COMMITTEE CE-033

DR AS/NZS 3845.2:2016

(Project ID: 100881)

Draft for Public Comment Australian/New Zealand Standard

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BEGINNING DATE FOR COMMENT:	**20 April 2016**
CLOSING DATE FOR COMMENT:	**22 June 2016**

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Road safety barrier systems and devices Part 2: Road safety devices (Revision of AS/NZS 3845:1999)

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Draft for Public Comment
Australian/New Zealand Standard

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SECTION 7 TRUCK UNDERRUN BARRIERS

7.1 SCOPE OF SECTION

This Section sets out the requirements for Truck Underrun Barriers (TUBs) that are installed on the rear of a truck or trailer.

The performance requirements set out in this Section for TUB's may be equally applied to any truck or trailer of an articulated truck that operates on any public road and are used to protect the occupants in a vehicle that runs into the back of the truck or trailer. TUBs are permanently fixed to such vehicles.

NOTES:

1 TUBs for any truck or trailer including the trailer on an articulated truck are discussed in the commentary in Appendix G.

2 Side underrun protection on heavy vehicles is discussed in Paragraph G7.6 of the commentary in Appendix G.

7.2 GENERAL

Subject to the noted modifications of Clause 7.3, MASH shall be the basis of testing procedures for TUBs in accordance with Clause 4.3.

TUBs are designed to protect the occupants of a vehicle impacting the rear of a slow moving or stationary truck. Due to the differences in sizes, impacting vehicles may under ride the back of the truck, resulting in intrusion of the impacting vehicle's occupant compartment.

TUBs are usually permanently mounted to the rear of trucks or trailers towed by such trucks. TUB's usually do not protrude from the rear of the truck and mostly rely on the vehicle's crashworthiness for the ride down decelerations for the occupants although some of the impact kinetic energy can be dissipated by the TUB.

NOTE: For commentary on this Clause, see Paragraph G7.2 in Appendix G.

7.3 TEST REQUIREMENTS

Truck Underrun Barriers shall be required to comply with the Tests 2-51, 2-52, 2-54 and 2-55 as follows:

(a) *Centred impact*: the test requirements of Impact Tests 2-51 and 2-54 as set out in Table 7.1 and Figure 7.1(a). Test 51 is designed to test the structural integrity of the underrun barrier when struck by a larger mass vehicle such as an SUV. Test 54 is designed to evaluate the underrun potential of the TUB in regard to vehicle into truck impact compatibility when struck by a sedan vehicle. The vehicles used in Test 51 and Test 54 are typical of those driven on Australian public roads.

(b) *Offset impact*: the test requirements of Impact Tests 2-52 and 2-55 as set out in Table 7.1 and Figure 7.1(b) where the test vehicle is offset by:

$$Y = \text{OFFSET} = \frac{A}{2} + 0.2\ W$$

as shown in Figure 7.1, A is the maximum width of the rear of the truck shown in Figure 4.4 and Figure 4.5 in Section 4.2 in MASH. In Figure 4.3 in MASH the dimension A = t.

TABLE 7.1

TEST MATRIX FOR TRUCK UNDERRUN BARRIERS

Test Level	Feature	Test designation	Impact conditions (Note 1)			Impact point	Evaluation Criteria (refer to Table 5.1 of MASH) (Note 3)
			Vehicle	Nominal Speed (km/h)	Nominal Angle θ deg.		
2	Truck underrun barrier	2-51	2270P	70	0	See Note 2	C,D,F
		2-52	2270P	70	0	See Note 2	C,D,F
		2-54	1500A	70	0	See Note 2	C,D,F
		2-55	1500A	70	0	See Note 2	C,D,F

NOTES:

1 Refer to Section 2.1.2 of MASH for tolerances on impact conditions.

2 See Figure 7.1 for impact point.

3 For evaluation criteria F in its cross reference to Clause 5.3 in MASH in regards to the section specifying 'deformation or intrusion' criteria the following criteria 'Side front panel (forward of A-pillar) ≤12 in. (305 mm).' does not apply.

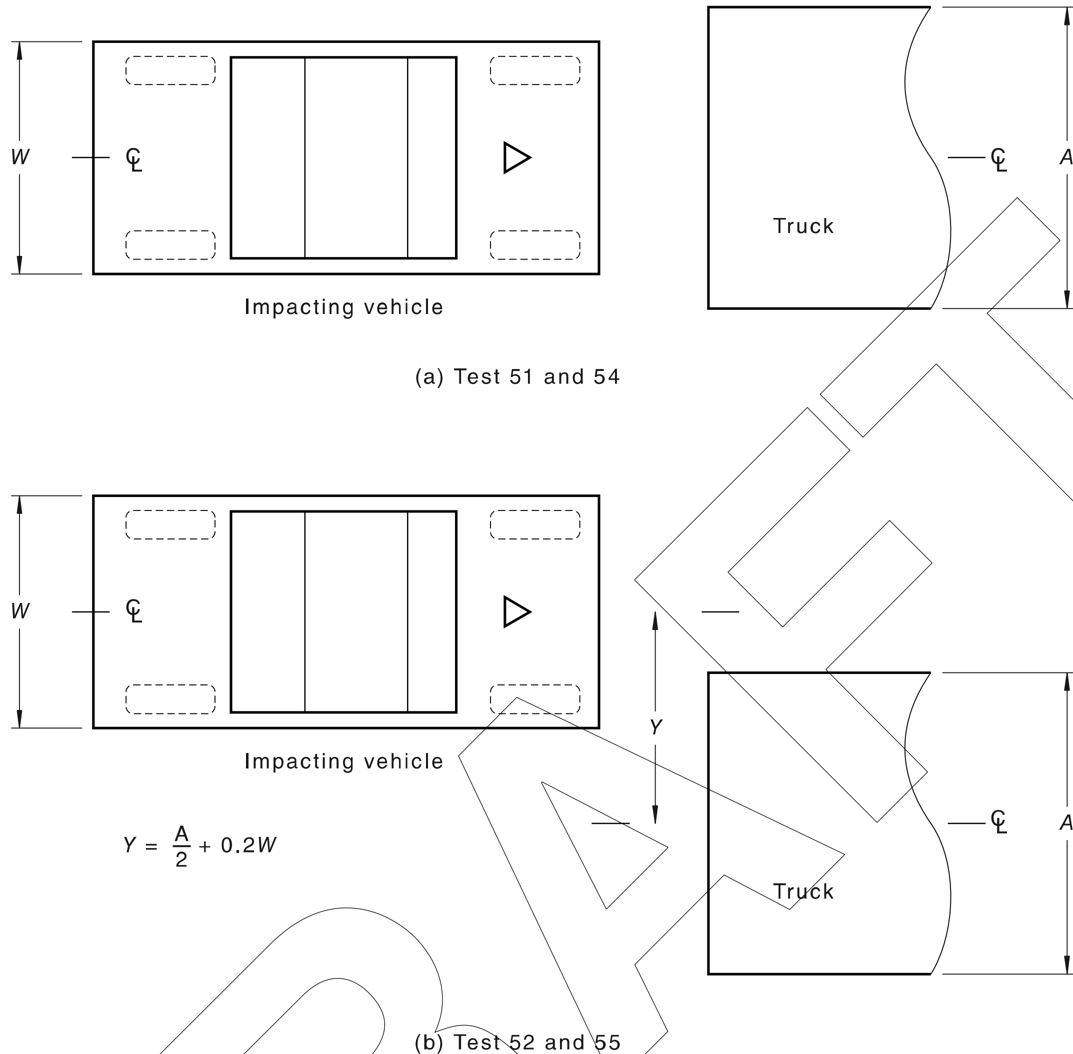

FIGURE 7.1 IMPACT CONDITIONS FOR TRUCK UNDERRUN BARRIERS

Tests 50, 51, 52 and 55 are to be conducted with either—

(a) the maximum allowable truck weight. The support truck should be placed in second gear and the parking brake set;

or

(b) a rigidly blocked support truck for unlimited support weight. The support truck shall be placed in second gear and the parking brake set and shall be blocked to prevent forward or lateral motion;

or

(c) a surrogate structure that replicates the rear back portion of the truck type to which the TUB will be used when in service. The surrogate structure shall be fixed against a crash test block commonly used at vehicle crash test facilities that is replicating a rigidly blocked support truck for unlimited support weight.

The TUB shall be fixed to the rear of the truck in the same way as it would be installed in service.

The maximum permitted rearward displacement of the TUB beyond the face of the rear of the truck shall not exceed 500 mm.

The TUB may deform under the impact loading but there shall be no joint failures or buckling of the TUBs key support structures or of the support truck structure.

NOTE: For commentary on this Clause, see Paragraph G7.3 in Appendix G.

7.4 DOCUMENTATION

In addition to the normal documentation required for road safety devices (see Clause 2.2), the following is required:

(a) Support truck (or support truck and trailer) roll-ahead distances should be carefully documented for all four tests in Clause 7.3.

(b) The make, model and ballasting of the truck tested for the TUB.

(c) The make, model and any ballasting of the impacting vehicle.

(d) The deformation of the impacting vehicle and what crashworthy features (e.g. airbag, seat-belt pretensioners, etc.) were triggered that assisted in reducing ride down decelerations during impact.

(e) Range of truck masses the TUB can be attached to.

(f) Details of how the truck is braked (i.e. parking brakes set, engine in second gear, etc.) or blocked against forward motion during operation when protecting a work zone.

(g) Geometric data including length, width, and height of TUB.

(h) Height of TUB with respect to the ground.

(i) Length of supporting truck.

(j) Mass of TUB and supporting hardware.

(k) Detailed drawings of mounting hardware.

(l) Descriptions of the test surface, including type (asphalt or concrete), finish, and state of wear.

(m) The type, location, and manner of securing the ballast.

(n) Ballast mass, test inertial mass, and the horizontal Centre of Gravity location of the ballast.

(o) Condition and type of brakes or blocks used to reduce or prevent vehicle roll ahead.

7.5 INSTALLATION CRITERIA DOCUMENTATION

The test condition documentation detailed in Clause 7.4 needs to be clearly documented for proper installation of the TUB. In addition, the following device requirements for the TUB’s shall be met:

(a) The TUB barrier height clearance above the road shall preferably be 350 mm but shall not exceed 400 mm for an unloaded truck.

(b) The barrier width should be within 100 mm of the outer frame of the truck to ensure effective operation in offset impacts.

APPENDIX G

COMMENTARY ON SECTION 7 (TRUCK UNDERRUN BARRIERS)

(Informative)

G7.1 SCOPE OF SECTION

There is no commentary for Clause 7.1.

G7.2 GENERAL

G7.2.1 General

Around twelve fatalities occur each year as a result of truck underruns in Australasia. The injuries are usually horrific (see references in Paragraph G7.2.1 for Rechnitzer and Fong (1991), Rechnitzer and Grzebieta (1991), Grzebieta and Rechnitzer (2001), Lambert and Rechnitzer (2002), Brumbelow (2011) and IIHS (2014)). Given that Australia has adopted a 'Vision Zero' road safety philosophy and the 'Safe System Approach' road safety strategy, all such foreseen fatalities need to be addressed if a design countermeasure can be implemented.

The US Insurance institute of Highway Safety has also identified that the truck underrun fatalities and serious injuries are occurring as a result of inadequate truck underrun barriers and the lack of a crash performance test standard (IIHS (2014)). They have rated a number of underrun barriers using a performance crash test protocol they recently developed.

All nature of trucks can operate within a road works site or be delivering materials to a road works or road maintenance site. Hence, the hierarchy of controls for managing risks within the Work Health and Safety legislation specifies that engineering controls which design out the hazard are considered more effective control measures than administrative controls. A truck that is delivering materials or used in the workplace is considered as mobile plant in the Work Health and Safety legislation. Therefore, TUBs should be fitted and used for any truck that is used within a work or maintenance site or delivering materials to such sites.

Truck Underrun Barriers (TUBs) are energy dissipating devices permanently fixed to the rear of any truck, or trailer of an articulated truck, to prevent injuries resulting from the vehicle underrunning the rear end of a truck, which in turn intrudes into the occupant compartment. TUBs can be thought of as a barrier or a crash cushion that prevents the vehicle from underrunning the truck, but in this instance the system is fixed to a truck as opposed to the road infrastructure.

While the performance requirements set out in this Section for TUBs are intended for trucks servicing work sites and maintenance, the performance criteria can be equally applied to any truck, or trailer of an articulated truck, that operates on any public road and are used to protect the occupants in a vehicle that runs into the back of the truck or trailer.

Such energy dissipating TUBs are usually attached to a truck or trailer of any large mass vehicle that is greater than 3 500 kg TARE mass. The trailer would typically be towed such as in the example of a tip truck and dog or a prime mover towing a semi-trailer, B double or B-triple configuration. The vehicle with the TUB attached can travel on any public road and is not necessarily associated with any road maintenance or roadwork. However, a public vehicle delivering materials to a roadwork site should have a TUB attached.

Summarising, energy dissipating TUBs have:

(a) A similar function to TMAs but with reduced energy dissipating capacity, i.e. decelerate the vehicles over a much shorter distance and rely mostly on the crashworthiness of the vehicle.

(b) Do not protrude from the rear of the truck or trailer in any significant manner and are compliant with Australian Design Rule (ADR) 42/00; albeit this ADR is grossly inadequate in terms of vehicle crashworthiness and strength capacity for crashes typical on higher speed limit roads.

(c) Are not special purpose built for maintenance or road works vehicles and trailers but are general underrun protection systems for any truck or trailer, including trailers for articulated road trucks such as semi-trailers, B-double and B-triple trucks.

(d) Are mainly used to protect the occupants inside the vehicle that strikes the back of a truck or trailer and occupants of the truck in any road environment.

(e) Are permanently fixed to the truck or trailer.

A road works or maintenance truck could also have a TUB attached in place of a TMA. In this case, the risk to occupants of an impacting vehicle, to the occupants of the truck, and to workers on the road ahead of the truck, and the anticipated roll-ahead distance, need to be assessed for the speed limit where the vehicle would function. Nevertheless, the amount of energy dissipated by a TUB compared to a TMA would usually be significantly less and hence pose a greater risk to both occupants and workers.

G7.2.2 Reference material

Rear truck and/or trailer underrun crashes are a serious issue in Australasia in terms of preventable deaths and injuries. Rear underrun crashes involving heavy vehicles with rear overhangs, represent the most extreme examples of system incompatibility between heavy vehicles and passenger cars [Rechnitzer & Foong (1991), Rechnitzer & Grzebieta (1991), Grzebieta & Rechnitzer (2001), Lambert J and Rechnitzer G (2002), Brumbelow (2011), and IIHS (2014)]. Any car impact protection devices such as crumple zones, frontal airbags, or pre-tensioning belts are completely negated by the obvious mismatch between the truck's rear and car's crashworthiness systems.

This type of crash often causes severe or fatal injuries to car occupants due to the mismatch in mass ratio, stiffness ratios and most importantly geometry. It is estimated that rear underrun crashes in Australia account for some 10 or so fatalities and around 150 serious injuries every year [Haworth and Symmonds (2003)]. Currently, there is no legislation or Australian Design Rule requiring dynamic crash testing of underrun barriers.

An overview of the issues concerning underrun crashes and proposed solutions are provided in the following articles, some of which can be downloaded from the internet:

1 Rechnitzer G and Foong C W, *Truck involved crash study: Fatal and injury crashes of cars into the rear of trucks*, MUARC Report No 26, Monash University, Clayton, Australia, 1991, http://www.monash.edu.au/miri/research/reports/muarc026.pdf

2 Rechnitzer G, Zou R and Grzebieta R H, *MADYMO computer modelling of energy absorbing rear underrun barriers for heavy vehicles—a pilot study*, MUARC Research Report No 112, 1997, Monash University,

http://www.monash.edu.au/miri/research/reports/muarc112.pdf

3 Rechnitzer G and Grzebieta R H, *Crashworthy Systems—A paradigm shift in road safety design*, Transport Engineering in Australia, IE Aust, Vol 5, No 2, December 1999.

4 Grzebieta R H and Rechnitzer G, *Crashworthy Systems—A paradigm shift in road safety design* (*Part II*), Transport Engineering in Australia, IE Aust, Vol 7, Nos 1 and 2, December 2001.

5 Lambert J and Rechnitzer G, *Review of Truck Safety: Stage 1: Frontal, Side and Rear Underrun Protection*, MUARC Report No 194, Monash University, Clayton, Australia, 2002, http://www.monash.edu.au/miri/research/reports/muarc194.pdf

6 Haworth N and Symmons M, *A Cost-Benefit Analysis of Heavy Vehicle Underrun Protection*, Proceedings Road Safety Research, Policing and Education Conference, 2003, Sydney, Australia,

http://acrs.org.au/files/arsrpe/RS030141.pdf (accessed 3 September 2009)

7 Brumberlow M L, *Crash Test Performance Of Large Truck Rear Underride Guards*, Proc. 22nd Enhanced Safety of Vehicles Conference, Paper No 11–0074, Washington DC, 2011, http://www-nrd.nhtsa.dot.gov/pdf/esv/esv22/22ESV-000074.pdf

8 Insurance Institute of Highway Safety (IIHS), *Status Report*, Vol 49, No 7, 9 October 2014.

9 Insurance Institute of Highway Safety (IIHS), *Small Overlap Frontal Crashworthiness Evaluation Crash Test Protocol (Version III)*, May 2014. http://www.iihs.org/media/ec54a7ea-1a1d-4fb2-8fc3-b2e018db2082/691118402/Ratings/Protocols/current/small_overlap_test_protocol.pdf

G7.3 TEST REQUIREMENTS

Current vehicle crashworthiness technology indicates that occupants will not suffer serious injury in an equivalent frontal impact speed (delta V or ΔV) of up to around 64 km/h into a deformable barrier if the car is a modern five star Australian New Car Assessment (ANCAP) vehicle. Moreover, the IIHS is now testing and rating cars for a narrow offset crash test where the vehicle is impacted into a rigid barrier at a speed of 64.4 km/h with a 25% offset (IIHS, 2014). This could mean that TUBs that are non-energy dissipating fixtures would be compliant with Clause 7.3, where the majority of the energy is required to be dissipated by the vehicle and the occupant restraint systems. If the car is designed to such ANCAP and IIHS test protocols with the maximum crashworthiness rating, it is likely that the occupants would not sustain serious injuries in a vehicle impacting such a TUB in the configurations shown in Figure 7.1.

The development of effective energy absorbing TUBs would both reduce the serious injury to vehicle occupants and increase the effect frontal impact speed ΔV above the 70 km/h test speed compared with a rigid TUB. The manufacturers of such TUBs and operators of heavy vehicles are encouraged to explore the application of energy absorbing systems for TUBs including rear air bags.

The maximum permitted rearward displacement of the TUB beyond the face of the rear of the truck is required to not exceed 500 mm. This is to ensure that underrun resulting in hazardous penetration of the vehicle windshield is prevented in most crash situations.

Whilst the TUB can deform under the impact loading the requirements that there are to be no joint failures or buckling of TUBs key support structures or of the support truck structure, is to ensure the TUB has residual load capacity for impacts above 70 km/h. While a Test Level 3 impact at 100 km/h would be desirable, this speed is considered too onerous with the current technology. However, the development of large capacity air bags on the rear of large trucks could meet occupant ride-down decelerations for Test Level 3 impact speed requirements.

G7.4 DOCUMENTATION

There is no commentary for Clause 7.4.

G7.5 INSTALLATION CRITERIA DOCUMENTATION

There is no commentary for Clause 7.5.

G7.6 SIDE UNDERRUN PROTECTION ON HEAVY VEHICLES

Side underrun protection for heavy vehicles has been recognised as being necessary for over 100 years, to act as a protective barrier device that helps prevent pedestrians or cyclists falling under the rear wheels of such vehicles, particularly when they are turning, and being killed or seriously injured as a result (ATA, 2012, Transport Industry Safety Group, 2007). It is important that such devices are attached to vehicles entering a roadworks site where there are workers walking around the site and working in close proximity to trucks that are delivering and extracting materials.

While many countries worldwide (e.g. Europe and Asia) have requirements for side underrun protection device, Australia does not.

G7.6.1 Guidance information (refer Rechnitzer & Grzebieta 2014)

UN-ECE Regulation No. 73 For The Provision Of Lateral Protection On Goods Vehicles, Trailers And Semitrailers.

The regulations are applicable to vehicles and trailers greater than 3.5 tonne gross mass. The regulation's objective is to offer effective protection to unprotected pedestrian road workers at roadworks sites against the risk of falling under the sides of the vehicle and being caught under the wheels. The major technical requirements of R73 are:

(a) The side guard can consist of a flat panel, or of one or more side rails.

(b) If side rails are used the maximum spacing is 300 mm, the minimum rail width is 50 mm for category N2 & O3, the minimum rail width is 100 mm for category N3 & O4.

(c) The lower edge of the sideguard shall be a maximum of 550 mm above the ground 109.

(d) The sideguards shall be essentially rigid, and able to withstand a horizontal static force of 1 kN, applied at any point on the guard.

The regulation also sets out detailed dimensional requirements at the sides and ends of the sideguards. The British Standard (refer Appendix 4 in Report No. 35, Rechnitzer, 1993b) sets out detailed requirements for the guard dimensions, similar to the ECE requirements. A major difference noted is the specification of a 2 kN test load compared with the ECE test load of 1 kN.

The clearance under the barrier of 550 mm as recommended by ECE R73 is much too high to ensure an unprotected pedestrian road worker is not run over by the wheels of the heavy vehicle.

Preferably side underrun guards should not be rails as there is the potential for an unprotected road worker to be caught up in them. Some Australian trailer manufacturers are moving to incorporate side underrun protection. Note however that with no Australian standard such barriers may be less than optimal.

G7.6.2 Recommendations on new and existing side guards

Based on the cited research and testing, and the detailed crash investigations undertaken (Rechnitzer, 1993, 1991, 1991b; Lambert & Rechnitzer 2002), improvements to the ECE regulations would require:

(a) Lowering the ground clearance to around 350 mm. This may have to be increased for some vehicles to take into account special clearance requirements;

(b) Preferably flat panel surfaces only, or railings at closer spacing (e.g. 100 mm).

(c) All exposed edges to be radiused (say 20-50 mm) to reduce edge loads on unprotected road users;

(d) The leading ends of side guards be curved inwards (at least 250 mm) to improve the interface with unprotected road users, so that spearing and direct end loading can not occur, and deflection to unprotected road users is provided.

(e) Adoption of the British lateral load test of 2 kN.

G7.6.3 References

1 Australian Trucking Association (ATA), 2012. *Advisory Procedure—Side Under Run Protection*. http://www.atatruck.net.au/system/files/industry-resources/Side%20underrun%20protection%20TAP%20NOV%2012_0.pdf.

2 Lambert J McK & Rechnitzer G, *Review of Truck Safety*: Stage 1: *Frontal, Side and Rear Underrun Protection*, Monash University Accident Research Centre. Report No. 194, for VicRoads, April 2002.

3 Rechnitzer G. & Grzebieta R.H., *So you want to increase cycling on roads: then we need side underrun barriers on all trucks*, Proceedings of the 2014 Australasian Road Safety Research, Policing & Education Conference 12-14 November 2014.

4 Rechnitzer G., (1991). *Truck Involved Crash Study— Summary Report on Two Recent Fatal Underun Crashes* (Coroner's Case No.s 3303/91 & 3434/91), Monash University Accident Research Centre, December 1991.

5 Rechnitzer G., (1993). *The Improvement Of Heavy Vehicle Design To Reduce Injury Risk in Crashes with Other Road Users*, PhD Thesis, Accident Research Centre and The Department of Civil Engineering, Monash University.

6 Rechnitzer, G. (1993b). *Truck Involved Crash Study: Fatal and Injury Crashes of Cars Into The Front and Sides of Heavy Vehicles*. Monash University Accident Research Centre, Report 35.

7 Transport Industry Safety Group, Victoria, *Buying A Safer Trailer*: http://www.artsa.com.au/library/TISG_Safe_Trailer_March_07.pdf, TISG, 2007.

8 UN-ECE Regulation No. 73 *For The Provision Of Lateral Protection On Goods Vehicles, Trailers And Semitrailers*. https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/R073r1e.pdf