IRTE A PROFESSIONAL SECTOR OF THE SOCIETY OF OPERATIONS ENGINEERS

GUIDE TO TIPPER STABILITY

Second Edition

£10.00

The Society of Operations Engineers

The Society of Operations Engineers (SOE) is a new kind of professional body formed to meet the needs of industry, its members and the public in a rapidly changing and increasingly competitive world.

The SOE was formed by the merger of two well-known professional bodies:

- The Institute of Road Transport Engineers (IRTE), established 1944;
- The Institution of Plant Engineers (IPlantE), established 1946.

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Society of Operations Engineers

The IRTE

The IRTE (Institute of Road Transport Engineers) is a Professional Sector of the Society of Operations Engineers (SOE) and embraces all disciplines of transport engineering from technicians and mechanics through to fleet managers and engineers. The IRTE is actively involved in a range of projects aimed at raising standards of excellence within the industry.

This publication is a result of work conducted by the IRTE Technical Committee.

If you are interested in becoming involved with the committee please contact Ian Chisholm, Head of Technical Services on 020 7630 1111 or by email at ian.chisholm@soe.org.uk.

IRTE A Professional Sector of The Society of Operations Engineers

Foreword

It gives me great pleasure to introduce the latest tipping vehicle stability guide from the Institute of Road Transport Engineers (IRTE).

In 1992 the IRTE was at the forefront of investigating vehicle-related problems and from this work came the original IRTE Guide to Tipper Stability.

That original work remained current until 2003 when it was felt that the guide might not be fully relevant to the vehicles of today. In-depth investigations into the original concept were undertaken along with liaison with industry, end-users, the enforcement authorities and the witnessing of several tilt tests. Finally, a seminar and debate was held in November 2003 to launch an industry-wide consultation on the subject and from this we have produced the 2004 version of the guide.

It is hoped that this will be a living document, kept under constant review to ensure that it remains up-to-date with changes in materials and manufacturing to give the end-user the best possible guide to vehicle stability. We are also hopeful that this work will form the basis of a European standard on tipping vehicle stability for future consideration.

The guide aims to assist engineers, fleet and transport managers in selecting a tipping vehicle that suits their needs. It also aims to aid bodies such as the Quarry Owners' Association which is attempting to increase its standards of safety in quarry operations.

This work cannot answer all of the questions posed by day-to-day operations but we hope it will act as a starting point.

Graham A L Ellis
IEng MSOE MIRTE CMILT MIMI LCGI MinstD
Chairman Vehicle Stability Working Party
March 2004

Caveat

This guide divides vehicles and trailers into two categories according to the maximum side-slope on which the full load can be lifted to maximum elevation. Vehicles in category A can cope with 7° or more of side-slope; vehicles in category B can cope with 5° to 7°. The implication being that any vehicle unable to cope with 5° of side-slope under the specified conditions is unsuitable for tipping. The specified values do not mean that these vehicles can safely tip on these side-slopes. The specified side-slope limits are used only as a convenient and meaningful 'yardstick' for vehicle stability.

In order to determine the vehicle category, the code recommends the application of a tilt table test. However, the code also allows calculations of the maximum side-slope, which takes into consideration the suspension, tyre and chassis stiffness as well as free-play in the suspension and hinge. The calculations are not specified and body manufacturers, who may certify vehicles and trailers, are advised to request the stiffness data from chassis manufacturers.

As manufacturers adopt new materials, the characteristics and operational behaviour of the materials must be considered in relation to the daily working performance of the vehicle and trailer. The continuing developments in component design and manufacture may influence stability and operating characteristics. It is for these reasons that this code should not be considered as a definitive work on tipper vehicle stability and, as such, the Society of Operations Engineers reserves the right to revise, update, modify and amend the code as necessary.

This publication is intended to indicate best practice from knowledge accumulated at the time of publication and should be used as guidance only. The Society of Operations Engineers or its Professional Sectors cannot accept responsibility for its use.

Introduction

The incidence of tipper vehicles and trailers overturning when their bodies are raised has been of concern to the road transport industry for a significant period of time. The most common incidents involve vehicles falling over sideways when discharging a load. There is currently no British or European recognised design standard which tipper truck manufacturers or body builders can use to ensure the integrity and stability of tipper trucks during operation. As a consequence, this IRTE Guide to Tipper Stability is essentially a performance standard that sets out specific stability performance criteria to be met by end tipping vehicles.

The primary aim of the guide is to inform operators and other interested parties of issues relating to the safe daily operation of tipping vehicles and trailers. Testing a vehicle to a predetermined level is used to demonstrate a technical standard and tipping at such high angles is not recommended.

In the absence of relevant statutory regulation 'Tipper Stability: The IRTE guide to the specification of more stable tipper trucks' was first published in 1992. This guide outlined the minimum stability standard when tipping on level hard surfaces and put forward a standard intended to relate to vehicles tipping on unmade or uneven ground.

Since the publication of the guide there have been significant changes to design, tyres and operating weights etc. The most notable of these is the increase in operating weight and the introduction of new types of suspension systems. When the guide was originally published the maximum operating weight of a vehicle was 38 tonnes, whereas now the current maximum operating weight is 44 tonnes. It is also acknowledged that safety working practices and procedures have evolved resulting in revised operational requirements for manufacturers, operators and drivers.

The Institute of Road Transport Engineers (IRTE), a Professional Sector of the Society of Operations Engineers (SOE), has undertaken a review of the guide and, in consultation with industry, has developed this revised edition.

Test Categories

With reference to a typical situation, in which tippers discharge their loads at the rear, two categories of minimum stability are recommended to guide purchasers of tippers.

Category B: This is a minimum stability standard and denotes the ability to discharge when tipping on hard level surfaces.

Category A: This standard is intended to cope, in general, when vehicles can be expected to tip on unmade or unlevel ground. Detailed operating instructions defining safe limits of operation should accompany any vehicle or trailer sold as a category A vehicle.

A fundamental and practical way to define stability is to measure the side-slope angle that a vehicle can withstand without wheel-lift when the body is fully raised and fully loaded. This condition can be accurately measured by testing and then calculated.

In use, it occasionally occurs that a tipper body can be fully raised with little or no discharge of load taking place (any small discharge from the rear may even make the situation slightly worse due to a raising of the centre of gravity of the vehicle). This condition can arise with certain sticking loads, or indeed in the winter as a result of freezing. When discharge then begins this is often on one side, and is a common cause of overturning. Thus it is necessary that any tipping vehicle should be able to have its body fully raised with the load in place and withstand an uneven discharge.

The worst condition for uneven load is approximately equivalent to standing the fully loaded, fully tipped vehicle on a 4° side-slope. As stability measurements and predictions are made on new vehicles, it is essential to include some margin for deterioration in service. Hence the minimum acceptable side-slope stability for any tipping vehicle must be 5°. That will correspond to category B of operating conditions.

Tipping vehicles often have to operate on sloping or uncompacted ground; for this reason a manufacturer may choose to design and prove a vehicle to a higher side-slope angle. When that is a minimum of 7° it reaches qualification for category A operating conditions.

The substantial deflections, which occur in the vehicle, tyres and suspension, are major factors influencing stability, and must be taken into account in any calculation method of assessing stability.

Constraints:

- This code of practice covers both rigid and articulated vehicles.
- Fundamentally the same rules apply to both rigid and articulated vehicles.
- The code applies to end tipping vehicles only.

CONFIRMATION OF FITNESS

Category B

A tipper of this standard must be capable of staying stable when fully loaded to plated maximum gross weight with the body fully raised on a 5° side slope. It must not be possible to raise the body to a point where rearwards overturning may occur. Compliance with the sideways capability must have been shown by test on one vehicle of a certain type. Other related vehicles can be confirmed by calculation.

The vehicle should be supplied with full operating instructions giving limitations in use and recommendations on safe operation. Those instructions should explain the category B capability as meaning that the vehicle may have its fully-laden body fully raised on level compacted ground. In all other circumstances, significant discharge must have taken place before the body is fully raised. An outline of the main safety points in operating the vehicle should be clearly displayed.

Category A

Any tipper of this standard must be capable of staying stable on a side-slope angle of at least 7° in the specified test, loaded to plated maximum gross weight and with its body fully raised. It must not be possible to raise the body to a point where overturning rearwards is possible.

The manufacturer may specify the use of the vehicle for difficult loads or conditions, provided that all aspects of such operation are covered in operating instructions supplied with the vehicle. These instructions should cover limitations on the angle to which the body can be raised taking into account any side-slope present.

Preferably the vehicle should be equipped with a means of indicating the angle of elevation of the body and side-slope relative to the ground.

An outline of the main safety points in operating the vehicle should be clearly displayed.

CONFORMITY

Suppliers of complete tipping vehicles and trailers (in practise, mostly bodybuilders) should state the stability-standard category to which they assure their products conform.

Research undertaken by the IRTE suggests that in the process of such self-certification, this should be based on an angle that allows for 3mm diametral clearance in tipper-hinge and stabiliser pivots from reasonable wear and tear. They shall assume that a vehicle is in a well-maintained condition, particularly in relation to structural integrity, suspension soundness and adequate inflation of all tyres, and that a vehicle in respect of its structure and load ratings conforms to type approval certification.

Manufacturers are advised to confirm a type calculation by physical test, which can also form a check on the strength of all the components at the overturn limit. They are also reminded of the value of certification by validation or witnessing by an independent body.

All forms of deflection occurring in the vehicle, its tyres and suspension must be included in any calculations.

Note: manufacturers should observe that under obligation to laws of product liability and quality, they need to keep records of calculations and test results. These may be required to demonstrate compliance with the stated category of the code of practice when the complete vehicle was designed or delivered.

Chassis data

For body builders to have a reliable basis for assessments of stability, chassis manufacturers should provide the following data on request:

- The torsional resistance of the chassis frame rear hinge point to rear suspension centre line.
- The roll stiffness of the suspension at the point of wheel lift on one side.
- The width of the effective spring base.
- The height of the suspension's roll centre.
- Any instructions or guidelines for the mounting or installation of tipping bodies and hoists.

General guidance on achieving standards

Deflections of vehicles and suspensions are a major concern in stability, and are areas over which the manufacturer has control. For any vehicle to reach these standards it is normally necessary to have:

- A centre of gravity as low as possible.
- A suspension with a high roll stiffness (particularly at the point of overturning).
- A torsionally stiff chassis between rear hinge and rear suspension.
- Minimum practicable free play in suspension and hinges (as widely spaced and large as possible).
- The rear hinge as close as possible to the rear suspension (or supports, if fitted).

Additional features such as sideways restraint frames between body and chassis are often useful in improving stability. The major determining factor in the overall stability of a vehicle is the most flexible element in the vehicle. Therefore, increasing the stiffness of this component will have the greatest beneficial effect.

Where design data is unavailable, inadequate or untrustworthy, it is advisable to conduct physical tests by applying loads and measuring deflections. Calculations can produce acceptable estimates and computer programs are available to assist with this. Greatest confidence in calculations arises, however, following a practical tilt test to establish the overturning angle and relative angularities of major structural constituents.

The test procedure

Vehicle weighing: The test procedure should commence with the vehicle being weighed in "road-going mode". The GVW (Gross Vehicle Weight) should be measured, followed by axle weights and finally side vehicle weights. The weight transferred to the rear bogie when the body is fully tipped to a body angle of 45° should also be determined.

Type of payload: The type of payload and the method of retention during testing should be representative of the loads carried by the vehicle during normal operation. The nature of the payload will influence the stability of the vehicle due to the position of the centre of gravity and the potential for the load to shift to one side during testing. The worst potential loading combination should be considered and this should be set as the standard load. The method for all tests is that a load which has a centre of gravity no lower than the midpoint of the side of the trailer should be used and that this shall be equally loaded across the total length of the trailer floor.

Fully raised body: Whilst it is appreciated that there may be variations in raised tipping angles between different chassis manufacturers, for the purposes of the test regime the desired raised tipping angle shall be 45°.

Method of payload retention: For the purposes of the stability test a payload should be chosen which fills the body as much as possible. The payload should also be retained in such a manner that it cannot discharge or move down the body. It may be necessary to use bulkheads with some types of load. Other loads may be adequately secured by clamping panels over the load. The payload shall correspond to the maximum design weight. The height of the load's centre of gravity shall be recorded.

Security of vehicle: The vehicle must be secured against overturning by restraining the chassis and the body. Body deflection, in particular, may be so great that arrangements will be needed for a moveable restraint; this can be achieved with the assistance of a safety support crane.

Tilt platform: Once the vehicle has been safely secured on the tilt platform and the appropriate test equipment has been installed and calibrated, the test sequence can begin. The body should first be raised to its maximum angle. The platform and vehicle are then tilted sideways in increments of 0.5° (or less), relaxing the body restraint after each increment. At this point consideration should be given to:

- Tyre deformation.
- Twisting of chassis rails and front hydraulic cylinder.
- Trailer rear body twist.
- 5th wheel coupling separation and loosening.
- Slipping of retaining bolts.

Effects of side wind: Still-air conditions are naturally desirable during a stability test, although stability tests are generally conducted in side winds of up to 10 knots. The effects of side wind are quite noticeable when the tipper body is fully raised and may produce misleading results.

Body alignment: On completion of the test the platform is levelled and the tipper body is lowered. The laden tipper body should return to its normal transit position without any form of external assistance. If the tipper body does not return to its normal transit position the vehicle should be deemed not to have attained the stability requirement. In order to satisfy the test criteria, the vehicle must be in a serviceable and roadworthy condition on completion of the test procedure.

Safety considerations: It is advisable to make all relevant information and technical expertise available for the duration of the stability tests. Where possible all interested parties including manufacturers, key suppliers, customers and operators should form part of the stability test team.

Manufacturers should ensure that the vehicle and body structure to be tested are of sufficient strength and construction to withstand the loads and forces imposed during the test procedures.

It is advisable to carry out the stability test to the point of “first wheel lift”. However, if a manufacturer requests that the test continue beyond this point, considerable care and vigilance should be exercised as sudden structural failure can produce catastrophic results.

The use of a suitable safety support crane during tipper stability tests provides a degree of control in the behaviour of the raised body when approaching vehicle instability.

If, at any point during the test procedure, safety is compromised in any way, the test must be stopped immediately.

Air suspension

The increasing fitment of air suspension to large tipper vehicles has added another dimension to the question of stability. The 1992 guide made no reference to air suspension; consequently the need to maintain or exhaust air within the suspension system during the tipping process was not addressed. The status of the suspension is a point of some debate, particularly in relation to testing. The issue of tipper stability is considerably more complex than merely deciding whether air should or should not remain in the suspension system. It may be considered that both ‘air in’ and ‘air out’ have their own advantages and disadvantages, but a number of other factors must also be considered. Principal amongst these are chassis construction and suspension configuration.

It is recognised that when air is exhausted from the suspension system during tipping, the rear end of the trailer roll stiffness is substantially increased due to the rearmost axle being effectively “on its bump stops”. However, under such circumstances, the load is no longer equally shared by the rear axle configuration and generally significant weight is transferred to the rearmost axle. Loads in excess of 20 tonnes have been recorded on the rearmost axle when the air from the suspension has been exhausted.

Tests may be undertaken with the air suspension in a condition which would normally give the truck reduced stability. Tipping with air exhausted from the suspension can lead to increased stability. However this should only be considered in the test process if the tipping operation is controlled with interlocks and if the axle/tyre chassis manufacturers can verify the integrity of the vehicle with the higher loads imposed on the rearmost axle. Where there is any doubt, then the trailer should be tested in the worst-case scenario i.e. with the air system inflated.

In any event, safety is the main consideration and the highest levels of safety should prevail.

Tyre deflection

High tyre deflections have been observed during test procedures and estimations indicate a maximum tyre load on the "down-slope" rear tyre to be in the region of 16 tonnes at 7.0° side slope. In this situation the tyre shows excessive deformation with the wheel rim beginning to impinge on the side wall of the tyre. As a result of the time taken to complete the test process, the tyre may be subjected to high load/deflection for extended periods.

It is considered that the static tyre load limits are most probably exceeded during tilt testing with both the air in or exhausted from the suspension system. It is therefore considered prudent for tipper manufacturers to remove and disregard those tyres that have been subject to high loads during tilt testing.

Type of tipping gear

The important criterion for stability is to keep the rear wheels firmly on the ground. In order to do this, the rear section of the vehicle or trailer frame must be torsionally stiff. It is therefore unlikely that a cylinder (ram) can substantially improve the stability of a fundamentally unstable trailer. However, some opinion in the industry suggests that tipper stability of 8x4 rigid vehicles may be enhanced by the use of underfloor tipping gear utilising a scissor-action brace frame. Manufacturers may wish to consider a similar effect of this mid-chassis bracing frame in the case of tri-axle semi trailers.

Pre-used tipping vehicles and trailers

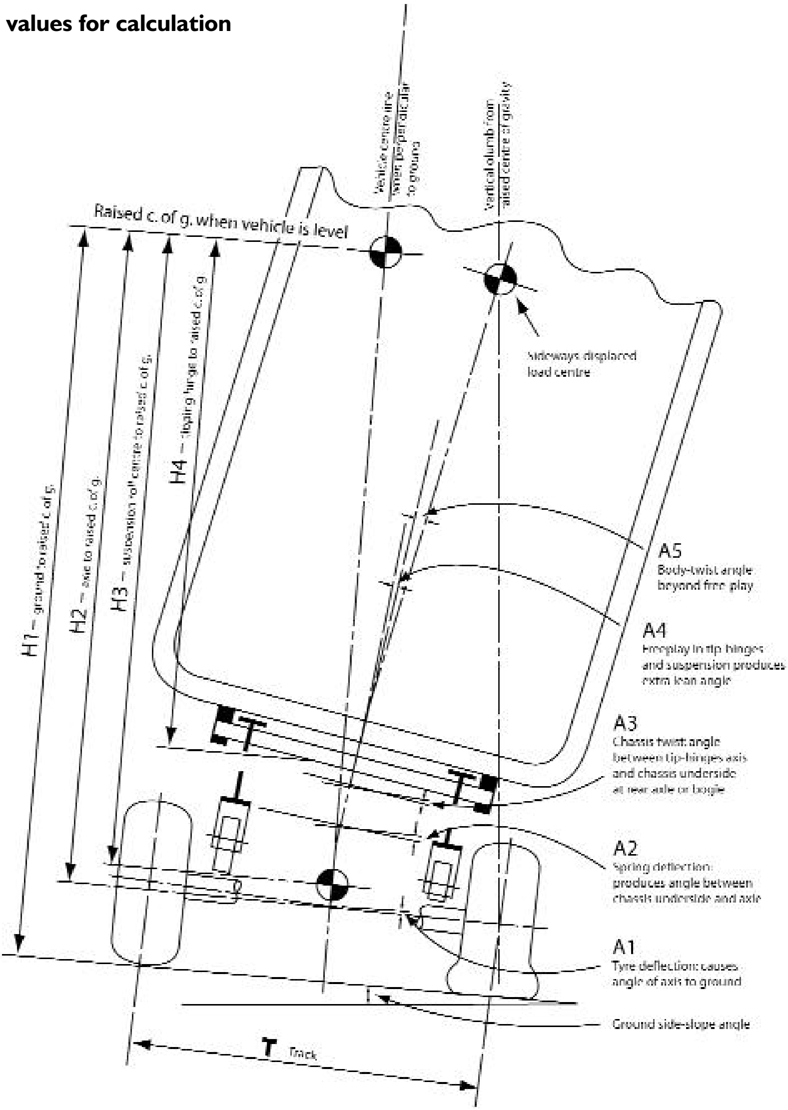
In general, this guide is relevant to the testing of new vehicles and trailers although it is acknowledged that there is concern when comparing the stability of a new and pre-used vehicle of the same make and specification. Operators purchasing pre-used vehicles may wish to consider testing the stability of the laden tipper before entering service with their company.

It should, however, be noted that the test includes some degree of latitude for wear in all linkages, but this cannot be exhaustive.

Technical Illustrations

Diagram 1

Nominal values for calculation



Note: In practice, slightly more than the nominal track is the effective track width (or more accurately, the effective half-track on the loaded side to which the tipper vehicle leans). However, tyre behaviour in roll tends to be imprecise, and therefore it is prudent to use the nominal track for calculations.

Diagram detail

H1 – the height from the ground to the centre of gravity of a fully-raised load in the body when the vehicle is standing on level ground.

H2 – the height of that level ground centre of gravity above the centre line of the rear axle.

H3 – the height of that level-ground centre of gravity above the roll centre of the rear suspension.

H4 – the mean height of the centre of gravity of the load in the raised body above the tipping hinges.

It should be noted that all these heights can be based on level-ground assessment since over the angles being considered, differences between level ground and leaned heights are negligible.

Principles of Stability Estimation

The various factors which contribute to the build-up of an overbalancing angle are considered in a cumulative formula:

$$\sin^{-1} \left\{ \frac{(T \div 2) - (H2 \times \sin A1) - (H3 \times \sin A2) - (H3 \times \sin A3) - (H4 \times \sin A4) - (H4 \times \sin A5)}{H1} \right\}$$

This formula will not provide a precise prediction of the overturning angle, but in most situations will serve for comparison purposes.

Diagram 2
Dimensional points

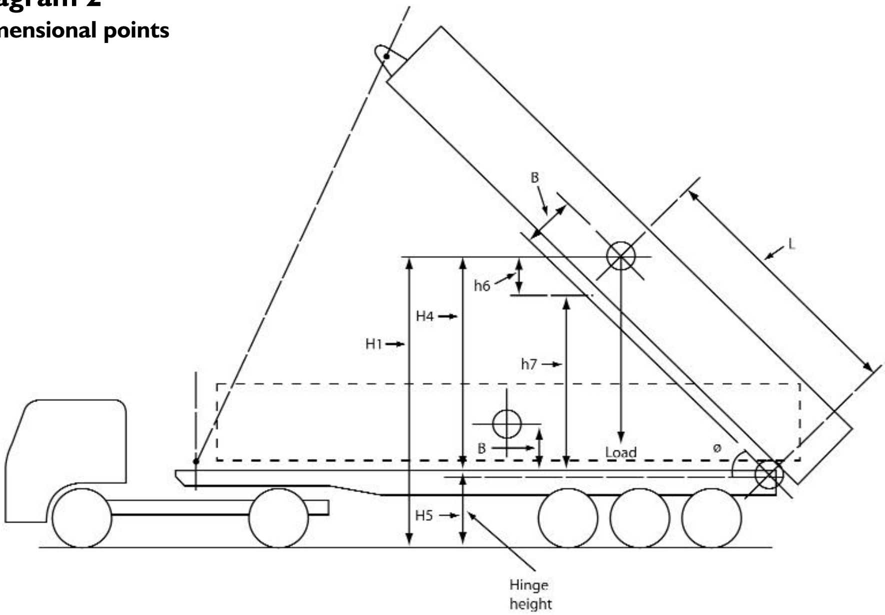


Diagram 3
Calculation for height of raised centre of gravity (H1)

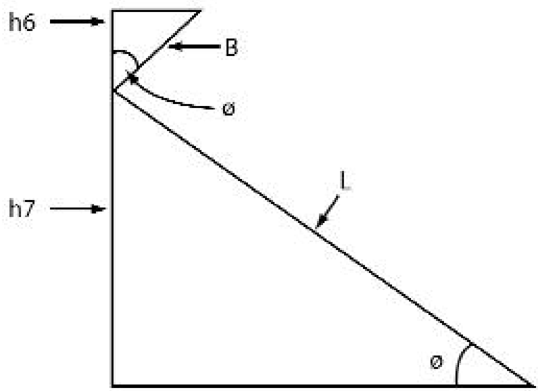
$h6 = B\cos ø$

$h7 – L\sin ø$

$H4 = h6 + h7$

$– B\cos ø + L\sin ø$

$H1 = H4 + H5$



Vehicle data and test record

This data is used to allow the effect of subsequent changes in the vehicle specification to be assessed for likely deviation from the tested performance and to extrapolate the results to derivative models. Such data is used for record purposes.

Chassis make, type and model designation gross plated weight	
Chassis wheelbase (trailers, pin to axle or bogie-centre)	
Length of body	
Height of body sides	
Height of load centre of gravity as submitted for test	
Unladen weight of bodied vehicle or trailer	
Unladen weight distribution front: rear or king pin: rear	
Gross vehicle or gross trailer weight for test	
Angle of tip	
Type, make & model of tipping gear & positioning distance from rear axle or bogie-centre	
Distance of tipping stabiliser linkage attachments from rear axle or bogie-centre	
Height of body floor above ground, front and rear	
Height of tip hinge centre above ground	
Rear overhang of body beyond tip hinge	
Distance from tip hinge to centre of rear axle or bogie	
Rear tyre size and whether twins or singles	
Rear wheel track	
Rear spring rate and spring-base width, or roll stiffness	
Suspension roll-centre height above ground	
Body material and construction (photo or general-arrangement drawing)	
Chassis material, yield strength, modulus & construction (photo or general-arrangement drawing)	
Dimensions of chassis side-member cross section	
a) general	
b) from rear suspension anchorage to tail	
Cross-member section-form and dimensions from rear suspension to tail	
Place of evaluation testPlace of evaluation test	
Date of evaluation test	
Name, address & signature of independent scrutineer or witness	

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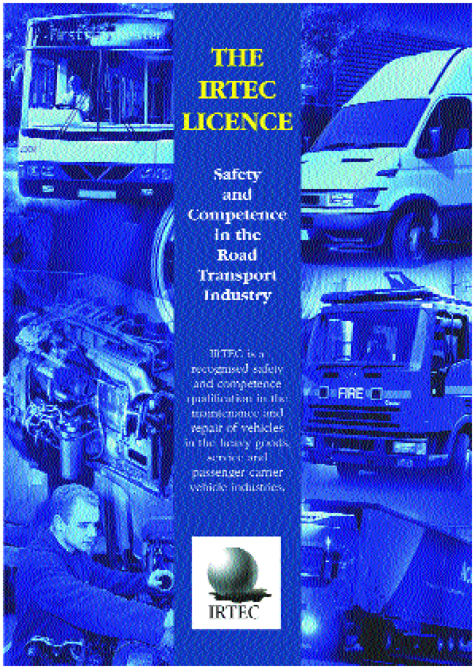
The Society of Operations Engineers manages the independent IRTEC Licensing Scheme on behalf of the industry to certify the current competence of those engaged in vehicle inspection, maintenance and repair. The Scheme is currently available in the heavy vehicle, bus and coach sectors and light commercial vehicle sectors.



To acquire the Licence, candidates must pass a series of practical tests and a theory paper developed and validated by the industry. These cover all working aspects of the industry, but concentrate on safety-critical elements and inspection.

Successful candidates are awarded a Certificate of Achievement detailing all areas of proven competence.

Candidates who pass all the practical modules and the theory test are awarded the full IRTEC licence which is valid for up to five years. Thereafter, a complete reassessment is required to maintain the Licence.

For more information call 020 7630 1111
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