolution of compliance requires knowledge of mirror technology. The mirrors in Figures 2, 3, and 4 above appear to be of a relatively flat glass, and this appears true through viewing the mirrors while sitting in the seat. The pictures illustrate

the type of view they provide will not show the area of the roadway to the rear of the vehicle. If compliance requires a different glass, other than the flat glass, to see the ground in the required areas this will involve the use of wide angle glass. Here mirror suppliers world-wide continually use the single rate of curvature convex glass as their solution when a wide angle mirror is necessary for vehicles. This remains true even though in all industries where wide angle mirrors are being used the two major complaints against mirror systems that use these mirrors has always been "blind spots" and "distortion".

BLIND SPOTS

It is accepted that the standard convex mirror provides a wider view but what must be remembered is that this wider field of view is produced in a cone shape coming off the face of the mirror. See Figures 5 & 6. As distance from the mirror face increases the view widens until such time as the cone of view ultimately will show the ground. The area on the vehicle below a line drawn from the face of the mirror to the location where the ground is first seen is a "blind spot". With the standard convex mirror the only way to reduce the extent of this blind spot i.e to show the ground sooner is to increase the rate of curvature of the mirror. Increasing the rate of curvature makes the mirror take on more round shape as opposed to a flat glass. Increasing the rate of curvature also has the effect of creating more distortion in the images presented to the operator.

DISTORTION

With the standard convex single rate of curvature mirror the element of distortion is created. In this type of mirror the images viewed will always be smaller than they are in actual size. When the object is viewed this affects the drive's perception as to where that object actually is in location to the operator's position. This effect is referred to as distortion. The operator knows the object is there but does not quite know where it is in relation to the operator's position so mental calculations are required and sometimes this will require actually turning the head to look into the area to locate the object before a maneuver is made into that area.

An example of the problem faced will explain. School bus mirrors are located 7 feet from the ground on the side of the bus. The field of view they produce does not show the ground until 10 feet behind the bus. The blind spot thus exists, from the location of the mirror on the bus to well behind the bus and this means children standing by the door to about the middle of the bus cannot be seen by the operator in the mirrors. In 1992 the Federal Agency in charge of school bus mirrors (National Highway Traffic Safety Administration) under executive order from the

President felt this was extremely dangerous so they demanded that mirror manufacturers show the location of the ground at the location of the mirror on the bus. The mirror manufacturers using only the single rate of curvature mirror clearly proved that the only way the ground could be shown to the operator was to use such a severe cut of glass that the images presented were so distorted the drivers refused to drive the vehicles and the project was dropped.

This same result would apply to the tractor, where the mirrors are located many time at least 7 to 10 feet from the ground. The single rate of curvature mirror would have to produce a field of view starting at the location of the mirror on the tractor to comply with the second requirement in the Standard and the distortion factor would make the information provided useless.

This would leave the manufacturer of the vehicle in the position of placing 2 mirrors and 2 video cameras on the vehicle to comply with the standard if current mirror technology were to be used.

Even considering the requirements of the Standard, it is important to remember that these are considered minimum requirements and completely missing is a study of what these standards actually accomplish to aid the operator.

Dr. Krzysztof Olejnik, in his paper, Agricultural Tractor Driver's Limitations of Visual Transmission in Aspect of Road Safety in Poland published in TEKA Kom. Mot. Energ. Roln., 2005, 5, 158-167 faults the rear view portion of the Standard for not taking into account the fact that many times the tractor is pulling a trailer wider than the tractor which has the effect of blocking a portion of the required field of view set forth by the Standard and occurs because of a lack of accommodation to the environment in which the tractor is operating and a consideration of the limitations caused be the tractor's cabin construction.

About the environment in which the tractor is operating, Dr. Olejnik makes the following observations:

"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 information 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." (page 158)

As to visual information and limitations placed thereon it is further stated at (page 158)

"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."

In illustrating the problem of wider equipment being towed by the tractor Dr. Olejnik sets forth an illustration as follows (page 166):

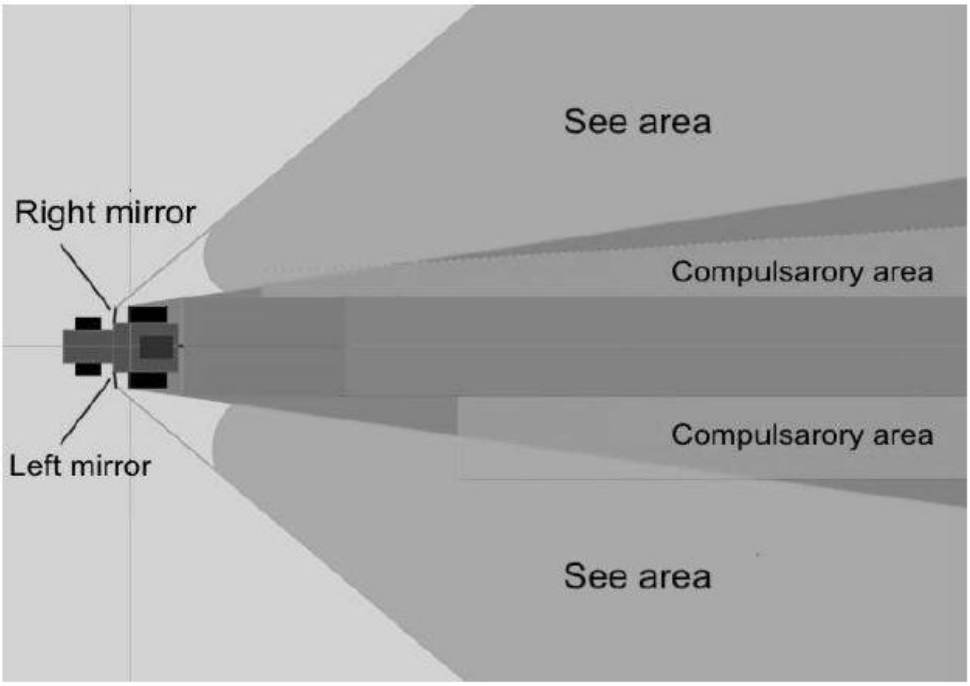


Fig. 5. Visibility in mirrors – a tractor and trailer set

In the diagram note the area marked "see area" which is part of environment in which the tractor is operating and yet is not covered by the rear view mirror requirement.

We believe that this "see area" as well as the proximity area surrounding the machine itself. both provide necessary information to the operator and should both be seen clearly by the operator of the vehicle. To accommodate this belief we have developed the M-C Glass Technology. (U.S. Patent no. 8172411)

THE M-C MIRROR GLASS (U.S. Patent no. 8172411) TECHNOLOGY SOLUTION

The M-C Glass differs from the single rate of curvature convex mirror as follows:

THE SINGLE RATE OF CURVATURE CONVEX MIRROR HAS ONLY ONE RATE OF CURVATURE SO NO POSSIBLE CHANGE IN THE SIZE OF IMAGES CAN BE INTRODUCED OR PRODUCED. THE M-C GLASS HAS MANY RATES OF CURVATURE IN THE ONE MIRROR SURFACE. HARMONIZING THESE RATES OF CURVATURE ALLOWS US TO CONTROL THE VIEW PROVIDED WHILE ENABLING US TO MANAGE THE SIZE OF THE IMAGES PRESENTED.

FURTHER, M-C TECHNOLOGY HAS DEVELOPED A METHOD OF FUSING TWO OR MORE RATES OF CURVATURE GLASS INTO A SINGLE MIRROR.

With our technology one part of the mirror can be used for the rearview requirement of the Standard, and the "see area" of Dr. Olejnik, thereby exceeding the minimum requirements of the standard, while the other part of the mirror can look at the area required to be seen by the wheels of the tractor. Both areas can be seen by the operator with sufficient clarity to allow the operator to act immediately upon what is seen, and this can be accomplished with a single mirror.

The transition between the two views will be seamless and not interfere with the operators perception of what is being seen because the size of the images will be maintained.

If you are looking for a new tractor and/or are considering upgrading your present mirror systems you should demand the M-C Mirror Systems. Our System is based upon providing the operator a 360 degree view of the tractor. Included in our 360 degree system requires a discussion of items other than the exterior mirrors on the tractor.

INTERIOR REAR VIEW MIRRORS, REMOTES, AND VIDEO CAMERAS

INTERIOR MIRRORS

All manufacturers include 1 and sometimes 2 interior rear view mirrors on their vehicles. Figure 2 and 4 above should be examined and focus placed on what is shown in the interior mirrors. Actually sitting in the operator's seat has illustrated to this writer that all offer a good view of the driver's head and/or the headliner on

the tractor cab and nothing else. Definition of the aid to the operator of the rear view mirror must first be determined, "the environment", and then a mirror is specified, that properly located, accomplishes that view which is part of our "360 degree" mirror system. Here again the wider view provided by the M-C Glass with clarity can make the interior mirror useful to the operator.

REMOTE SYSTEM

As part of the 360 degree mirror system we believe the exterior rear view mirrors must be remote controlled and telescopic. This allows the operator to adjust the mirrors from the seat, as necessary to accommodate the operator, and the flexibility to accommodate the mirror system to the requirements of the particular task.

VIDEO CAMERAS

Not all areas required to be seen by the operator on the tractor can be seen using mirrors. Specifically the area of the power take off, which should be monitored at all times the vehicle is operating, is not shown by the current mirror systems. This area can illustrated by the following photo.

Figure 7

As part of our 360 degree visibility system we believe this is the place proper for a video camera application.

At M-C North America we are constantly updating our list of products offered as solutions are developed. Consult our Product Page to see our current offerings and how they may aid you in making your tractor safer to operate.

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