



## **THE RIGID HAUL TRUCK AND CONSTRUCTION EQUIPMENT ISO 14401 AND ISO 5006 COMPLIANCE REGARDING REQUIRED OPERATOR VISIBILITY**

The problem of “blind-spots in the operator’s field of vision on the rigid mine haul truck and construction equipment has long been researched and determined to be a major cause of accidents in the mining and construction equipment industry. Recent events have led to the filing of 2 petitions with the EU Commission alleging construction accidents have happened in Germany as a result of the visibility of the operator of construction mobile equipment, which also has a bearing on mining mobile equipment. This has led the EU Commission to issue a warning that following the requirements of EN 474-1 does not give the presumption of conformity on visibility as was previously the case. This will remain true unless changes in ISO 5006 are made as follows:

- 1. Priority must always be given to direct visibility**
- 2. Close range visibility must be improved by reduction of the height of the test body from 1.5 meters to 1.0 meters.**
- 3. Visual aids such as CCTV Systems and mirrors must be fitted in the forward direction of view.**
- 4. Visual aids must not be obstructed by moving parts of the machinery (such as excavator arms)**

## **5. Mirror to Mirror systems are not permissible.**

**(Source KAN Brief 4/14 by Dr. Michael Thierbach)**

**Once these changes are made to ISO 5006 all 12 parts of the EN 474 series of standards will be revised, and the presumption of conformity for visibility will be effective by following the EN 474 applicable provision. Remember when you certify in your Declaration of Conformity you are in compliance with the particular supart of 474 for your type of equipment you are bound by the general requirements of EN 474 1 which provides in Section 5.8.1**

### **“Visibility**

**Earth moving machines shall be designed in accordance with ISO:5006:2006 so that the operator has sufficient visibility from the operator’s station in relation to the travel and work areas of the machine that are necessary for the intended use of the machine.**

**Earth –moving machines shall be equipped with rear view mirrors according to ISO 14401.”**

**This paper will be based upon inclusion of the changes to ISO 5006.**

**The EU health and safety requirement is Directive 2006/42/EC which provides**

### **“3.2.1. Driving position**

**Visibility from the driving position must be such that the driver can, in complete safety for himself and the exposed persons, operate the machinery and its tools in their foreseeable conditions of use. Where necessary appropriate devices must be provided to remedy hazards due to inadequate vision.”**

**Manufacturers must state in detail their technical documentation of how their risk assessment has been performed on their equipment and the steps taken to comply with the visibility requirements and**

**maintain these documents for possible future requests by the proper authorities.**

**ISO 20474-1:2008 states further in complying with the Directive;**

**Specifies the general safety requirements for earth moving machines and states**

#### **4.8.1 Operator's field of view**

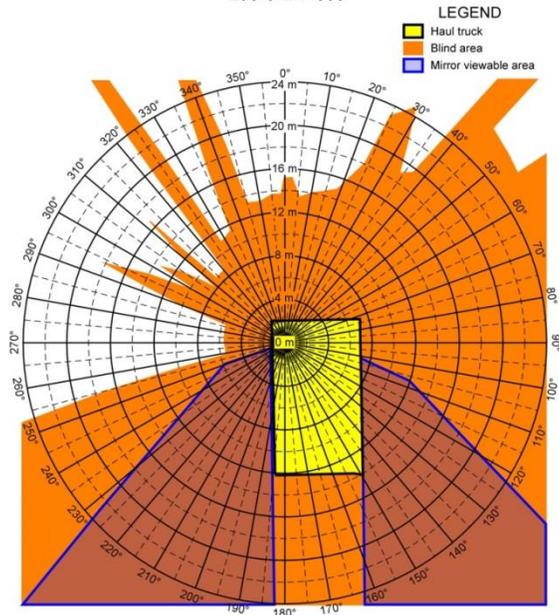
**“Earth-moving machines shall be designed so that the operator has sufficient visibility from the operator's station in relation to the travel and work areas of the machine necessary for its intended uses. The performance criteria shall be in accordance with ISO 5006. And Earth moving machines shall be equipped with rear view mirrors compliant with ISO 14401-1 and ISO 14401-2.”**

#### **Assessment of the risks**

**We have as a starting point the fact that there exist many illustrations of blind areas on this equipment. For instance, on the CDC web site we have illustrations of blind areas for various types of equipment per contract with Caterpillar Inc. using the basic approach set out in ISO 5006. The blind area for a 280 ton rigid haul truck is illustrated by the following diagram:**

**Figure 1**

Blind Area Diagram for Haul Truck  
Ground Plane  
Euclid EH4500

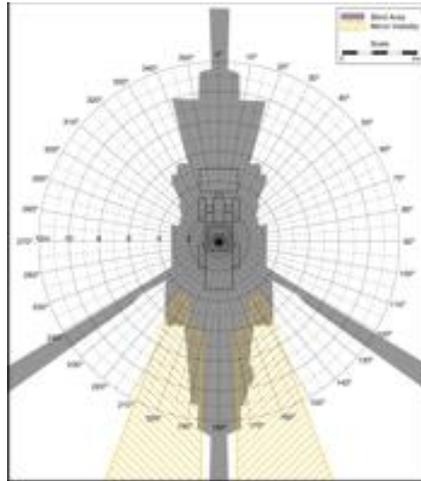


**For visibility such a diagram could be used for possible risk assessment purposes.**

**For further types of equipment the CDC report presents the following illustrations.**

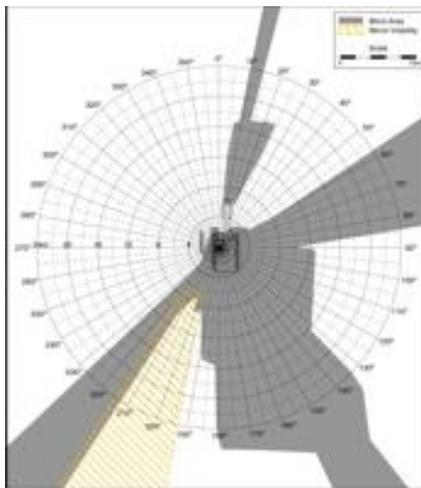
**In the CDC report the operator view for the front end loader is illustrated as follows;**

**Figure 2**  
**Blind area diagram for Front-End Loader Volvo L110E**



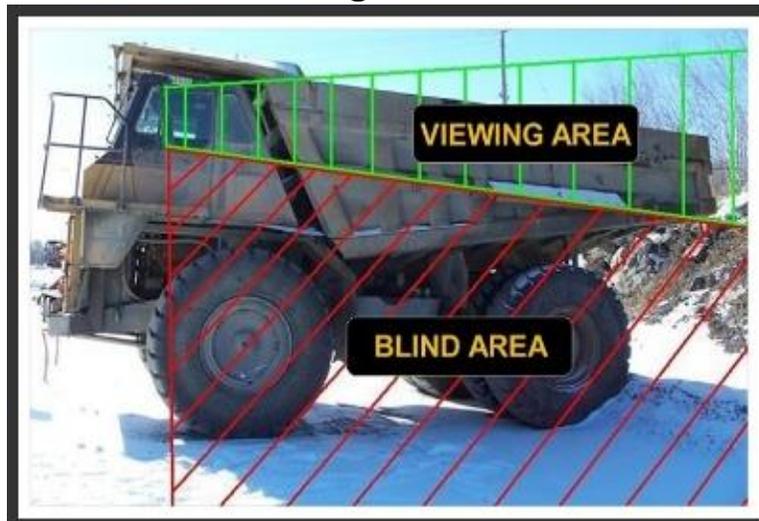
In the CDC report the operator view for the excavator is illustrated as follows

**Figure 3**  
**Blind area for CAT 325B Excavator**



In reviewing these diagrams remember the view provided in all these illustrations includes the area shown by the mirrors which is developed using the single rate of curvature mirror. This type of wide angle mirror glass has been used since mirrors were first placed on vehicles and is still offered today by all mirror manufacturers. One of the physical characteristics of the single rate of curvature mirror is that the mirror produces a cone shaped field of view that starts at the face of the mirror and opens up as distance from the face of the mirror is introduced. Because of this characteristic the view of the ground on the 5006 blind area diagram in Figure 1 is not complete because it does not take into account the vertical blind area which can be illustrated by the below photo (view sitting in driver's seat and actually measuring to a point where the ground can first be seen in the mirrors). As shown the ground is not visible until well behind the vehicle.

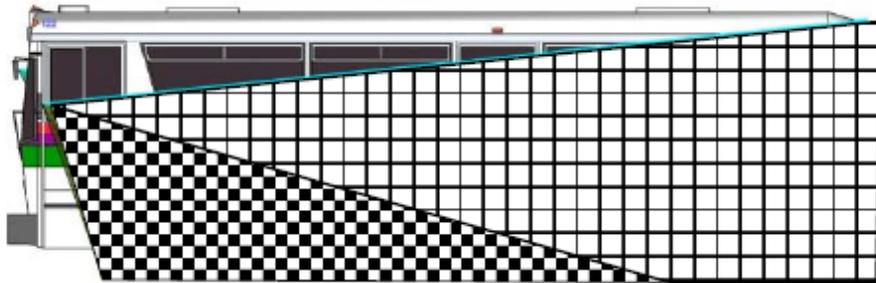
Figure 4



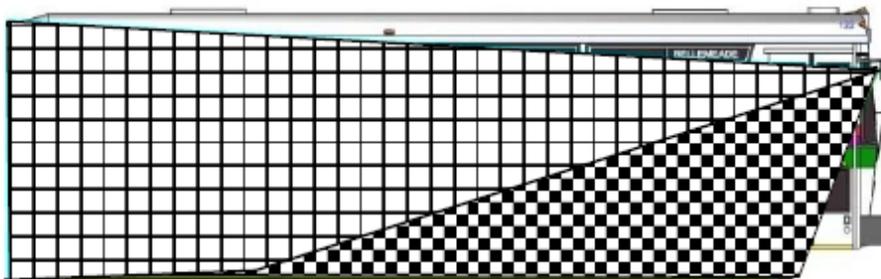
The same principle can be shown with other vehicles such as the transit bus isometric view found in Florida DOT Final Report BDK 85Two 97 "Evaluation of camera based systems to reduce transit bus side collisions". In the following Figure 5 the large checks are the view

provided by the mirrors and the checkered area below this illustrate the blind spots left on the bottom of the bus.

Figure 5



(c) Driver side view



(d) Passenger side view

No matter what type of vehicle is being viewed the result will always be the same using the single rate of curvature mirror, the only type of mirror that all mirror manufacturers are using.

#### APPLICATION OF ISO 14401

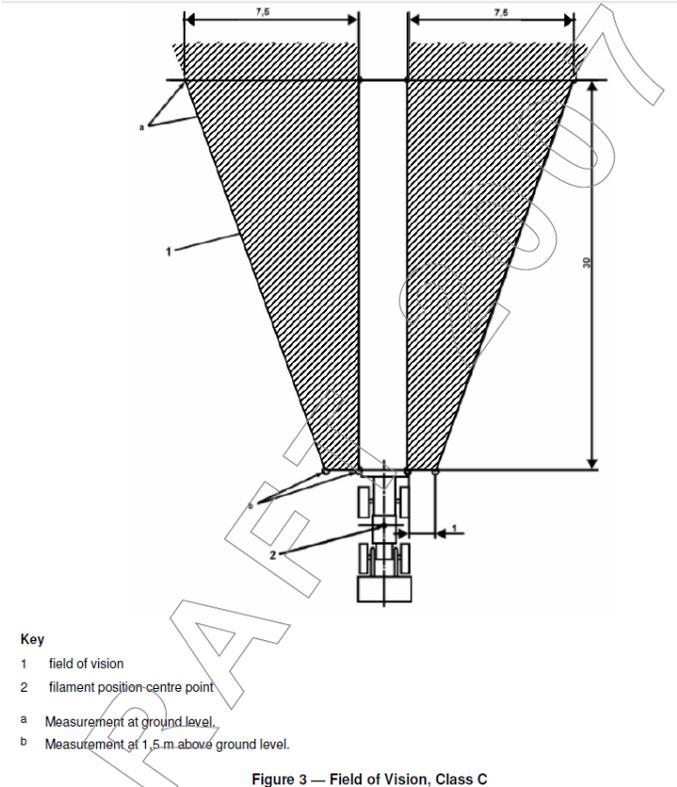
The standards sets different views of different areas on the machine that must be shown by the exterior mirrors on different types of equipment.

For the Rigid Haul Truck the standard specifies that for this type of vehicle both a Class C , and a Class D mirror must be used.

The Standard then specifies the field of view that must be provided by:

The class C mirror view which is illustrated by the following:

Figure 6

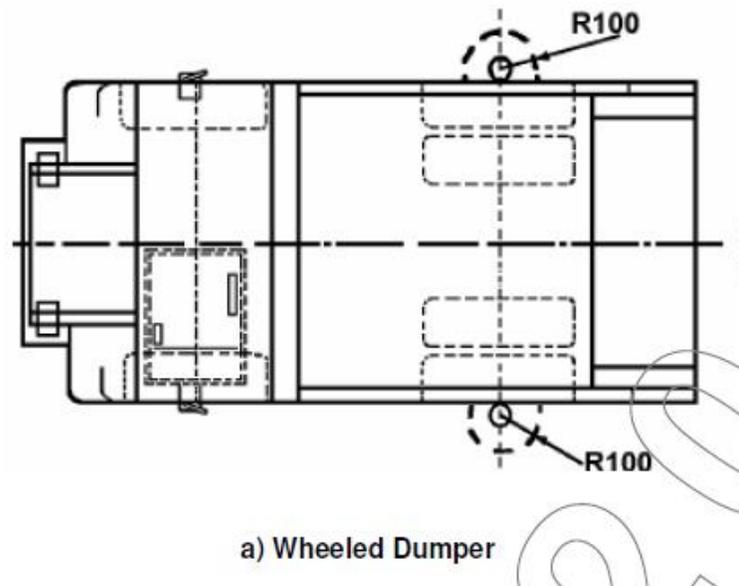


**NOTE:** The view provided must commence at the immediate rear of the vehicle at 1 meter and extend for 30 meters at a final width of 7.5 meters. Here we must be careful that any mirrors used for Class C mirrors actually provide the view starting at the rear of the machine because with the use of flat glass mirrors or single rate of curvature mirrors the ground is many times shown actually starting well behind

the immediate rear of the vehicle. It cannot be just assumed that the mirror selected will suffice.

The Class D mirror view which is illustrated by the following:

Figure 7



A view of the circular area with a radius of 100mm centered on the rear wheel assembly must be visible to the operator on each side of the truck and this view must be provided by the Class D mirror.

The standard specifies that the required minimum radius of curvature for the class C mirror is 1000mm and Class D mirrors may have a minimum radius of curvature of 300mm.

For the Front End Loader and Excavators 14401 provides the following at least a Class B mirror must be provided. The Class B Mirror view is almost the same as the Class C mirror with the exception that the view must start at the immediate rear of the machine at a width of

**.75 meters and extend to the rear 30 meters ending in a 5 meter width.**

## **ACTUAL PRACTICE OF MIRRORING SUCH VEHICLES**

**On the rigid haul trucks we have seen driver's side mirrors made of flat glass. Mirrors from 44 inches to 55 inches have been seen. They are used because the mirrors are necessary to back the vehicle and driver's want real time images which the flat glass produces. The problem with using these mirrors is two-fold, do they show the ground at the immediate rear of the vehicle (Class C Mirror) and do they show the area by the center of the rear axle (Class D Mirror). From those we have checked they offer neither of the 2 requirements.**

**Other times we see a combination of 2 mirrors being used. One is a flat glass to be used for backing and the second is a single rate of curvature wide angle mirror. The problem with where the flat glass first sees the ground remains (Class C Mirror) and with the second mirror, does it show the ground by the center of the rear axle (Class D Mirror). In choosing the single rate of curvature wide angle mirror the problem of distortion becomes important. The single rate of curvature mirror always produces images that are smaller than they are in real time. The only way to generate field of view with such a glass is to use a sharper rate of curvature and as this is done the distortion factor increases. The standard says the Class D mirror may have a minimum rate of curvature of 300mm. The images presented would appear much as they do in the attached photo:**

**Figure 8**



**The distortion factor would be so great that the driver would be unable to identify what is being shown.**

**Generally the manufacturers would like a less distorted image so they choose a compromise rate of curvature, say 1200mm which provides the widest view with the least amount of distortion. The result is that they end up with with a mirror, because of the cone shaped field of view, that must essentially be aimed at the rear axle of truck to accommodate the Class D required view and the result is shown by the following photos:**

**Figure 9**



**Driver's side 2 mirror system**

**Figure 10**



**Passenger's side 2 mirror system**

**Note the angle of the bottom mirror. It can probably show the view required of the Class D Mirror but the question is can the operator of the truck even see the mirror.**

**On construction equipment the same type of compromised mirror is used. One that produces a wider field of view but that still keeps distortion to a minimum, again typically 1200mm, The result can be shown by the following illustration:**

**Figure 11**



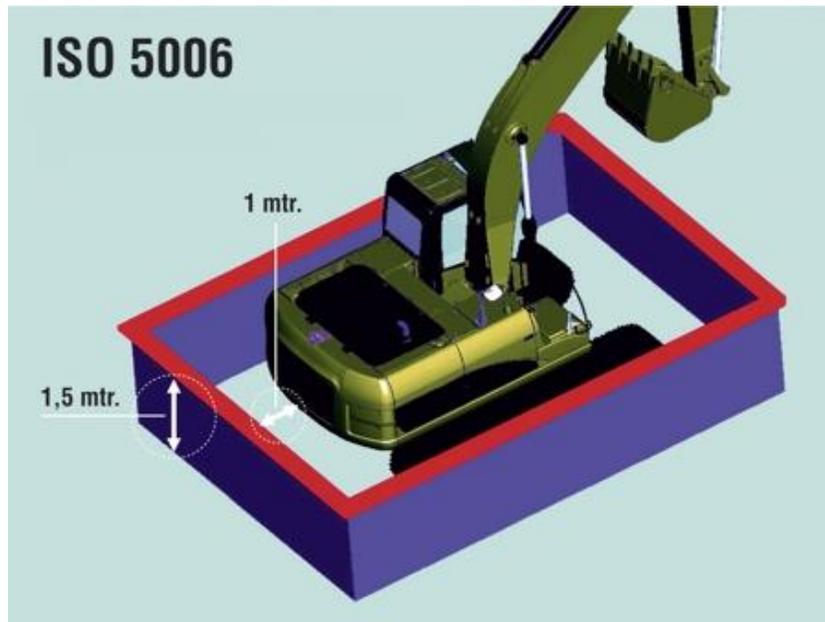
**The mirror does not show the ground at the immediate rear of the machine and leaves a vertical blind spot along the side of the unit at the rear so there is non-compliance with 14401 and 5006.**

**It must be remembered that compliance with ISO 14401 can only be established by the exterior mirrors.**

### **APPLICATION OF ISO 5006**

**This standard sets forth a specific perimeter around the vehicle at 1 meters distance and with the amended 5006 to soon be available is at the height of 1 meter. The test required is best illustrated by the attached diagram;**

**Figure 12**



**Note- Per the proposed amendment to 5006 the 1.5 meter measurement is now 1.0 meters.**

**We have seen that with the mirror technology that is currently being used, the exterior mirrors do not aid in meeting the 5006 requirements and do not even satisfy the requirements of 14401. Manufacturers have used the installation of cameras and other electronic methods to supplement the mirrors in an attempt to accomplish the 5006 visibility requirement. A complete discussion of the various technology is not going to be included herein. We believe the chart developed by the Florida DOT, supra, explains the pros and cons of each as well as possible. The chart states as follows;**

**Figure 13**

**Table 2-8. Comparison of systems for side collision avoidance**

<b>System</b>	<b>Advantages</b>	<b>Disadvantages</b>
<b>Mirror-Based</b>	Used since beginning of vehicle manufacturing. Default device on all vehicles. Trusted by drivers. Does not malfunction except if removed. Relatively inexpensive.	Does not cover the necessary area on the side to help drivers avoid all potential collisions. Passive devices (require driver attention to work). Weather deteriorates their effectiveness.
<b>Sensor-Based</b> (ultrasonic, Lidar, radar, infrared, computer vision)	Relatively accurate, active devices that provide the driver with audio/visual warning on eminent hazard. Long range, cover all blind zones. Used for a decade on vehicles. Beginning to gain driver's trust.	Expensive. Prone to damage easily. Can malfunction. Maintenance required. Some environmental conditions required to work. Shown to not work 100% of the time. Does not provide visual image.
<b>Camera-Based</b>	Used to add views in blind zones. Relatively expensive. Provide a visual image, similar to the mirrors. Can cover a very large area covering all blind zones.	Passive devices like mirrors. Fog deteriorates their effectiveness. More expensive than mirrors. Not widespread use yet. Can malfunction. Require maintenance.

**At M-C North America we feel that the operator is best served by the development of a complete Vision System that would incorporate both the mirrors and cameras, with the emphasis being upon the exterior mirrors. This conclusion was developed mainly because of the following factors:**

**Mirrors have been placed upon vehicles since vehicles have been manufactured and hence are trusted by drivers.**

**Mirrors are less expensive.**

**Mirrors are more reliable and fail-safe because they are not affected by electronic failures or equipment failures**

**If broken during operation, downtime is less because they are easily replaced.**

### **USE OF THE M-C MIRROR TECHNOLOGY TO DEVELOP A COMPLETE MIRROR SYSTEM**

**To develop a complete Vision System and make the exterior mirrors the primary source of information for the operator, we realized that**

**such a system could not be established using the single radius of curvature mirror technology, and proceeded to develop the M-C Multi-Radius Mirror Technology (US Patent No. 8,172,411)**

**This multi-radius mirror technology allows us greater control over the size of images presented to the operator. Where images presented by the single rate of curvature mirror are always smaller, requiring the operator to make mental calculations as to where the object is in relation to the vehicle, our images can be used instantly by the operator in making decisions.**

**This multi-radius glass also allows us greater flexibility in fusing various rate of curvature in the same glass seamlessly to retain a view that could incorporate areas of particular interest that are necessary for the operator of the type of equipment we are working with i.e. a large flat area for backing, surrounded by more convex section to provide a view down, out, or up all combined in one glass, an accomplishment that cannot be made with the distortion element inherent in the single rate of curvature mirror.**

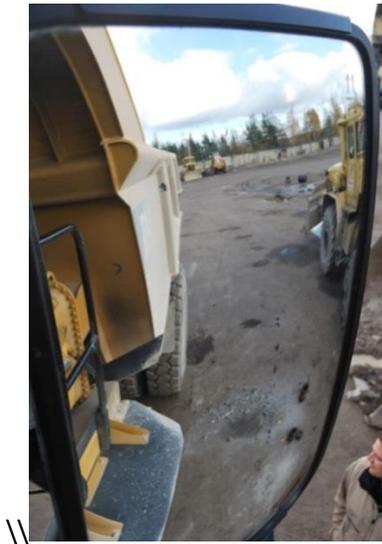
**ISO 14401-2 specifies in the Introduction, the following:**

**“Mirrors provided on earth-moving machinery can be fitted to:**

**---overcome direct visibility blockages i.e. as identified using ISO 5006”**

**To illustrate that our M-C Mirror Technology can aid to overcome direct visibility blockages identified by 5006, we include a photo of a 100 ton rigid haul truck:**

**Figure 14**



**15 x 25 inches (381mm by 635mm)**

**This is a multi-radius mirror with a large flatter portion fused with a more convex multi-radius on the side and bottom of the glass.**

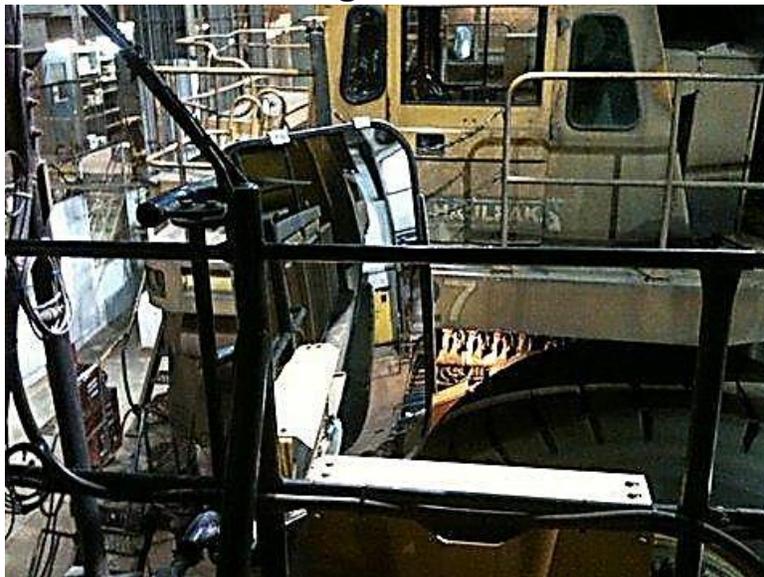
**The photo clearly illustrates the view provided exceeds  
the ISO 14401 Class C mirror (view to the rear)  
the ISO 14401 Class D mirror (view of the area of the  
rear wheel)**

**compliance with the requirement of ISO 5006, 1 meter out and 1 meter height, along the side of the truck, from the location of the mirror on the truck to the rear of the truck. ( Here it should be noted that as Dr. Thierbach stated at the beginning of this paper, that proposed changes to ISO 5006 would require that visual aids such as CCTV Systems and mirrors must be fitted in the forward direction of view, and if this results in the final draft of 5006 in the mirrors being located at the front of the truck where they should be, the view provided by our mirror would be along the entire side of the truck).**

**The multi-radius mirror technology would produce the same results on loaders and excavators. The major portion of the 5006 requirements for these types of vehicles could be obtained by the mirrors.**

**As to rigid haul trucks larger than 100 tons, the photo here shows the same mirror located on a 244 ton truck**

**Figure 15**



**The mirror is difficult for the operator to see because of the obstruction of the railing, but you will note still performs the function of the two requirements of ISO 14401. From this we learned that the larger truck placed the operator further from the mirror and a larger size was necessary so the mirror could be seen, so we have developed a 20 inch by 35 inch (508mm) by 889mm) multi-radius mirror for the off side of the truck, sample of glass photo illustrated in Figure 13**

**Figure 13**



**For the driver's side of the truck a smaller mirror can be used because of the operator's location in relation to the mirror. This mirror measures 20 inches by 25 inches (508mm by 635mm). Sample of glass photo:**

**Figure 14**



**Both of these mirrors contained multi-radius fuse rates of curvature.**

**To complete our Vision System we know that video cameras would be necessary**

**For the rear of the truck, loader, excavator or other mobile equipment**

**Possibly for each side of the vehicle to be located on the lower portion of the right side and left side to cover areas behind the location of the mirror to the front of the vehicle**

**For the immediate front of the vehicle we offer a mirror/camera option.**

**We have a video camera for use in situations where mirrors do not perform. With our Vision System, the driver is given the opportunity to perform the necessary functions to ensure proper operation of the vehicle while at the same time have options to look at specific areas at critical times such as backing and at start-up.**

**Richard T. Ince  
VP Safety  
M-C North America Inc.**