Practical Testing of Vehicles Equipped with Stability Control Systems

General:

Within the EVSC group and GRRF several government representatives have suggested that a practical test(s) must be defined to enable the assessment of a vehicle equipped with a stability control system to be carried out at the time of type approval. In principle this approach is correct to ensure that uniform methods of assessment are applied by all technical services. However to achieve this objective a number of conditions must be considered:

- Definition of uniform test procedures.
- Availability of suitable test facilities.
- Ensure the safety of personnel and equipment during testing.

When applying the above it is necessary to consider the vehicle type as different requirements will apply when assessing a passenger car compared to a heavy commercial vehicle.

Test Procedures:

There are three possible conditions to be assessed, under steer, over steer and roll-over. It can be stated that on a dry high adhesion surface a heavy commercial vehicle will roll-over before the limit of adhesion is reached on a given axle. This is simply due to the height of the centre of gravity relative to the vehicle track width. Equally it is well recorded that the number of accidents involving passenger car roll-overs on high adhesion is very limited unless the vehicle leaves the highway and is “tripped”. However this is a very general statement and in reality if over steer is produced on any vehicle on a dry high adhesion surface there is a high risk of roll-over.

Appendix 1 has been produced to provide an “indication” of the respective stability conditions relative to the test surface for a given vehicle type. From this table it can be seen that it is not possible to safely demonstrate the three instability conditions on a dry high friction surface therefore a common test procedure cannot be defined that will cover all vehicle categories. This is particularly relevant to vehicles in the M1 and N3 categories where the range of vehicle types/specifications and associated stability characteristics is very wide.

Additionally it can also be concluded that for assessment of roll-over this must be carried out on a dry high adhesion surface and for assessment of directional control a low to mid adhesion surface is necessary so that the possibility of roll-over is removed. In consequence any test procedure would need to take this into consideration.

There are numerous stability tests currently defined and are often used by vehicle manufacturers to assess the stability of a vehicle with or without a stability control system. The following tests are typical of those used for this purpose:

- J Turn (decreasing radius turn).
- Single lane change
- Double lane change
- Collision avoidance (severe single or double lane change) [1/]

1/ The latter test is inappropriate for the purpose of assessing the stability of a vehicle or stability control system as the result is too driver dependent and speed critical.

Currently no dynamic stability tests are prescribed for any vehicle irrespective of whether it is installed with a stability control system or not. The above tests are utilised by vehicle manufacturers to ensure a given vehicle behaves in a reasonable manner relative to the specification and application of the vehicle. As no specific tests are prescribed that define

minimum dynamic stability requirements how then is it possible to define a common test procedure suitable for all vehicle categories.

If it is required to demonstrate the effectiveness of an electronic stability control system the specific test conditions required to produce the three conditions of instability will vary with vehicle type and test surface. To demonstrate instability it is necessary to take a given vehicle to the limits of adhesion which as already stated is a variable, equally the speed at which a given type of instability occurs will be another variable. It would be unrealistic to apply the same test procedure and criteria to a passenger car and a heavy commercial vehicle. Therefore any test procedure must be developed to take into consideration the following:

- Vehicle type
- Test surface
- Safety of personnel and vehicles [2/]

2/ It was necessary to reduce the high to low surface transition speed for certain types of vehicle when assessing anti-lock brake performance from 80% v_{max} to a lower value due to a number of accidents that occurred carrying out this test.

Conclusions:
Based on the above the following can be concluded:

- A common test procedure cannot be applied to all vehicle categories.
- The speed at which a give type of instability occurs is vehicle dependent
- Roll over control can only be demonstrated on a high adhesion surface.
- Directional control can only be demonstrated on a low or medium adhesion surface to eliminate the potential of roll-over.
- The effectiveness of a stability control system can only be realistically determined for a specific vehicle by making comparisons of vehicle behaviour with the system inhibited and operational

Test Facilities:

To be able to evaluate the effectiveness of any form of control system the test facilities must be generally available to enable a test(s) to be carried out effectively and safely. It has already been concluded above that the assessment of directional control can only be carried out safely on a low adhesion surface and the roll-over control should be assessed on a high adhesion surface. Dynamic platforms are available at many test facilities which offer the space for manoeuvres to be carried out. However, such facilities are constructed with a high adhesion surface which will enable roll-over control systems to be assessed.

To demonstrate directional control it is necessary to utilise a low or medium adhesion surface. Such surfaces are widely used for the assessment of ABS equipped vehicles however these are generally unsuitable for assessing the stability of a vehicle. ABS assessment requires the vehicle to be braked it a straight line therefore the majority of test tracks are around 5m wide which means there is inadequate space to perform a dynamic manoeuvre such as a J turn etc. Should the test tracks be wider to enable a manoeuvre to carried out there still needs to be a significant area of the same adhesion surface for run off purposes. Otherwise should a vehicle at the limits of stability become unstable it must be possible for the vehicle to slide without hitting any obstacle or traversing onto a high adhesion surface, either of these conditions can result in vehicle roll-over. This is supported by the earlier comment relating high to low transitions during ABS testing. In the cases where accidents have occurred vehicles have became unstable on the low adhesion surface and ran off sideways onto a high adhesion surface and rolled over. Any test facility must therefore have an area which will enable any test to be performed safely without endangering personnel of equipment.

The majority of the development of stability control systems is carried out during winter testing where manoeuvres are carried on test tracks generated on frozen lakes which consist of large flat areas surrounded by snow banks. Such conditions enable system development to be carried out safely under controlled conditions.

Conclusions:
Based on the above analysis the following can be concluded:

- Test facilities are generally available to demonstrate the operation of vehicles equipped with roll-over control
- Demonstration of direction control should be carried out on test areas that offer a wide expanse of low or medium adhesion surface with adequate space to limit the possibility of a roll-over as a result of being “tripped” or sliding onto a high adhesion surface.
- Low or medium adhesion facilities as described above are not generally available as the majority of directional control development and assessment is carried out during winter testing which would be inappropriate for the accepted methods of type approval.

Safety of Personnel and Equipment:

In the last section there was significant reference to safety and the need for large opens spaces to enable testing to be carried out safely. Provided such low adhesion facilities are used for the testing of direction control then any risks are minimised. However as soon as testing is carried out on high adhesion surfaces where vehicles are taken to the limit of adhesion and stability the risk to personnel and equipment increases significantly. The exception to this is when a vehicle under steers in which case the vehicle will no longer follow an intended course but the front wheels will slide out until speed has been reduced to allow the steering forces to be generated. Over steer and roll-over are by far the most dangerous as an over steering vehicle can very quickly roll-over irrespective of its type.

To be able to demonstrate the effectiveness of roll-over control it is necessary to carry out a given manoeuvre with the system inhibited. Taking the vehicle to the point of roll-over without actual rolling over is virtually impossible to realise and is unrepeatable. Small changes in speed or driver steering can make the difference between a vehicle remaining stable and rolling over. Therefore it is essential that the vehicle is equipped with some form of mechanical device which limits the amount of physical roll. These usually take the form of outriggers which is a mechanical structure attached to a rigid part of the motor vehicle or trailer with wheels attached to the extremities. Appendix 2 illustrates such devices as follows:

Figure 1 illustrates M3 coach installed with outriggers. Such an installation requires very careful design as the body of a coach is usually a stressed member therefore adding such safety equipment to every vehicle that is subject to type approval is impractical.

Figure 2 illustrates a semi-trailer combination where the outriggers are in stalled on a specific test trailer for the purposes of demonstrating the performance of a towing vehicle equipped with roll-over control. In this case the impact of adding outriggers to the trailer does not affect the towing vehicle which is being approved although combination dynamics may be affected.

Figure 3 illustrates a semi-trailer combination where the outriggers are again installed on the trailer for the purposes of demonstrating the performance of a trailer equipped with roll-over control. As it is the trailer control system which is being demonstrated the installation of the outriggers is very specific to the type of trailer to be approved therefore adding such safety equipment to every trailer that is subject to type approval is impractical.

Figure 4 illustrates a rigid truck installed with outriggers. Usually such vehicles are approved as a chassis cab configuration with a load frame attached to the chassis for the purposes of adding load to the vehicle. When demonstrating roll-over control the load frame is constructed with the provision for outriggers.

Today some technical services demand that a vehicle submitted for approval must be installed with a roll cage when an ABS assessment is to be carried out. Testing a vehicle on a high adhesion surface to the limit of adhesion or roll-over is potentially much more dangerous that ABS testing and therefore the installation of a roll cage should be considered mandatory. Appendix 3 illustrates a commercial vehicle cab installed with a roll cage. If the roll cage is to be effective it must be designed and constructed specifically for the interior of the cab or body of the vehicle.

By adding additional equipment such as outriggers and roll cages to a given vehicle the weight, weight distribution and dynamic handling characteristics of the vehicle have been modified to the extent that the vehicle may no longer be directly representative of the vehicle to be approved

Conclusions:
Based on the above analysis the following can be concluded:

- For safety reasons vehicles that are to be taken to the limit if adhesion over steer or roll on a high adhesion surface must be equipped with a roll cage and where appropriate outriggers.
- Certain vehicle types must have the outriggers specifically designed to suit the construction of the vehicle to be approved.
- Installation of a roll cage and outriggers has an impact on the basic load distribution and handling characteristics of the vehicle.

Appendix 1

Vehicle Stability Relative to Road Surface Adhesion

Vehicle Type	Instability Condition			Road Surface			
	Over Steer	Under Steer	Roll-Over	Low Adhesion	Medium Adhesion	Wet High Adhesion	Dry High Adhesion
Passenger car	X[1/]	X	X[1/]	-	-	-	X
	X	X		X	X	X	
SPV / SUV	X	X	X[1/]	-	-	X	X
	X	X	-	X	X	-	-
Mini Bus & Light CV	X	X	X[1/]	-	-	X	X
	X	X	-	X	X	X	
Coach	X	X	X[1/]	-	-	-	X
	X	X	-	X	X	X	-
Heavy CV	-	X	X[2/]	-	-	-	X
	X[2/]	X	X[2/]	-	-	X	-
	X	X	-	X	X	-	-
Semi-Trailer	N/A	N/A	X[2/]	-	-	X	X
Centre Axle Trailer	N/A	N/A	X[2/]	-	-	X	X
Full Trailer	X[2/]	X	X[2/]	-	-	X	X
	X	X	-	X	X	-	-

1/ Will generally require high speed and severe steering input.

2/ Dependent on load and centre of gravity.

Appendix 2

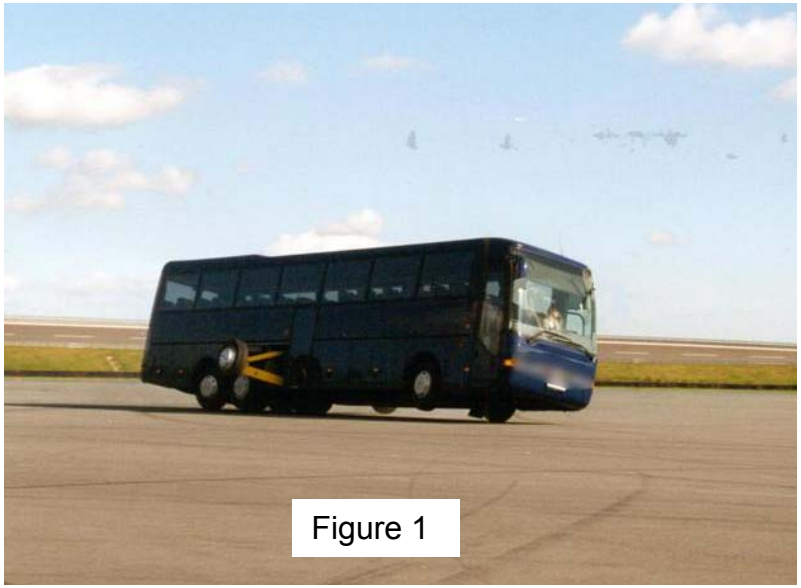

Figure 1

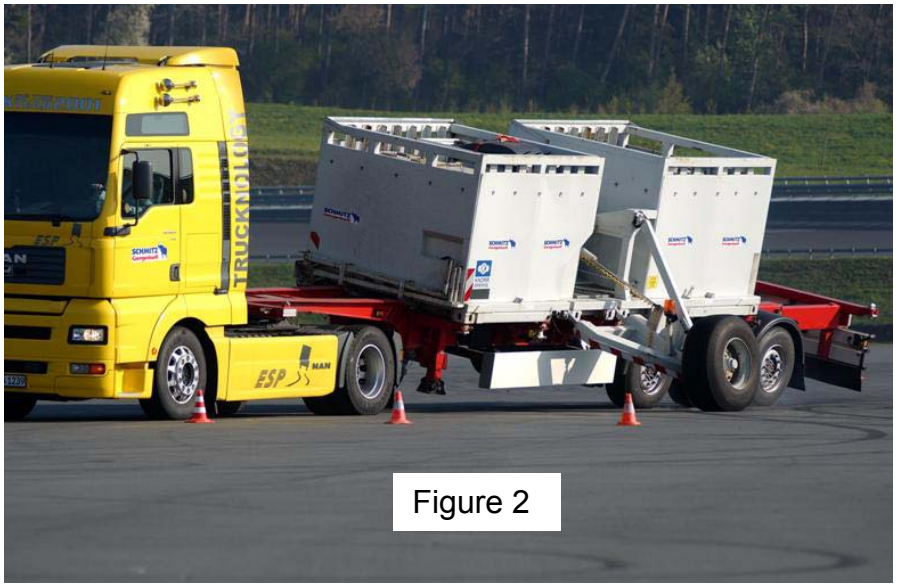

Figure 2

Figure 3

Figure 4

Appendix 3