AIS-151

AUTOMOTIVE INDUSTRY STANDARD

AUTOMOTIVE VEHICLES – UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES OF CATEGORIES M1 AND N1 WITH REGARD TO BRAKING

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ON BEHALF OF
AUTOMOTIVE INDUSTRY STANDARDS COMMITTEE

UNDER
CENTRAL MOTOR VEHICLE RULES – TECHNICAL STANDING COMMITTEE

SET-UP BY
MINISTRY OF ROAD TRANSPORT & HIGHWAYS
(DEPARTMENT OF ROAD TRANSPORT & HIGHWAYS)
GOVERNMENT OF INDIA

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Status chart of the standard to be used by the purchaser for updating the record

Sr. No.	Corrigenda.	Amendment	Revision	Date	Remark	Misc.
General remarks :						

INTRDUCTION

The Government of India felt the need for a permanent agency to expedite the publication of standards and development of test facilities in parallel when the work on the preparation of the standards is going on, as the development of improved safety critical parts can be undertaken only after the publication of the standard and commissioning of test facilities. To this end, the erstwhile Ministry of Surface Transport (MOST) has constituted a permanent Automotive Industry Standards Committee (AISC) vide order No. RT-11028/11/97-MVL dated September 15, 1997. The standards prepared by AISC will be approved by the permanent CMVR Technical Standing Committee (CTSC). After approval, the Automotive Research Association of India, (ARAI), Pune, being the Secretariat of the AIS Committee, has published this standard. For better dissemination of this information ARAI may publish this standard on their web site.

This standard covers uniform provisions concerning the approval of vehicles of category M1 and N1 and is aligned with UN R13 H (Revision 3 Amendment 2).

Uniform provisions concerning the approval of vehicles of category N1 is also covered in AIS 150 which is based on UN R13 (Revision 8 Amendment 4). Manufactures of category N1 vehicles have option to test their vehicle using either of these standards till the time both standards are acceptable.

Keeping in view Indian context this standard is having following differences as compared to UN R:

a) Coefficient of adhesion of road surface to be at least 0.8 whereas in UN R requirement is given as subjective.

b) Additional India specific requirements are added as below:

   1) Criteria for extension of approval to be used for selection of vehicle for testing and extension of approvals added;

   2) Tolerance on test speed added to ± 2 percent; and

   3) Max speed in type '0' test restricted to 120 km/h.

   NOTE - The maximum speed is restricted to 120 km/h due to lack of test tracks in India. As soon as the NATRIP will be ready with test tracks for testing at a speed specified in UN R the standard will be reviewed for incorporating the test speed in this standard.

   An informative Annex K has been incorporated in this standard indicating corresponding clauses of this standard and UN R 13H.

   The AISC panel and the Automotive Industry Standards Committee (AISC) responsible for preparation of this standard are given in Annex-H and Annex-J respectively.

   For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

AUTOMOTIVE VEHICLES – UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES OF CATEGORIES M1 AND N1 WITH REGARD TO BRAKING

1.0 SCOPE

1.1 This standard specifies uniform provisions concerning the approval of vehicles of

1.1.1 Category M1, as defined in AIS-053, with regard to braking.

1.1.2 Alternative provisions concerning the approval of vehicles of category N1, as defined in AIS-053, with regard to braking.

1.2 This standard does not cover:

a) Vehicles with a design speed not exceeding 25 km/h; and

b) Vehicles fitted for invalid drivers.

2.0 REFERENCES

The following standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

IS/ISO No.	Title
11852 : 2011	Uniform provisions concerning the approval of vehicles of categories M, N and T (*second revision*)
14272 : 2011	Automotive Vehicles – Types – Terminology (*first revision*)
ISO 9128: 2006	Road vehicles – Graphical symbols to designate brake fluid types
AIS-004	Electromagnetic Radiation from Automotive Vehicle – Permissible Levels and Methods of Tests.

3.0 DEFINITIONS

For the purposes of this standard, the following definitions shall apply.

3.1 **Approval of a Vehicle** – The approval of a vehicle type with regard to braking.

3.2 **Vehicle Type** – A category of vehicles which do not differ in such essential respects as:

a) Maximum Mass (*see* 3.11);

b) Distribution of mass among the axles;

c) Maximum design speed;

d) A different type of braking equipment, with more particular

reference to the presence or otherwise of equipment for braking a trailer or any presence of electric braking system;

e) Engine type;

f) Number and ratios of gears;

g) Final drive ratios; and

h) Tyre dimensions.

3.3 **Braking Equipment** — The combination of parts whose function is progressively to reduce the speed of a moving vehicle or bring it to a halt, or to keep it stationary, if it is already halted; these functions are specified in 5.1.2. The equipment consists of the control, the transmission, and the brake proper.

3.4 **Control** — The part actuated directly by the driver to furnish to the transmission the energy required for braking or controlling it. This energy may be the muscular energy of the driver, or energy from another source controlled by the driver, or a combination of these various kinds of energy.

3.5 **Transmission** — The combination of components comprised between the control and the brake linking them functionally. The transmission may be mechanical, hydraulic, pneumatic, electric or mixed. Where the braking power is derived from or assisted by a source of energy independent of the driver, the reserve of energy in the system is likewise part of the transmission.

The transmission is divided into two independent functions: (a) control transmission; and (b) energy transmission. Whenever the term 'transmission' is used alone in this standard, it means both the 'control transmission' and the 'energy transmission'.

3.5.1 **Control Transmission** — The combination of the components of the transmission which control the function and the necessary reserve(s) of energy.

3.5.2 **Energy Transmission** — The combination of the components which supply to the brakes the necessary energy for their function including the reserve(s) of energy necessary for the operation of the brakes.

3.6 **Brake** — The part in which the forces opposing the movement of the vehicle develop. It may be a friction brake (when the forces are generated by friction between two parts of the vehicle moving relatively to one another); an electrical brake (when the forces are generated by electro-magnetic action between two parts of the vehicle moving relatively to but not in contact with one another); a fluid brake (when the forces are generated by the action of a fluid situated between two parts of the vehicle moving relatively to one another); or an engine brake (when the forces are derived from an artificial increase in the braking action, transmitted to the wheels, of the engine).

3.7 **Different Types of Braking Equipment** — Equipment which differs in such essential respects as:

a) components having different characteristics;

b) a component made of materials having different characteristics, or a component differing in shape or size; and

c) a different assembly of the components.

3.8 **Component of the Braking Equipment** — One of the individual parts which, when assembled, constitutes the braking equipment.

3.9 **Progressive and Graduated Braking** — Braking during which, within the normal operating range of the device and during actuation of the brakes (*see* 3.16).

3.9.1 The driver can at any moment increase or decrease the braking force by acting on the control.

3.9.2 The braking force varies proportionally as the action on the control (Monotonic function).

3.9.3 The braking force can be easily regulated with sufficient precision.

3.10 **Laden Vehicle** — Except where otherwise stated, a vehicle so laden as to attain its maximum mass (*see* 3.11).

3.11 **Maximum Mass** — The maximum mass stated by the vehicle manufacturer to be technically permissible (this mass may be higher than the permissible maximum mass laid down by the statutory authority).

3.12 **Distribution of Mass Among the Axles** — The distribution of the effect of the gravity on the mass of the vehicle and/or its contents among the axles.

3.13 **Wheel/Axle Load** — The vertical static reaction (force) of the road surface in the contact area on the wheel/wheels of the axle.

3.14 **Maximum Stationary Wheel/Axle Load** — The stationary wheel/axle load achieved under the condition of the laden vehicle.

3.15 **Hydraulic Braking Equipment with Stored Energy** — Braking equipment where energy is supplied by a hydraulic fluid under pressure, stored in one or more accumulator(s) fed from one or more pressure pump(s), each fitted with a means of limiting the pressure to a maximum value. This value shall be specified by the manufacturer.

3.16 **Actuation** — Both application and release of the control.

3.17 **Electric Regenerative Braking** — A braking system which, during deceleration, provides for the conversion of vehicle kinetic energy into electrical energy.

3.17.1 **Electric Regenerative Braking Control** — A device which modulates the action of the electric regenerative braking system.

3.17.2 **Electric Regenerative Braking System of Category A** — An electric regenerative braking system which is not part of the service braking system.

3.17.3 **Electric Regenerative Braking System of Category B** — An electric regenerative braking system which is part of the service braking system.

3.17.4 **Electric State of Charge** — The instantaneous ratio of electric quantity of energy stored in the traction battery relative to the maximum quantity of electric energy which could be stored in this battery.

3.17.5 **Traction Battery** — An assembly of accumulators constituting the storage of energy used for powering the traction motor(s) of the vehicle.

3.18 **Phased Braking** — A means which may be used where two or more sources of braking are operated from a common control, whereby one source may be given priority by phasing back the other source(s) so as to make increased control movement necessary before they begin to be brought into operation.

3.19 **Nominal Value** — Definitions for braking reference performance are required to put a value on the transfer function of the braking system, relating output to input for vehicles individually. Nominal value is defined as the characteristic which can be demonstrated at type approval and which relates the braking rate of the vehicle on its own to the level of the braking input variable.

3.20 **Automatically Commanded Braking** — A function within a complex electronic control system where actuation of the braking system(s) or brakes of certain axles is made for the purpose of generating vehicle retardation with or without a direct action of the driver, resulting from the automatic evaluation of on-board initiated information.

3.21 **Braking Signal** — Logic Signal or communication indicating brake activation as specified in 5.2.22.

3.22 **Selective Braking** — A function within a complex electronic control system; where actuation of individual brakes is made by automatic means in which vehicle retardation is secondary to vehicle behavior modification.

3.23 **Emergency Braking Signal** — Logic Signal or communication indicating emergency braking as specified in 5.2.23.

3.24 **Identification code** identifies the brake discs or brake drums covered by the braking system approval according to this standard. It contains at least the manufacturer's trade name or trademark and an identification number / part number.

4.0 APPLICATION FOR APPROVAL

4.1 The application for approval of a vehicle type with regard to braking shall be submitted by the vehicle manufacturer or by his duly accredited representative.

4.2 It shall be accompanied by the under mentioned documents in triplicate and by the following particulars:

a) A description of the vehicle type with regard to the items specified in 3.2. The numbers and/or symbols identifying the vehicle type and the engine type shall be specified;

b) A list of the components, duly identified, constituting the braking equipment;

c) A diagram of assembled braking equipment and an indication of the position of its components on the vehicle;

d) Detailed drawings of each component to enable it to be easily located and identified.

4.3 A vehicle, representative of the vehicle type to be approved, shall be submitted to the Testing Agency conducting the approval tests.

5.0 SPECIFICATIONS

5.1 General

5.1.1 Braking Equipment

5.1.1.1 The braking equipment shall be so designed, constructed and fitted as to enable the vehicle in normal use, despite the vibration to which it may be subjected, to comply with the provisions of this standard.

5.1.1.2 In particular, the braking equipment shall be so designed, constructed and fitted as to be able to resist the corroding and ageing phenomena to which it is exposed.

5.1.1.3 The effectiveness of the braking equipment shall not be adversely affected by magnetic or electrical fields (This shall be demonstrated by compliance with AIS-004 (Part 3)).

5.1.1.4 Brake linings shall not contain asbestos.

5.1.1.5 A failure detection signal may interrupt momentarily (< 10 ms) the demand signal in the control transmission, provided that the braking performance is thereby not reduced.

5.1.2 Functions of the Braking Equipment

The braking equipment defined in **3.3** shall fulfil the following functions.

a) **Service braking system** — The service braking system shall make it possible to control the movement of the vehicle and to halt it safely, speedily and effectively, whatever its speed and load, on any up or down gradient. It shall be possible to graduate this braking action. The driver shall be able to achieve this braking action from his driving seat without removing his hands from the steering control.

b) **Secondary braking system** — The secondary braking system shall make it possible by application of the service brake control to halt the vehicle within a reasonable distance in the event of failure of the service braking system. It shall be possible to graduate this braking action. The driver shall be able to obtain this braking action from his driving seat without removing his hands from the steering control. For the purposes of these provisions it is assumed that not more than one failure of the service braking system can occur at one time.

c) **Parking braking system** — The parking braking system shall make it possible to hold the vehicle stationary on an up or down gradient even in the absence of the driver, the working parts being then held in the locked position by a purely mechanical device. The driver shall be able to achieve this braking action from his driving seat.

5.1.3 The requirements of Annex G shall be applied to the safety aspects of all complex electronic vehicle control systems, including those defined in an independent regulation, which provide or form part of the control transmission of the braking function included those which utilize the braking system(s) for automatically commanded braking or selective braking.

However, vehicles equipped with systems or functions, including those defined in an independent regulation, which use the braking system as the means of achieving a higher level objective, are subject to Annex G only insofar as they have a direct effect on the braking system. If such systems are provided, they shall not be deactivated during type approval testing of the braking system.

5.1.4 **Provisions for the periodic technical inspection of braking systems:**

5.1.4.1 It shall be possible to assess the wear condition of the components of the service brake that are subject to wear, for example friction linings and drums/discs (in the case of drums or discs, wear assessment may not necessarily be carried out at the time of periodic technical inspection). The method by which this may be realized is defined in 5.2.11.2.

5.1.4.2 It shall be possible to verify, in a frequent and simple way, the correct operational status of those complex electronic systems which have control over braking. If special information is needed, this shall be made freely available.

5.1.4.2.1 Where the operational status is indicated to the driver by warning signals, as specified in this Standard, it shall be possible at a periodic technical inspection to confirm the correct operational status by visual observation of the warning signals following a power-on.

5.1.4.2.2 At the time of type approval, the means implemented to protect against simple unauthorized modification of the operation to the verification means chosen by the manufacturer (for example warning signal) shall be confidentially outlined. Alternatively, this protection requirement is fulfilled when a secondary means of checking the correct operational status is available.

5.1.4.3 It shall be possible to generate maximum braking forces under static conditions on a rolling road or roller brake tester.

5.2 **Characteristics of Braking Systems**

5.2.1 The set of braking systems with which a vehicle is equipped shall satisfy the requirements laid down for service, secondary and parking braking systems.

5.2.2 The systems providing service, secondary and parking braking may have common components so long as they fulfill the following conditions.

a) There shall be at least two controls, independent of each other and readily accessible to the driver from his normal driving position. Every brake control shall be designed such that it returns to the fully off position when released. This requirement shall not apply to a parking brake control when it is mechanically locked in an applied position.

b) Control of the service braking system shall be independent of the control of the parking braking system.

c) Effectiveness of the linkage between the control of the service braking system and the different components of the transmission systems shall not be liable to diminish after a certain period of use.

d) Parking braking system shall be so designed that it can be actuated when the vehicle is in motion; this requirement may be met by the actuation of the vehicles service braking system, even partially, by means of an auxiliary control.

e) Without prejudice to the requirements of 5.1.2 (c), the service braking system and parking braking system may use common components in their transmission(s), provided that in the event of a failure of the transmission(s) the requirements for the secondary braking are still ensured.

f) In the event of breakage of any component other than the brakes (as defined in 3.6) and the components referred to in 5.2.2 (k), or of any other failure of the service braking system (malfunction, partial or total exhaustion of an energy reserve), that part of the service braking system which is not affected by the failure, shall be able to bring the vehicle to a halt in the conditions prescribed for secondary braking,

g) If service braking is ensured by the action of the driver's muscular energy assisted by one or more energy reserves, secondary braking shall, in the event of failure of that assistance, be capable of being ensured by the driver's muscular energy assisted by the energy reserves, if any, which are unaffected by the failure, the force applied to the service brake control not exceeding the prescribed maximum.

h) If the service braking force and transmission depend exclusively on the use, controlled by the driver, of an energy reserve, there shall be at least two completely independent energy reserves, each provided with its own transmission, likewise independent; each of them may act on the brakes of only two or more wheels so selected as to be capable of ensuring by themselves the prescribed degree of secondary braking without endangering the stability of the vehicle during braking; in addition, each of the aforesaid energy reserves shall be equipped with a warning device as defined in 5.2.14.

j) If the service braking force and transmission depend exclusively on the use of an energy reserve, one energy reserve for the transmission is deemed to be sufficient , provided that the prescribed secondary braking is ensured by the action of the driver's muscular energy acting on the service brake control and the requirement of the 5.2.5 are met.

k) Certain parts, such as the pedal and its bearing, the master cylinder and its piston or pistons, the control valve, the linkage between the pedal and the master cylinder or the control valve, the brake cylinders and their pistons, and the lever-and-cam assemblies of brakes, shall not be regarded as liable to breakage if they are amply dimensioned, are readily accessible for maintenance, and exhibit safety features at least equal to those prescribed for other essential components (such as the steering linkage) of the vehicle. Any such part as aforesaid whose failure would make it impossible to brake the vehicle with a degree of effectiveness at least equal to that prescribed for secondary braking shall be made of metal or of a material with equivalent characteristics and shall not undergo notable distortion in normal operation of the braking systems.

5.2.3 The failure of a part of a hydraulic transmission system shall be signalled to the driver by a device comprising a red tell-tale signal lighting up before or upon application of a differential pressure of not more than 1.55 MPa between the active and failed brake equipment, measured at the master cylinder outlet and remaining lit as long as the failure persists and the ignition (start) switch is in the 'on' (run) position. However, a device comprising a red tell-tale signal lighting up when the fluid in the reservoir is below a certain level specified by the manufacturer is permitted. The tell-tale signal shall be visible even by daylight; the satisfactory condition of the signal shall be easily verifiable by the driver from the driver's seat.

The failure of a component of the device shall not entail total loss of the braking equipment's effectiveness. Application of the parking brake shall also be indicated to the driver. The same tell-tale signal may be used.

5.2.4 Where use is made of energy other than the muscular energy of the driver, there need not be more than one source of such energy (hydraulic pump, air compressor, etc.), but the means by which the device constituting that source is driven shall be as safe as practicable.

5.2.4.1 In the event of failure in any part of the transmission of a braking system, the feed to the part not affected by the failure shall continue to be ensured, if required for the purpose of halting the vehicle with the degree of effectiveness prescribed for secondary braking. This condition shall be met by means of devices which can easily be actuated when the vehicle is stationary, or by automatic means.

5.2.4.2 Furthermore, storage devices located down-circuit of this device shall be such that in the case of a failure in the energy supply after four full-stroke actuations of the service brake control, under the conditions prescribed in B-1.2, it is still possible to halt the vehicle at the fifth application, with the degree of effectiveness prescribed for secondary braking.

5.2.4.3 However, for hydraulic braking systems with stored energy, these provisions can be considered to be met provided that the requirements of B-1.3 are satisfied.

5.2.5 The requirements of 5.2.2, 5.2.3 and 5.2.4 shall be met without the use of any automatic device of a kind such that its ineffectiveness might pass unnoticed through the fact that parts normally in a position of rest come into action only in the event of failure in the braking system.

5.2.6 The service braking system shall act on all wheels of the vehicle and shall distribute its action appropriately among the axles.

5.2.7 In the case of vehicles equipped with electric regenerative braking systems of category B, the braking input from other sources of braking may be suitably phased to allow the electric regenerative braking system alone to be applied, provided that both the following conditions are met:

a) Intrinsic variations in the torque output of the electrical regenerative braking system (for example as a result of changes in the electric state of charge in the traction batteries) are automatically compensated by appropriate variation in the phasing relationship as long as the requirements (see Note) of B-1.3.2 or E-5.3 (including the case with the electric motor engaged) and

b) Wherever necessary, to ensure that braking rate (see Note below 5.2.7 (a)) remains related to the driver's braking demand, having regard to the available tyre/road adhesion, braking shall automatically be caused to act on all wheels of the vehicle.

NOTE – The authority, which is to grant approval, shall have the right to check the service braking system by additional vehicle test procedures.

5.2.8 The action of the service braking system shall be distributed between the wheels of one and the same axle symmetrically in relation to the longitudinal median plane of the vehicle. Compensation and functions, such as anti-lock, which may cause deviations from this symmetrical distribution, shall be declared.

5.2.8.1 Compensation by the electric control transmission for deterioration or defect within the braking system shall be indicated to the driver by means of the yellow warning signal specified in 5.2.21.1.2. This requirement shall apply for all conditions of loading when compensation exceeds the following limit:

a) A difference in transverse braking pressures on any axle,

1) Of 25 percent of the higher value for vehicle decelerations ≥ 2 m/s^2; and

2) A value corresponding to 25 percent at 2 m/s^2 for decelerations below this rate.

b) An individual compensating value on any axle:

1) > 50 percent of the nominal value for vehicle decelerations ≥ 2 m/s^2; and

2) a value corresponding to 50 percent of the nominal value at 2 m/s^2 for decelerations below this rate.

5.2.8.2 Compensation as defined above is permitted only when the initial brake application is made at vehicle speeds greater than 10 km/h.

5.2.9 Malfunctions of the electric control transmission shall not apply the brakes contrary to the driver's intentions.

5.2.10 The service, secondary and parking braking systems shall act on braking surfaces connected to the wheels through components of adequate strength.

Where braking torque for a particular axle or axles is provided by both a friction braking system and an electrical regenerative braking system of category B, disconnection of the latter source is permitted, providing that the friction braking source remains permanently connected and able to provide the compensation referred to in 5.2.7 (a).

However, in the case of short disconnection transients, incomplete compensation is accepted, but within 1s, this compensation shall have attained at least 75 percent of its final value.

Nevertheless, in all cases, the permanently connected friction braking source shall ensure that both the service and secondary braking systems continue to operate with the prescribed degree of effectiveness.

Disconnection of the braking surfaces of the parking braking system shall be permitted only on condition that the disconnection is controlled exclusively by the driver from his driving seat, by a system incapable of being brought into action by a leak.

5.2.11 Wear of the brakes shall be capable of being easily taken up by means of a system of manual or automatic adjustment. In addition, the control and the components of the transmission and of the brakes shall possess a reserve of travel and, if necessary, suitable means of compensation such that, when the brakes become heated, or the brake linings have reached a certain degree of wear, effective braking is ensured without immediate adjustment being necessary.

5.2.11.1 Wear adjustment shall be automatic for the service brakes. Automatic wear adjustment devices shall be such that after heating followed by cooling of the brakes, effective braking is still ensured. In particular, the vehicle shall remain capable of normal running after the tests conducted in accordance with B-1.5.

5.2.11.2 **Checking the wear of the service brake friction components**

5.2.11.2.1 It shall be possible to easily check this wear on service brake linings from the outside or underside of the vehicle without the removal of the wheels, by the provision of appropriate inspection holes or by some other means. This may be achieved by utilizing simple standard workshop tools or common inspection equipment for vehicles. Alternatively, a sensing device per wheel (twin wheels are considered as a single wheel), which will warn the driver at his driving position when lining replacement is necessary is acceptable. The yellow warning signal specified in 5.2.21.1.2 may be used Alternatively, a sensing device per wheel (twin wheels are considered as a single wheel), which will warn the driver at his driving position when lining replacement is necessary, is acceptable. The yellow warning signal specified in paragraph 5.2.21.1.2. below may be used.

5.2.11.2.2 Assessment of the wear condition of the friction surfaces of brake discs or drums may only be performed by direct measurement of the actual component or examination of any brake disc or drum wear indicators, which may necessitate some level of disassembly. Therefore, at the time of type approval, the vehicle manufacturer shall define the following:

(a) The method by which wear of the friction surfaces of drums and discs may be assessed, including the level of disassembly required and the tools and process required to achieve this.

(b) Information defining the maximum acceptable wear limit at the point at which replacement becomes necessary.

This information shall be made freely available, e.g. vehicle handbook or electronic data record.

5.2.12 In hydraulic-transmission braking systems, the filling ports of the fluid reservoirs shall be readily accessible; in addition, the receptacles containing the reserve fluid shall be so designed and constructed that the level of the reserve fluid can be easily checked without the receptacles having to be opened, and the minimum total reservoir capacity is equivalent to the fluid displacement resulting when all the wheel cylinders or caliper pistons serviced by the reservoirs move from a new lining, fully retracted position to a fully worn, fully applied position. If these latter conditions are not fulfilled, the red warning signal specified in 5.2.21.1.1 shall draw the driver's attention to any fall in the level of reserve fluid liable to cause a failure of the braking system.

5.2.13 The type of fluid to be used in hydraulic transmission braking systems shall be identified by the symbol in accordance with Figures 1 or 2 of ISO 9128:2006 and the symbol DOT3/DOT4/ DOT5, as appropriate. The symbols and the marking shall be affixed in a visible position in indelible form within 100 mm of the filling ports of the fluid reservoirs; additional information may be provided by the manufacturer.

5.2.14 **Warning Device**

5.2.14.1 Any vehicle fitted with a service brake actuated from an energy reservoir shall, where the prescribed secondary braking performance cannot be obtained by means of this brake without the use of the stored energy, be provided with a warning device, giving an optical or acoustic signal when the stored energy, in any part of the system, falls to a value at which without re-charging of the reservoir and irrespective of the load conditions of the vehicle, it is possible to apply the service brake control a fifth time after four full-stroke actuations and obtain the prescribed secondary braking performance (without faults in the service brake transmission device and with the brakes adjusted as closely as possible). This warning device shall be directly and permanently connected to the circuit. When the engine is running under normal operating conditions and there are no faults in the braking system, as is the case in type approval tests, the warning device shall give no signal except during the time required for charging the energy reservoir(s) after start-up of the engine. The red warning signal specified in 5.2.21.1.1 shall be used as the optical warning signal.

5.2.14.2 However, in the case of vehicles which are only considered to comply with the requirements of 5.2.4.1 by virtue of meeting the requirements of C-1.3, the warning device shall consist of an acoustic signal in addition to an optical signal. These devices need not operate simultaneously, provided that each of them meets the above requirements and the acoustic signal is not actuated before the optical signal. The red warning signal specified in 5.2.21.1.1 shall be used as the optical warning signal.

5.2.14.3 This acoustic device may be rendered inoperative while the parking brake is applied and/or, at the choice of the manufacturer, in the case of automatic transmission the selector is in the 'Park' position.

5.2.15 Without prejudice to the requirements of 5.1.2 (c), where an auxiliary source of energy is essential to the functioning of a braking system, the reserve of energy shall be such as to ensure that, if the engine stops or in the event of a failure of the means by which the energy source is driven, the braking performance remains adequate to bring the vehicle to a halt in the prescribed conditions. In addition, if the muscular effort applied by the driver to the parking braking system is reinforced by a servo device, the actuation of parking braking shall be ensured in the event of a failure of the servo device, if necessary by using a reserve of energy independent of that normally supplying the servo device. This reserve of energy may be that intended for the service braking system.

5.2.16 The pneumatic/hydraulic auxiliary equipment shall be supplied with energy in such a way that during its operation the prescribed deceleration values can be reached and that even in the event of damage to the source of energy the operation of the auxiliary equipment cannot cause the reserves of energy feeding the braking systems to fall below the level indicated in 5.2.14.

5.2.17 In the case of a motor vehicle equipped to tow a trailer with electric service brakes, the following requirements shall be met:

a) The power supply (generator and battery) of the motor vehicle shall have a sufficient capacity to provide the current for an electric braking system. With the engine running at the idling speed recommended by the manufacturer and all electrical devices supplied by the manufacturer as standard equipment of the vehicle switched on, the voltage in the electrical lines shall at maximum current consumption of the electrical braking system (15 A) not fall below the value of 9.6V measured at the connection. The electrical lines shall not be capable of short circuiting even when overloaded.

b) In the event of a failure in the motor vehicle's service braking system, where that system consists of at least two independent units, the unit or units not affected by the failure shall be capable of partially or fully actuating the brakes of the trailer.

c) The use of the stop-lamp switch and circuit for actuating the electrical braking system is permissible only if the actuating line is connected in parallel with the stop-lamp and the existing stop-lamp switch and circuit are capable of taking the extra load.

5.2.18 **Additional Requirements for Vehicles Equipped with Electric Regenerative Braking Systems**

5.2.18.1 Vehicles fitted with an electric regenerative braking system of category A.

5.2.18.1.1 The electric regenerative braking shall only be activated by the accelerator control and/or the gear neutral position.

5.2.18.2 Vehicles fitted with an electric regenerative braking system of category B

5.2.18.2.1 It shall not be possible to disconnect, partially or totally, one part of the service braking system other than by automatic means. This should not be construed as a departure from the requirements of 5.2.10.

5.2.18.2.2 The service braking system shall have only one control device.

5.2.18.2.3 The service braking system shall not be adversely affected by the disengagement of the motor(s) or by the gear ratio used.

5.2.18.2.4 If the operation of the electric component of braking is ensured by a relation established between information coming from the control of the service brake and the braking force to the wheels which of it results, a failure of this relation leading to the non-respect of the prescriptions of distribution of braking among the axles (see Annex D or E, which is applicable) shall be warned to the driver by an optical warning signal at the latest when the control is actuated and having to remain lit as long as this defect exists and that the switch of 'contact' is in the position 'go'.

5.2.18.3 For vehicles fitted with an electric regenerative braking system of either category, all the relevant prescriptions shall apply except 5.2.18.1.1. In this case, the electric regenerative braking may be actuated by the accelerator control and/or the gear neutral position. Additionally, the action on the service braking control shall not reduce the above braking effect generated by the release of the accelerator control;

5.2.18.4 The operation of the electric braking shall not be adversely affected by magnetic or electric fields.

5.2.18.5 For vehicles equipped with an anti-lock device, the anti-lock device shall control the electric braking system.

5.2.18.6 The state of charge of the traction batteries is determined by the method set out in B-4 (see also Note).

NOTE – By agreement with the Type Approval authority, state of charge assessment shall not be required for vehicles, which have an on-board energy source for charging the traction batteries and the means for regulating their state of charge.

5.2.19 Special Additional Requirements for the Electric Transmission of the Parking Braking System.

5.2.19.1 In the case of a failure within the electric transmission, any unintended actuation of the parking braking system shall be prevented.

5.2.19.2 In the case of an electrical failure in the control or a break in the wiring within the electric control transmission between the control and the ECU directly connected with it, excluding the energy supply, it shall remain possible to apply the parking braking system from the driver's seat and thereby be capable of holding the laden vehicle stationary on an 8 percent up or down gradient. Alternatively, in this case, an automatic actuation of the parking brake is allowed when the vehicle is stationary, provided that the above performance is achieved and, once applied, the parking brake remains engaged independently of the status of the ignition (start) switch. In this alternative, the parking brake shall be automatically released as soon as the driver starts to set the vehicle in motion again. The engine/manual transmission or the automatic transmission (park position) may be used to achieve or assist in achieving the above performance.

5.2.19.2.1 A break in the wiring within the electrical transmission, or an electrical failure in the control of the parking braking system shall be signaled to the driver by the yellow warning signal specified in 5.2.21.1.2. When caused by a break in the wiring within the electrical control transmission of the parking braking system, this yellow warning signal shall be signaled as soon as the break occurs. In addition, such an electrical failure in the control or break in the wiring external electronic control unit(s) and excluding energy supply shall be signaled to the driver by flashing the red warning signal specified in 5.2.21.1.1 as long as the ignition (start) switch is in the 'on' (run) position including a period of not less than 10 s thereafter and the control is in the 'on' (activated) position. However, if the parking braking system detects correct clamping of the parking brake, the flashing of the red warning signal may be suppressed and the non-flashing red signal shall be used to indicate "parking brake applied". Where actuation of the parking brake is normally indicated by a separate red warning signal satisfying all the requirements of 5.2.21.2, the signal shall be used to satisfy the above requirements for a red signal.

5.2.19.3 Auxiliary equipment may draw its energy from the energy reserve of the electric transmission of the parking braking system, provided that the actuation of the parking braking system will not be affected. In addition, where the energy reserve is also used by the service braking system, the requirements of 5.2.20.6 shall apply.

5.2.19.4 After the ignition/start switch which controls the electrical energy for the braking equipment has been switched off and/or the key removed, it shall remain possible to apply the parking braking system, whereas releasing shall be prevented.

5.2.20 Special Additional Requirements for Service Braking Systems with Electric Control Transmission:

5.2.20.1 With the parking brake released, the service braking system shall be able to fulfil the following requirements:

(a) With the propulsion system on/off control in the "On" ("Run") position, generate a static total braking force at least equivalent to that required by the Type-0 test for service braking performance as prescribed in B-2.1.,

(b) During the first 60 seconds after the propulsion system on/off control has been deactivated to the "Off" or "Lock" position and/or the ignition key has been removed, three brake applications shall generate a static total braking force at least equivalent to that required by the Type-0 test for service braking performance as prescribed in B-2.1., and

(c) After the period mentioned above, or as from the fourth brake application within the 60 second period, whichever occurs first, generate a static total braking force at least equivalent to that required by the Type-0 test for secondary braking performance as prescribed in paragraph B-2.2.

It should be understood that sufficient energy is available in the energy transmission of the service braking system.

5.2.20.2 In the case of a single temporary failure (< 40 ms) within the electric control transmission (for example non-transmitted signal or data error) there shall be no distinguishable effect on the service braking performance.

5.2.20.3 A failure within the electric transmission (*see* Note) not including its energy reservoir affects the function and performance of systems addressed in the standard shall be indicated to the driver by the red or yellow warning signal specified in 5.2.21.1.1 and 5.2.21.1.2 respectively, as appropriate. When the service braking performance can no longer be achieved (red warning signal), failures resulting from a loss of electrical continuity (for example breakage, disconnection) shall be signaled to the driver as soon as they occur, and the prescribed residual braking performance shall be fulfilled by operating the service braking control in accordance with B-2.2.

NOTE – Until uniform test procedures have been agreed, the manufacturer shall provide the Technical Service with an analysis of potential failures within the control transmission and their effects. This information shall be subject to discussion and agreement between the Technical Service and the vehicle manufacturer.

5.2.20.4 In the event of a failure of the energy source of the electric control transmission, starting from the nominal value of the energy level, the full control range of the service braking system shall be guaranteed after twenty consecutive full stroke actuations of the service braking control. During the test, the braking control shall be fully applied for 20 s and released for 5 s on each actuation. It should be understood that during the above test sufficient energy is available in the energy transmission to ensure full actuation of the service braking system. This requirement shall not be construed as a departure from the requirements of Annex C.

5.2.20.5 When the battery voltage falls below a value nominated by the manufacturer at which the prescribed service braking performance can no longer be guaranteed and/or which precludes at least two independent service braking circuits from each achieving the prescribed secondary or residual braking performance, the red warning signal specified in 5.2.21.1.1 shall be activated. After the warning signal has been activated, it shall be possible to apply the service braking control and obtain at least the residual performance prescribed in B-2.2. It should be understood that sufficient energy is available in the energy transmission of the service braking system.

5.2.20.6 If the auxiliary equipment is supplied with energy from the same reserve as the electric control transmission, it shall be ensured that ,with the engine running at a speed not greater than 80 percent of the maximum power speed, the supply of the energy shall be sufficient to fulfill the prescribed deceleration values by either provision of an energy supply which is able to prevent discharge of this reserve when all auxiliary equipment is functioning or by automatically switching off pre-selected parts of the auxiliary equipment at a voltage above critical level referred to in 5.2.20.5 such that further discharge of reserve is prevented. Compliance may be demonstrated by calculation or by a practical test. This paragraph does not apply to vehicles where the prescribed deceleration values can be reached without the use of electrical energy

5.2.20.7 If the auxiliary equipment is supplied with energy from the electric control transmission following requirements to be fulfilled:

a) In the event of a failure in the energy source, whilst the vehicle is in motion, the energy in the reservoir shall be sufficient to actuate the brakes when the control is applied;

b) In the event of a failure in the energy source, whilst the vehicle is stationary and the parking braking system applied, the energy in the reservoir shall be sufficient to actuate the lights even when the brakes are applied.

5.2.21 The general requirements for optical warning signals whose function is to indicate to the driver certain specified failures or defect within the braking equipment of the motor vehicle, are set out in the following sub-paragraph. Other than as described in 5.2.21.5 these signals be used exclusively prescribed by this standard.

5.2.21.1 Motor vehicles shall be capable of providing optical brake failure and defect warning signals, as follows:

5.2.21.1.1 A red warning signal, indicating a failure within the vehicle braking equipment which precludes achievement of the prescribed service braking performance and/or which precludes the functioning of at least one of two independent service braking circuits;

5.2.21.1.2 Where applicable, a yellow warning signal indicating an electrically detected defect within the vehicle braking equipment, which is not indicated by the red warning signal described in 5.2.21.1.1.

5.2.21.2 The warning signals shall be visible, even by daylight; the satisfactory condition of the signals shall be easily verifiable by the driver from the driver's seat; the failure of a component of the warning devices shall not entail any loss of the braking system's performance.

5.2.21.3 **Except where stated otherwise,**

a) A specified failure or defect shall be signaled to the driver by the above-mentioned warning signal(s) not later than on actuation of the service braking control;

b) The warning signal(s) shall remain displayed as long as the failure/defect persists and the ignition (start) switch is in the 'on' (run) position; and

c) The warning signal shall be constant (not flashing).

5.2.21.4 The warning signal(s) mentioned above shall light up when the electrical equipment of the vehicle (and the braking system) is energized. With the vehicle stationary, the braking system shall verify that none of the specified failures or defects are present before extinguishing the signals. Specified failures or defects which should activate the warning signals mentioned above, but which are not detected under static conditions, shall be stored upon detection and be displayed at start-up and at all times when the ignition (start) switch is in the 'on' (run) position, as long as the failure or defect persists.

5.2.21.5 Non-specified failures (or defects) or other information concerning to the brakes and/or running gear of the power-driven vehicle may be indicated by the yellow signal specified in 5.2.21.1.2, provided that all the following conditions are fulfilled:

a) The vehicle is stationary;

b) After the braking equipment is first energized and the signal has indicated that, following the procedures detailed in 5.2.21.4, no specified failures (no defects) vehicle identified; and

c) Non- specified faults or other information shall be indicated only by the flashing of the warning signal. However, the warning signal shall be extinguished by the time when the vehicle speed exceeds 10 km/h.

5.2.22 **Generation of a Braking Signal to Illuminate Stop Lamps**

5.2.22.1 Activation of the service braking system by the driver shall generate a signal that will be used to illuminate stop lamps.

5.2.22.2 Activation of the service braking system by 'automatically commanded braking' shall generate the signal mentioned above. However, when the retardation generated is less than 0.7 m/s^2 the signal may be suppressed (*see* Note).

NOTE – At the time of approval, compliance with this requirement shall be confirmed by the vehicle manufacturers

5.2.22.3 Activation of part of the service braking system by selective braking shall not generate the signal mentioned above (see Note).

NOTE – During a selective braking event, the function may change to automatically command braking.

5.2.22.4 Electric regenerative braking systems as defined in paragraph 3.17, which produce a retarding force upon release of the accelerator control, shall generate a signal mentioned above according to the following provisions:

Vehicle decelerations	Signal generation
≤ 0.7 m/s²	The signal shall not be generated
> 0.7 m/s² and ≤ 1.3 m/s²	The signal may be generated
> 1.3 m/s²	The signal shall be generated

In all cases the signal shall be de-activated at the latest when the deceleration has fallen below 0.7 m/s² (see Note).

Note: At the time of type approval, compliance with this requirement shall be confirmed by the vehicle manufacturer.

5.2.23 When a vehicle is equipped with the means to indicate emergency braking, activation and de-activation of the emergency braking signal shall only be generated by the application of the service braking system when the following conditions are fulfilled (See Note) :

Note: At the time of type approval, compliance with this requirement shall be confirmed by the vehicle manufacturer.

a) The signal shall not be activated when the vehicle deceleration is below 6 m/s² but it may be generated at any deceleration at or above this value, the actual value being defined by the vehicle manufacturer.

The signal shall be de-activated at the latest when the deceleration has fallen below 2.5 m/s^2.

The following conditions may also be used:

The signal may be generated from a prediction of the vehicle deceleration resulting from the braking demand respecting the activation and de-activation thresholds defined in paragraph 5.2.23.1;

or

b) The signal may be activated at a speed above 50 km/h when the antilock system is fully cycling (as defined in E-2.7).

The signal shall be deactivated when the antilock system is no longer fully cycling.

5.2.24. Power driven vehicles of category M1 and N1 equipped with temporary use spare wheels/tyres shall satisfy the relevant technical requirements of AIS-110.

6.0 TESTS AND TEST METHODS

6.1 Braking tests which the vehicles submitted for approval are required to undergo, and the braking performance required, are described in Annex B.

7.0 MODIFICATION OF VEHICLE TYPE OR BRAKING SYSTEM AND EXTENSION OF APPROVAL

7.1 Every modification of the vehicle type or of its braking system with regard to the characteristics in Annex A shall be notified to the testing agency which approved the vehicle type. That testing agency may then either,

a) Consider that the modifications made are unlikely to have an appreciable adverse effect and that in any case the vehicle still meets the requirements; or

b) Require a further report from the testing agency responsible for carrying out the tests.

ANNEX A
(*Clause* 7.1)
INFORMATION ON TECHNICAL SPECIFICATIONS TO BE SUBMITTED BY THE MANUFACTURER

<table>
<tr><th>Sl. No.</th><th>Technical Specification</th></tr>
<tr><td>1</td><td>Trade name or mark of the vehicle:</td></tr>
<tr><td>2</td><td>Vehicle type:</td></tr>
<tr><td>3</td><td>Manufacturer's name and address:</td></tr>
<tr><td>4</td><td>Mass of vehicle:</td></tr>
<tr><td>4.1</td><td>Maximum mass of vehicle:</td></tr>
<tr><td>4.2</td><td>Minimum mass of vehicle:</td></tr>
<tr><td>5</td><td>Distribution of mass of each axle (maximum value):</td></tr>
<tr><td>6</td><td>Make and type of brake linings:</td></tr>
<tr><td>6.1</td><td>Brake linings tested to all relevant prescriptions of Annex C.</td></tr>
<tr><td>7</td><td>Engine Type</td></tr>
<tr><td>8</td><td>Number and ratios of gears</td></tr>
<tr><td>9</td><td>Final drive ratio(s)</td></tr>
<tr><td>10</td><td>If applicable, maximum mass of trailer which may be coupled</td></tr>
<tr><td>10.1</td><td>Unbraked trailer</td></tr>
<tr><td>11</td><td>Tyre</td></tr>
<tr><td>11.1</td><td>Dimensions</td></tr>
<tr><td>11.2</td><td>Temporary-use spare wheel/tyre dimensions:</td></tr>
<tr><td>11.3</td><td>Vehicle meets the technical requirements of AIS-110: Yes/No</td></tr>
<tr><td>12</td><td>Maximum designed speed</td></tr>
<tr><td>13</td><td>Brief description of braking equipment:</td></tr>
<tr><td>14</td><td>Mass of vehicle when tested:
<table>
<tr><th></th><th>Laden (kg)</th><th>Unladen (kg)</th></tr>
<tr><td>Axle No.1</td><td></td><td></td></tr>
<tr><td>Axle No.2</td><td></td><td></td></tr>
<tr><td>TOTAL</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>15</td><td>Vehicle is / is not equipped to tow a trailer with electrical braking systems.</td></tr>
<tr><td>16</td><td>Vehicle is / is not equipped with an anti-lock system.</td></tr>
<tr><td>16.1.</td><td>The vehicle fulfils the requirement of Annex E: Yes / No</td></tr>
<tr><td>17</td><td>Adequate documentation according to annex G was supplied in respect of the following system(s): ..... Yes / No / Not applicable</td></tr>
<tr><td>18</td><td>Vehicle submitted for approval on:</td></tr>
</table>

19	**Tyre dimensions**
19.1	Temporary-use spare wheel/tyre dimensions:
19.2	Vehicle meets the technical requirements of AIS-110: Yes/No
20	**Brake Assist System**
20.1	Category of Brake Assist System A / B
20.1.1.	For category A systems, define the force threshold at which the ratio between pedal force and brake pressure increases
20.1.2.	For category B systems, define the brake pedal speed which must be achieved in order to activate the Brake Assist System (e.g. pedal stroke speed (mm/s) during a given time interval)
21	**Adequate documentation according to annex G (Complex electronics vehicle control systems) provided in respect of the following system(s): ..... Yes / No / Not applicable**
21.1	List of complex functions covered:
21.2	Manufacturer's documents contain information showing the interaction of complex braking functions with other vehicle systems and/or how the system directly controls output variables.
21.3	Manufacturer's documents explain the functionality and safety concept of the system and describe how the operational status may be checked.
21.4	A list of input and output variables, including their working range, is provided.
21.5	Documentation includes an inventory of components, outlines the function of each unit, its interconnection/interaction with other systems and defines signal flow priorities.
21.5	Each unit of the system is clearly identified in a manner which defines clearly the hardware and software version as appropriate.
21.6	Safety concept statement verifies that the system will not prejudice the safe operation of the braking system under non-fault conditions.
21.7	System architecture, design methods and tools identified.
21.8	Information regarding design provisions in case of failure is provided including any error messages, warning signals, partial performance conditions, back-up modes and/or removal of high-level functions.
21.9	Additional material and analysis (FMEA, FTA) of fault conditions made available for inspection and maintained by the manufacturer.
21.10	Document reference and date of inspection:
21.11	Vehicle complies with all other performance requirements of IS 15986 (2015) / AIS 151 and meets manufacturer's specifications under non-fault conditions.

21.12	Under fault conditions, vehicle response corresponds to that described in the manufacturer's documents / failure analysis and safety concept is verified.
21.13	(see annex 4 of this report for test data)
22	**Electronic Stability Control system as per AIS-133 (Yes/No/Optional)**
22.1	If yes or optional, details of ESC
22.2	ESC System Technical Documentation. To ensure a vehicle is equipped with an ESC system that meets the definition of "ESC System" in paragraph 2.0, the vehicle manufacturer shall make available to the test agency, upon request, the documentation specified below.
22.3	System diagram identifying all ESC system hardware.
22.4	A brief written explanation sufficient to describe the ESC system basic operational characteristics.
22.4.1	Logic diagram
22.4.2	Understeer information.
22.4.3	Static Stability Factor
22.4.4	Make and Country of manufacturer(if imported)
22.5	Software Id / version
22.6	Hardware Id
22.7	Brief description of failure warning tell–tale
22.8	Control function (Directional / Roll / Directional and Roll)
23	**Steering Angle Sensor**
23.1	Make and Country of manufacturer(if imported)
23.2	Identification No. / Part No.
23.3	Brief description and features
24	**Yaw Rate Sensor**
24.1	Make and Country of manufacturer(if imported)
24.2	Identification No. / Part No.
24.3	Brief description and features
25	**Additional Component details, if any**
25.1	**Component 1**
25.1.1	Make and Country of manufacturer(if imported)
25.1.2	Identification No. / Part No.

25.2	**Component 2**
25.2.1	Make and Country of manufacturer(if imported)
25.2.2	Identification No. / Part No.
25.3	**Component 3**
25.3.1	Make and Country of manufacturer(if imported)
25.3.2	Identification No. / Part No.

ANNEX B
BRAKING TESTS AND PERFORMANCE OF BRAKING SYSTEMS

(*Clauses* 5.2.4.2, 5.2.4.3, 5.2.7, 5.2.11.1, 5.2.18.6, 5.2.20.3, 5.2.20.5, 5.2.23, 6, D-3.1, E-5.2, F-1.3, F-2.1.1, F-3.1, F-3.2, F- 4.3.2, F- 4.4.1.1 and F- 4.4.2.1)

B-1 BRAKING TESTS

B-1.1 General

B-1.1.1 The performance prescribed for braking systems is based on the stopping distance and the mean fully developed deceleration. The performance of a braking system shall be determined by measuring the stopping distance in relation to the initial speed of the vehicle and/or by measuring the mean fully developed deceleration during the test.

B-1.1.2 The stopping distance shall be the distance covered by the vehicle from the moment when the driver begins to actuate the control of the braking system until the moment when the vehicle stops; the initial speed shall be the speed at the moment when the driver begins to actuate the control of the braking system; the initial speed shall not be less than 98 percent of the prescribed speed for the test in question.

The mean fully developed deceleration (d_m) shall be calculated as the deceleration averaged with respect to distance over the interval v_b to v_e , according to the following formula:

$$d_m = \frac{v^2_b - v^2_e}{25.92\ (s_e - s_b)}$$

where

v_o = initial vehicle speed, in km/h;

v_b = vehicle speed at 0.8 v_o, in km/h;

v_e = vehicle speed at 0.1 v_o, in km/h;

s_b = distance travelled between v_o and v_b, in m; and

s_e = distance travelled between v_o and v_e, in m.

The speed and distance shall be determined using instrumentation having an accuracy of ±1 percent at the prescribed speed for the test. The d_m may be determined by other methods than the measurement of speed and distance; in this case, the accuracy of the d_m shall be within ±3 percent.

B-1.2 For the approval of any vehicle, the braking performance shall be measured during road tests conducted in the following conditions:

B-1.2.1 The vehicle's condition as regards mass shall be as prescribed for each type of test and be specified in the test report;

B-1.2.2 The test shall be carried out at the speeds prescribed for each type of test; if the maximum design speed of a vehicle is lower than the speed prescribed for a test, the test shall be performed at the vehicle's maximum speed;

B-1.2.3 During the tests, the force applied to the brake control in order to obtain the prescribed performance shall not exceed the maximum force laid down;

B-1.2.4 The road shall have a surface affording good adhesion, unless specified otherwise in the relevant annexes;

B-1.2.5 The tests shall be performed when there is no wind liable to affect the results;

B-1.2.6 At the start of the tests, the tyres shall be cold and at the pressure prescribed for the load actually borne by the wheels when the vehicle is stationary;

B-1.2.7 The prescribed performance shall be obtained without locking of the wheels at speeds exceeding 15 km/h, without deviation of the vehicle from a 3.5 m wide lane, without exceeding a yaw angle of 15° and without abnormal vibrations.

B-1.2.8 For vehicles powered completely or partially by an electric motor (or motors), permanently connected to the wheels, all tests shall be carried out with these motor(s) connected.

B-1.2.9 For vehicles as described in B-1.2.8, fitted with an electric regenerative braking system of category A, behavior tests defined in B-1.4.3.1 shall be carried out on a track with a low adhesion coefficient (as defined in E-5.2.2) at a speed equal to 80 per cent of the maximum speed but not exceeding 120 km/h, to check that stability is retained;

B-1.2.9.1 Moreover, for vehicles fitted with an electric regenerative braking system of category A, transient conditions as gear changes or accelerator control release shall not affect the behavior of the vehicle in condition described in B-1.2.9;

B-1.2.10 In the tests provided in B-1.2.9 and B-1.2.9.1-wheel locking is not allowed. However, steering correction is permitted if the angular rotation of the steering control is within 120° during the initial 2 s and not more than 240° in all.

B-1.2.11 For a vehicle with electrically actuated service brakes powered from traction batteries (or an auxiliary battery) which receive(s) energy only from an independent external charging system, these batteries shall, during braking performance testing, be at an average of not more than 5 percent above that state of charge at which the brake failure warning prescribed in 5.2.20.5 is required to be given.

If this warning is given, the batteries may receive some recharge during the tests, to keep them in the required state of charge range.

B-1.3 **Behaviour of the Vehicle During Braking**

B-1.3.1 In braking tests, and in particular in those at high speed, the general behaviour of the vehicle during braking shall be checked.

B-1.3.2 Behaviour of the vehicle during braking on a road on which adhesion is reduced shall meet the relevant requirements of Annex D and/or Annex E**.**

B-1.3.2.1 In the case of a braking system according to **5.2.7** where the braking for a particular axle (or axles) is comprised of more than one source of braking torque, and any individual source can be varied with respect to the other(s), the vehicle shall satisfy the requirements of Annex D, or alternatively, Annex E under all relationships permitted by its control strategy (see Note).

NOTE – The manufacturer shall provide the testing agency with the family of braking curves permitted by the automatic control strategy. These curves may be verified by the testing agency.

B-1.4 **Type 0 Test (Ordinary Performance Test with Cold Brakes)**

B-1.4.1 **General**

B-1.4.1.1 The average temperature of the service brakes on the hottest axle of the vehicle measured inside the brake linings or on the braking path of the disc or drum is between 65°C and 100°C prior to any brake application.

B-1.4.1.2 The test shall be conducted in the following conditions:

B-1.4.1.2.1 The vehicle shall be laden, the distribution of its mass among the axles being that stated by the manufacturer; where provision is made for several arrangements of the load on the axles the distribution of the maximum mass among the axles shall be such that the mass on each axle is proportional to the maximum permissible mass for each axle;

B-1.4.1.2.2 Every test shall be repeated on the unladen vehicle; there may be, in addition to the driver, a second person on the front seat who is responsible for noting the results of the test;

B-1.4.1.2.3 In the case of a vehicle equipped with an electric regenerative braking system, the requirements depend on the category of this system:

a) ***Category A*** - Any separate electric regenerative braking control which is provided, shall not be used during the Type 0 tests.

b) ***Category B*** - The contribution of the electric regenerative braking system to the braking force generated shall not exceed that minimum level guaranteed by the system design.

This condition is deemed to be satisfied, if the state of charge of the batteries is in one of the following conditions:

a) At the maximum charge level recommended by the manufacturer, as listed in the vehicle specification;

b) At a level not less than 95 percent of the full charge level, where the manufacturer has made no specific recommendation; and

c) At a maximum level resulting from automatic charge control on the vehicle ; or

d) When the tests are conducted without a regenerative braking component regardless of the state of charge of the batteries.

B-1.4.1.2.4 The limits prescribed for minimum performance, both for tests with the vehicle unladen and for tests with the vehicle laden, shall be those laid down hereunder; the vehicle shall satisfy both the prescribed stopping distance and the prescribed mean fully developed deceleration, but it may not be necessary to actually measure both parameters;

B-1.4.1.2.5 The road shall be level; unless otherwise specified each test may comprise up to six stops including any needed for familiarization.

B-1.4.2 Type 0 test with engine disconnected, service braking in accordance with B-2.1.1(A).

The test shall be carried out at the speed prescribed, the figures prescribed in this connection being subject to a certain margin of tolerance. The minimum performance prescribed shall be attained.

B-1.4.3 Type 0 test with engine connected, service braking in accordance with B-2.1.1(B).

B-1.4.3.1 The test shall be carried out with the engine connected, from the speed prescribed in B-2.1.1(B). The minimum performance prescribed shall be attained. This test is not run if the maximum speed of the vehicle is ≤ 125 km/h.

B-1.4.3.2 The maximum practical performance figures shall be measured, and the behavior of the vehicle shall be in accordance with B-1.3.2. However, if the maximum speed of the vehicle is greater than 200 km/h, the test speed shall be 120 km/h.

B-1.5 **Type I Test (Fade and Recovery Test)**

B-1.5.1 **Heating Procedure**

B-1.5.1.1 The service brakes of all vehicles shall be tested by successively applying and releasing the brakes a number of times, the vehicle being laden, in the conditions shown in the table below:

Conditions			
V_1 km/h	V_2 km/h	t s	n
80 percent V_{max} ≤120	½ V_1	45	15

V_1 = initial speed, at beginning of braking

V_2 = speed at end of braking

V_{max} = maximum speed of the vehicle

n = number of brake applications

Δt = duration of a braking cycle: time elapsing between the initiation of one brake application and the initiation of the next.

B-1.5.1.2 If the characteristics of the vehicle make it impossible to abide by the duration prescribed for Δt, the duration may be increased; in any event, in addition to the time necessary for braking and accelerating the vehicle, a period of 10 s shall be allowed in each cycle for stabilizing the speed V_1.

B-1.5.1.3 In these tests, the force applied to the control shall be so adjusted as to attain a mean deceleration of 3 m/s^2 during every brake application; two preliminary tests may be carried out to determine the appropriate control force.

B-1.5.1.4 During brake applications, the highest gear ratio (excluding overdrive, etc) shall be continuously engaged.

B-1.5.1.5 For regaining speed after braking, the gearbox shall be used in such a way as to attain the speed V_1 in the shortest possible time (maximum acceleration allowed by the engine and gearbox).

B-1.5.1.6 For vehicles not having sufficient autonomy to carry out the cycles of heating of the brakes, the tests shall be carried out by achieving the prescribed speed before the first braking application and thereafter by using the maximum acceleration available to regain speed and then braking successively at the speed reached at the end of each 45 s cycle duration.

B-1.5.1.7 For vehicles equipped with an electric regenerative braking system of category B, the condition of the vehicle batteries at the start of the test, shall be such that the braking force contribution provided by the electric regenerative braking system does not exceed the minimum guaranteed by the system design. This requirement is deemed to be satisfied if the batteries are at one of the state of charge conditions as listed in B-1.4.1.2.3.

B-1.5.2 **Hot Performance**

B-1.5.2.1 At the end of the Type I test (see B-1.5.1) the hot performance of the service braking system shall be measured in the same conditions (and in particular at a mean control force no greater than the mean force actually used) as for the Type 0 test with the engine disconnected (the temperature conditions may be different).

B-1.5.2.2 This hot performance shall not be less than 75 percent of that prescribed (see Note), nor less than 60 percent of the figure recorded in the Type 0 test with the engine disconnected.

NOTE – This corresponds to a stopping distance of $0.1\ v + 0.008\ 0\ v^2$ and a mean fully developed deceleration of $4.82\ m/s^2$.

B-1.5.2.3 For vehicles fitted with an electric regenerative braking system of category A, during brake applications, the highest gear shall be continuously engaged and the separate electric braking control, if any, not used.

B-1.5.2.4 In the case of vehicles equipped with an electric regenerative braking system of category B, having carried out the heating cycles according to B-1.5.1.6, the hot performance test shall be carried out at the maximum speed which can be reached by the vehicle at the end of the brake heating cycles, unless the speed specified in B-2.1.1 (A) can be reached.

For comparison, a later Type 0 test with cold brakes shall be repeated from this same speed and with a similar electric regenerative braking contribution, as set by an appropriate state of battery charge, as was available during the hot performance test.

Following the recovery process and test, further reconditioning of the linings shall be permitted before the test is made to compare this second cold performance with that achieved in the hot test, against the criteria of B-1.5.2.2 or B-1.5.2.5.

The tests may be conducted without a regenerative braking component. In this case, the requirement on the state of charge of the batteries is not applicable.

B-1.5.2.5 In the case of a vehicle which satisfies the 60 percent requirement specified in B-1.5.2.2, but which cannot comply with the 75 percent requirement of B-1.5.2.2 (see Note), a further hot performance test may be carried out using a control force not exceeding that specified in B-2. The results of both tests shall be entered in the report.

NOTE – This corresponds to a stopping distance of $0.1\ v + 0.0080\ v^2$ and a mean fully developed deceleration of $4.82\ m/s^2$.

B-1.5.3 **Recovery Procedure**

Immediately after the hot performance test, make four stops from 50 km/h with the engine connected, at a mean deceleration of 3 m/s^2. Allow an interval of 1.5 km between the start of successive stops. Immediately after each stop, accelerate at maximum rate to 50 km/h and maintain that speed until making the next stop.

B-1.5.3.1 Vehicles equipped with an electrical regenerative braking system of category B may have their batteries re-charged or replaced by a charged set, in order to complete the recovery procedure.

The procedures may be conducted without a regenerative braking component.

B-1.5.4 **Recovery Performance**

At the end of the recovery procedure, the recovery performance of the service braking system shall be measured in the same conditions as for the Type 0 test with the engine disconnected (the temperature conditions may be different), using a mean force on the control, which is not more than the mean control force used in the corresponding Type 0 test.

This recovery performance shall not be less than 70 percent, nor more than 150 percent, of the figure recorded in the Type 0 test with the engine disconnected.

B-1.5.4.1 For vehicles equipped with an electrical regenerative braking system of category B, the recovery test shall be made with no regenerative braking component, i.e. under the conditions of B-1.5.4.

After the further reconditioning of the linings, a second repeat Type 0 test shall be made from the same speed and with no electric regenerative braking contribution as in the recovery test with the engine/motors disconnected, and comparison shall be made between these test results.

The recovery performance shall not be less than 70 percent, nor more than 150 percent of the figure recorded in this final repeat Type 0 test.

B-2 PERFORMANCE OF BRAKING SYSTEMS

B-2.1 Service Braking System

B-2.1.1 The service brakes shall be tested under the conditions shown in the following table:

Parameters (1)	Condition (A) Type 0 test with engine disconnected (2)	Condition (B) Type 0 test with engine connected (3)
v	100	80 percent v_{max} or ≤ 120
$s \leq$	$0.1v + 0.0060\ v^2$	$0.1v + 0.0067\ v^2$
$d_m \geq$	6.43	5.76
f	6.5 - 50	6.5 – 50

where

v = test speed, in km/h;

s = stopping distance, in m;

d_m = mean fully developed deceleration, in m/s^2;

f = force applied to foot control, in daN; and

v_{max} = maximum speed of the vehicle, in km/h.

B-2.1.2 In the case of a motor vehicle authorized to tow an unbraked trailer, the minimum Type-0 performance of the combination shall not be less than 5.4 m/s^2 in both the laden and unladen conditions.

The combination performance shall be verified by calculations referring to the maximum braking performance actually achieved by the motor vehicle alone (laden) during the Type 0 test with the engine disconnected, using the following formula (no practical tests with a coupled unbraked trailer are required):

$$d_{M+R} = d_M * \frac{P_M}{P_M + P_R}.$$

where

d_{M+R} = calculated mean fully developed deceleration of the motor vehicle when coupled to an unbraked trailer, in m/s^2

d_M = maximum mean fully developed deceleration of the motor vehicle alone achieved during the Type-0 test with engine disconnected, in m/s^2;

P_M = mass of the motor vehicle (laden); and

P_R = maximum mass of an unbraked trailer which may be coupled, as declared by the motor vehicle manufacturer.

B-2.2 **Secondary Braking System**

B-2.2.1 The performance of the secondary braking system shall be tested by the Type 0 test with the engine disconnected from an initial vehicle speed of 100 km/h and a force applied to the service brake control not less than 6.5 daN and not exceeding 50 daN.

B-2.2.2 The secondary braking system shall give a stopping distance not exceeding the following value:

$$0.1\ v + 0.0158\ v^2 \text{ (m)}$$

and a mean fully developed deceleration not less than 2.44 m/s^2 (corresponding to the second term of the above formula).

B-2.2.3 The secondary braking effectiveness test shall be conducted by simulating the actual failure conditions in the service braking system.

B-2.2.4 For vehicles employing electric regenerative braking systems, the braking performance shall additionally be checked under the two following failure conditions:

a) For a total failure of the electric component of the service braking output; and

b) In the case where the failure condition causes the electric component to deliver its maximum braking force.

B-2.3 **Parking Braking System**

B-2.3.1 The parking braking system shall be capable of holding the laden vehicle stationary on a 20 percent up or down gradient.

B-2.3.2 On vehicles to which the coupling of a trailer is authorized, the parking braking system of the motor vehicle shall be capable of holding the combination of vehicles stationary on a 12 percent up or down gradient.

B-2.3.3 If the control device is hand control, the force applied to it shall not exceed 40 daN.

B-2.3.4 If it is a foot control device, the force exerted on the control shall not exceed 50 daN.

B-2.3.5 A parking braking system which has to be actuated several times before it attains the prescribed performance is admissible.

B-2.3.6 To check compliance with the requirement specified in 5.2.2 (d), a Type 0 test shall be carried out, with the engine disconnected, at an initial test speed of 30 km/h. The mean fully developed deceleration on application of the control of the parking brake system and the deceleration immediately before the vehicle stops, shall not be less than 1.5 m/s^2. The test shall be carried out with the laden vehicle. The force exerted on the braking control device shall not exceed the specified values.

B-3 RESPONSE TIME

B-3.1 Where a vehicle is equipped with a service braking system which is totally or partially dependent on a source of energy other than the muscular effort of the driver, the following requirements shall be satisfied:

a) In an emergency manoeuvre, the time elapsing between the moment when the control device begins to be actuated and the moment when the braking force on the least favourable placed axle reaches the level corresponding to the prescribed performance shall not exceed 0.6 s; and

b) In the case of vehicles fitted with hydraulic braking systems, the requirements of B-3.1 (a) are considered to be satisfied if, in an emergency manoeuvre, the deceleration of the vehicle or the pressure at the least favorable brake cylinder, reaches a level corresponding to the prescribed performance within 0.6 s.

B-4 PROCEDURE FOR MONITORING THE STATE OF BATTERY CHARGE

This procedure is applicable to vehicle batteries used for traction and regenerative braking. The procedure requires the use of a bi-directional dc watt-hour meter or a bi-directional DC Ampere-hour meter.

B-4.1 **Procedure**

If the batteries are new or have been subject to extended storage, they shall be cycled as recommended by the manufacturer. A minimum 8 h soak period at ambient temperature shall be allowed after completion of cycling.

B-4.2 A full charge shall be established using the manufacturer's recommended charging procedure.

B-4.3 When the braking tests of B-1.2.11, B-1.4.1.2.3, B-1.5.1.6, B-1.5.1.7 and B-1.5.2.4 are conducted the watt-hours consumed by the traction motors and supplied by the regenerative braking system shall be recorded as a running total which shall then be used to determine the state of charge existing at the beginning or end of a particular test.

B-4.4 To replicate a level of state of charge in the batteries for comparative tests, such as those of B-1.5.2.4, the batteries shall be either recharged to that level or charged to above that level and discharged into a fixed load at approximately constant power until the required state of charge is reached. Alternatively, for vehicles with battery powered electric traction only, the state of charge may be adjusted by running the vehicle. Tests conducted with a battery partially charged at their start shall be commenced as soon as possible after the desired state of charge has been reached.

ANNEX C

PROVISIONS RELATING TO ENERGY SOURCES AND ENERGY STORAGE DEVICES (ENERGY ACCUMULATORS),

(*Clauses* 5.2.14.2, 5.2.20.4 *and* E-7.1.1.8)

C-1 CAPACITY OF ENERGY STORAGE DEVICES (ENERGY ACCUMULATORS)

C-1.1 **General**

C-1.1.1 Vehicles on which the braking equipment requires the use of stored energy provided by hydraulic fluid under pressure shall be equipped with energy storage devices (energy accumulators) of a capacity meeting the requirements of C-1.2 or C-1.3.

C-1.1.2 However, the energy storage devices shall not be required to be of a prescribed capacity, if the braking system is such that in the absence of any energy reserve it is possible with the service brake control to achieve a braking performance at least equal to that prescribed for the secondary braking system.

C-1.1.3 In verifying compliance with the requirements of C-1.2, C-1.3 and C-2.1, the brakes shall be adjusted as closely as possible and, for C-1.2, the rate of full-stroke actuations shall be such as to provide an interval of at least 60 s between each actuation.

C-1.2 Vehicles equipped with a hydraulic braking system with stored energy shall meet the following requirements:

a) After eight full-stroke actuations of the service brake control, it shall still be possible to achieve, on the ninth application, the performance prescribed for the secondary braking system; and

b) Testing shall be performed in conformity with the following requirements:

1) Testing shall commence at a pressure that may be specified by the manufacturer but is not higher than the cut-in pressure (*see* Note); and

NOTE – The initial energy level shall be stated in the test report.

2) The energy storage device(s) shall not be fed; in addition, any energy storage device(s) for auxiliary equipment shall be isolated.

C-1.3 Vehicles equipped with a hydraulic braking system with stored energy which cannot meet the requirements of 5.2.4.1 shall be deemed to satisfy that paragraph, if the following requirements are met:

a) After any single transmission failure, it shall still be possible after eight full-stroke actuations of the service brake control, to achieve, at the ninth application, at least the performance prescribed for the secondary braking system; and

b) Testing shall be performed in conformity with the following requirements:

1) With the energy source stationary or operating at a speed corresponding to the engine idling speed, any transmission failure may be induced. Before inducing such a failure, the energy storage device(s) shall be at a pressure that may be specified by the manufacturer but not exceeding the cut-in pressure; and

2) The auxiliary equipment and its energy storage devices, if any, shall be isolated.

C-2 CAPACITY OF HYDRAULIC FLUID ENERGY SOURCES

C-2.1 The energy sources shall meet the requirements set out in the following paragraphs.

C-.1.1 **Definitions**

C-2.1.1.1 **'**p_1' represents the maximum system operational pressure (cut-out pressure) in the energy storage device(s) specified by the manufacturer.

C-2.1.1.2 'p_2' represents the pressure after four full-stroke actuations with the service brake control, starting at p_1, without having fed the energy storage device(s).

C-2.1.1.3 't' represents the time required for the pressure to rise from p_2 to p_1 in the energy storage device(s) without application of the brake control.

C-2.1.2 **Conditions of Measurement**

C-2.1.2.1 During the tests to determine the time t, the feed rate of the energy source shall be that obtained when the engine is running at the speed corresponding to its maximum power or at the speed allowed by the over-speed governor.

C-2.1.2.2 During the test to determine the time t, energy storage device(s) for auxiliary equipment shall not be isolated other than automatically.

C-2.1.3 **Interpretation of Results** – In the case of all vehicles, the time t shall not exceed 20 s.

C-3 CHARACTERISTICS OF WARNING DEVICES

With the engine stationary and commencing at a pressure that may be specified by the manufacturer but does not exceed the cut-in pressure, the warning device shall not operate following two full-stroke actuations of the service brake control.

ANNEX D
DISTRIBUTION OF BRAKING AMONG THE AXLES OF VEHICLES
(*Clause* 5.2.18.2, B-1.3.2, E-1.2, E-3.1.3 *and* E-7.1.1.5)

D-1 GENERAL

Vehicles which are not equipped with an anti-lock system as defined in Annex E shall meet all the requirements of this annex. If a special device is used, this shall operate automatically.

D-2 SYMBOLS

i = axle index (i = 1, front axle; i = 2, rear axle);

Pi = normal reaction of road surface on axle i under static conditions;

Ni = normal reaction of road surface on axle i under braking;

Ti = force exerted by the brakes on axle i under normal braking conditions on the road;

fi = Ti/Ni , adhesion utilised by axle i (*see* Note);

J = deceleration of the vehicle;

g = acceleration due to gravity: g = 9.81 m/s^2;

z = braking rate of vehicle = J/g;

P = mass of vehicle;

h = height of centre of gravity specified by the manufacturer and agreed by the Testing agency conducting the approval test;

E = wheel base; and

k = theoretical coefficient of adhesion between tyre and road.

NOTE – Adhesion utilization curves of a vehicle means curves showing, for specified load conditions, the adhesion utilized by each axle i plotted against the braking rate of the vehicle

D-3 REQUIREMENTS

D-3.1 For all states of load of the vehicle, the adhesion utilization curve of the rear axle shall not be situated above that for the front axle for all braking rates between 0.15 and 0.8 (*see* Note); and

For k values between 0.2 and 0.8:

$z \geq 0.1 + 0.7\ (k - 0.2)$ (*see* Fig. 1)

NOTE – The provisions of D-3.1 do not affect the requirements of Annex B relating to the braking performance. However, if, in tests made under the provisions of D-3.1, braking performances are obtained which are higher than those prescribed in Annex B, the provisions relating to the adhesion utilization curves shall be applied within the areas of Fig. 1 defined by the straight lines k = 0.8 and z = 0.8.

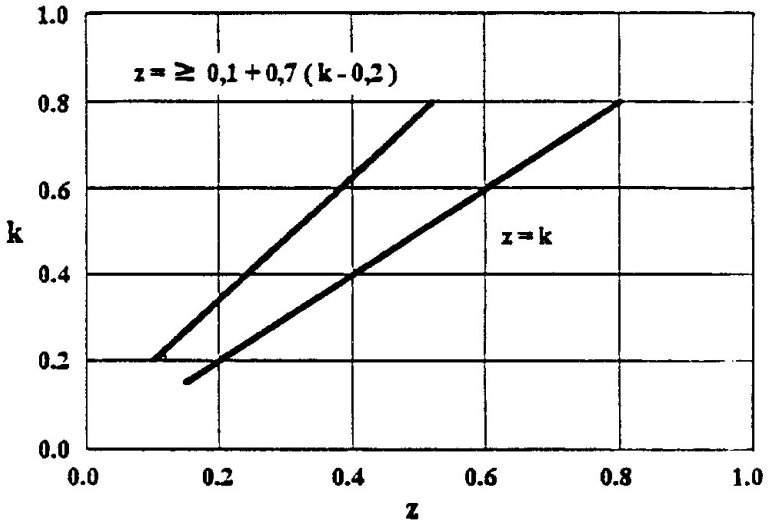

FIG. 1
ADHESION UTILIZATION CURVES

D-3.2 In order to verify the requirements of D-3.1, the manufacturer shall provide the adhesion utilization curves for the front and rear axles calculated by the formulae:

$$f_1 = T_1 \div N_1 = T_1 \div [P_1 + z.(h/E).P.g]$$

$$f_2 = T_2 \div N_2 = T_2 \div [P_2 - z.(h/E).P.g]$$

The curves shall be plotted for both the following load conditions:

a) Unladen, in running order with the driver on board;

b) Laden; where provision is made for several possibilities of load distribution, the one whereby the front axle is the most heavily laden shall be the one considered; and

c) For vehicles fitted with an electric regenerative braking system of category B, where the electric regenerative braking capacity is influenced by the electric state of charge, the curves shall be plotted by taking account of the electric braking component under the minimal and maximum conditions of delivered braking force. This requirement is not applicable if the vehicle is equipped with an anti-lock device which controls the wheels connected to the electric braking then the requirements of Annex E shall apply.

D-4 REQUIREMENTS TO BE MET IN CASE OF FAILURE OF THE BRAKING DISTRIBUTION SYSTEM

When the requirements of this annex are fulfilled by means of a special device (for example controlled mechanically by the suspension of the vehicle), it shall be possible, in the event of the failure of its control, (for example by disconnecting the control linkage), to stop the vehicle under the conditions of the Type 0 test with the engine disconnected to give a stopping distance not exceeding $0.1\ v + 0.010\ 0\ v^2$ (m) and a mean fully developed deceleration not less than 3.86 m/s^2.

D-5 VEHICLE TESTING

During the type-approval testing of a vehicle, the technical inspection authority shall verify conformity with the requirements contained in the present annex, by carrying out the following tests:

D-5.1 **Wheel - Lock Sequence Test** (*see* **D** 6)

If the wheel-lock sequence test confirms that the front wheels lock before or simultaneously with the rear wheels, conformity with D-3 has been verified and testing is complete.

D-5.2 **Additional Tests**

If the wheel-lock sequence test indicates that the rear wheels lock before the front wheels, then the vehicle:

a) shall be subjected to additional testing, as follows:

1) Additional wheel-lock sequence tests; and/or

2) Torque wheel tests (*see* D 7) to determine brake factors to generate adhesion utilization curves; these curves shall satisfy the requirements in D-3.1.

b) may be refused type-approval.

D-5.3 The results of the practical tests shall be appended to the type-approval report.

D-6 WHEEL-LOCK SEQUENCE TEST PROCEDURE

D-6.1 **General Information**

a) The purpose of this test is to ensure that lockup of both front wheels occurs at a lower deceleration rate than the lockup of both rear wheels when tested on road surfaces on which wheel lockup occurs at braking rates between 0.15 and 0.8.

b) A simultaneous lockup of the front and rear wheels refers to the condition when the time interval between the lockup of the last (second) wheel on the rear axle and the last (second) wheel on the front axle is < 0.1 s for vehicle speeds > 30 km/h.

D-6.2 **Vehicle Conditions**

a) Vehicle load – Laden and unladen; and

b) Transmission position – Engine disconnected.

D-6.3 **Test Conditions and Procedures**

a) Initial brake temperature – Between 65°C and 100°C average on the hottest axle.

b) Test speed:

1) 65 km/h for a braking rate ≤ 0.50; and

2) 100 km/h for a braking rate > 0.50.

c) Pedal force:

1) Pedal force is applied and controlled by a skilled driver or by a mechanical brake pedal actuator.

2) Pedal force is increased at a linear rate such that the first axle lockup occurs not less than 0.5 s and not more than 1.5 s after the initial application of the pedal.

3) The pedal is released when the second axle locks, or when the pedal force reaches 1 kN, or 0.1 s after the first lockup, whichever occurs first.

d) Wheel lockup – Only wheel lockups above a vehicle speed of 15 km/h are considered.

e) *Test surface* – This test is conducted on road test surfaces on which wheel lockup occurs at braking rates between 0.15 and 0.8

f) Data to be recorded – The following information shall be automatically recorded in phase continuously throughout each test run such that values of the variables can be cross referenced in real time:

1) Vehicle speed;

2) Instantaneous vehicle braking rate (for example, by differentiation of vehicle speed);

3) Brake pedal force (or hydraulic line pressure); and

4) Angular velocity at each wheel.

g) Each test run shall be repeated once to confirm the wheel lockup sequence: if one of these two results indicates a failure to comply, then a third test run under the same conditions will be decisive.

D-6.4 **Performance Requirements**

a) Both rear wheels shall not reach a locked condition prior to both front wheels being locked at vehicle braking rates between 0.15 and 0.8.

b) If, when tested to the procedure specified above, and at vehicle braking rates between 0.15 and 0.8 the vehicle meets one of the following criteria, then it passes this wheel lockup sequence requirement:

1) No wheels lock;
2) Both wheels on the front axle and one or no wheels on the rear axle lock; and
3) Both axles simultaneously lock.

c) If wheel lockup commences at a braking rate less than 0.15 and more than 0.8 then the test is invalid and should be repeated on a different road surface.

d) If, either laden or unladen, at a braking rate between 0.15 and 0.8 both wheels on the rear axle and one or no wheels on the front axle lock, then it fails the wheel lockup sequence test. In this latter case, the vehicle shall be submitted to the 'torque wheels' test procedure to determine the objective brake factors for calculation of the adhesion utilization curves.

D-7 TORQUE WHEEL TEST PROCEDURE

D-7.1 **General Information**

The purpose of this test is to measure the brake factors and thus determine the adhesion utilization of the front and rear axles over a range of braking rates between 0.15 and 0 .8.

D-7.2 **Vehicle Conditions**

a) Vehicle load – Laden and unladen; and

b) Transmission position – Engine disconnected.

D-7.3 **Test Conditions and Procedures**

a) Initial brake temperature – Between 65°C and 100°C average on the hottest axle.

b) Test speeds – 100 km/h and 50 km/h.

c) Pedal force – Pedal force is increased at a linear rate between 100 and 150 N/s for the 100 km/h test speed, or between 100 and 200 N/s for the 50 km/h test speed, until the first axle locks or until a pedal force of 1 kN is reached, whichever occurs first.

d) **Brake cooling** – Between brake applications, the vehicle is driven at speeds up to 100 km/h until the initial brake temperature specified in D-7.3 (a) is reached.

e) **Number of runs** – With the vehicle unladen, run five stops from a speed of 100 km/h and five stops from a speed of 50 km/h, while alternating between the two test speeds after each stop. With the vehicle laden, repeat the five stops at each test speed while alternating between the two test speeds.

f) **Test surface** – This test is conducted on a road test surface affording good adhesion.

g) **Data to be recorded** – The following information shall be automatically recorded in phase continuously throughout each test run such that values of the variables can be cross referenced in real time:

1) Vehicle speed;

2) Brake pedal force;

3) Angular velocity of each wheel;

4) Brake torque at each wheel;

5) Hydraulic line pressure in each brake circuit, including transducers on at least one front wheel and one rear wheel downstream of any operative proportioning or pressure limiting valve(s); and

6) Vehicle deceleration.

(h) ***Sample rate*** – All data acquisition and recording equipment shall support a minimum sample rate of 40 Hz on all channels.

(i) ***Determination of front versus rear brake pressure*** – Determine the front versus rear brake pressure relationship over the entire range of line pressures. Unless the vehicle has a variable brake proportioning system, this determination is made by static tests. If the vehicle has a variable brake proportioning system, dynamic tests are run with the vehicle both laden and unladen. Fifteen snubs from 50 km/h are made for each of the two load conditions, using the same initial conditions specified in D-7.

D-7.4 **Data Reduction**

a) The data from each brake application prescribed in D-7.3 (e) above is filtered using a five-point, on-centre moving average for each data channel.

b) For each brake application prescribed in D-7.3(e), determine the slope (brake factor) and pressure axis intercept (brake hold-off pressure) of the linear least squares equation best describing the measured torque output at each braked wheel as a function of measured line pressure applied at the same wheel. Only torque output values obtained from data collected when the vehicle deceleration is within the range of 0.15 g to 0.80 g are used in the regression analysis.

c) Average the results of D-7.4 (b) to calculate the average brake factor and brake hold-off pressure for all brake applications for the front axle.

d) Average the results of D-7.4 (b) to calculate the average brake factor and brake hold-off pressure for all brake applications for the rear axle.

e) Using the relationship between front and rear brake line pressure determined in D-7.3 (j) and the dynamic tyre rolling radius, calculate the braking force at each axle as a function of front brake line pressure.

f) Calculate the braking rate of the vehicle as a function of the front brake line pressure using the following equation:

$$z = [(T_1 + T_2) \div (P. g)]$$

Where

z = braking rate at a given front brake line pressure;

T_1 , T_2 = braking forces at the front and rear axles respectively, corresponding to the same front brake line pressure; and

P = vehicle mass.

g) Calculate the adhesion utilized at each axle as a function of braking rate using the following formulae:

$$f_1 = T_1 \div [P_1 + z.(h/E). P. g]$$

$$f_2 = T_2 \div [P_2 - z.(h/E). P. g]$$

NOTE – The symbols are defined in D-2.

j) Plot f_1 and f_2 as a function of z, for both laden and unladen load conditions. These are the adhesion utilization curves for the vehicle, which shall satisfy the requirements in D-5.2 (a) (2).

ANNEX E
TEST REQUIREMENTS FOR VEHICLES FITTED WITH ANTI-LOCK SYSTEMS

(*Clause* 5.2.7, 5.2.18.2, 5.2.23, B-1.2.9, B-1.3.2, D-1 *and* D-3)

E-1 GENERAL

E-1.1 This annex defines the required braking performance for road vehicles fitted with anti-lock systems.

E-1.2 The anti-lock systems known at present comprise a sensor or sensors, a controller or controllers and a modulator or modulators. Any device of a different design which may be introduced in the future, or where an anti-lock braking function is integrated into another system, shall be deemed to be an anti-lock braking system within the meaning of this annex and Annex D, if it provides performance equal to that prescribed by this annex.

E-2 DEFINITIONS

E-2.1 **Anti-Lock System –** It is a part of a service braking system which automatically controls the degree of slip, in the direction of rotation of the wheel(s), on one or more wheels of the vehicle during braking.

E-2.2 **Sensor –** A component designed to identify and transmit to the controller the conditions of rotation of the wheel(s) or the dynamic conditions of the vehicle.

E-2.3 **Controller –** A component designed to evaluate the data transmitted by the sensor(s) and to transmit a signal to the modulator.

E-2.4 **Modulator –** A component designed to vary the braking force(s) in accordance with the signal received from the controller.

E-2.5 **Directly Controlled Wheel –** A wheel whose braking force is modulated according to data provided at least by its own sensor (*see* Note).

NOTE – Anti-lock systems with select-high control are deemed to include both directly and indirectly controlled wheels; in systems with select-low control, all sensed wheels are deemed to be directly controlled wheels.

E-2.6 **Indirectly Controlled Wheel –** A wheel whose braking force is modulated according to data provided by the sensor(s) of other wheel(s) (*see* Note under E-2.5).

E-2.7 **Full Cycling –** The anti-lock system is repeatedly modulating the brake force to prevent the directly controlled wheels from locking. Brake applications where modulation only occurs once during the stop shall not be considered to meet this definition.

E-3 TYPES OF ANTI-LOCK SYSTEMS

E-3.1 A vehicle is deemed to be equipped with an anti-lock system within the meaning of E-2.1, if one of the following systems is fitted:

E-3.1.1 **Category 1 Anti-Lock System** – A vehicle equipped with a category 1 anti-lock system shall meet all the requirements of this annex.

E-3.1.2 **Category 2 Anti-Lock System** – A vehicle equipped with a category 2 anti-lock system shall meet all the requirements of this annex, except those of E-5.3.5.

E-3.1.3 **Category 3 Anti-Lock System** – A vehicle equipped with a category 3 anti-lock system shall meet all the requirements of this annex, except those of E-5.3.4 and E-5.3.5. On such vehicles, any individual axle which does not include at least one directly controlled wheel shall fulfill the conditions of adhesion utilization and the wheel-locking sequence of Annex D, instead of the adhesion utilization requirements prescribed in E-5.2. However, if the relative positions of the adhesion utilization curves do not meet the requirements of D-3.1, a check shall be made to ensure that the wheels on at least one of the rear axles do not lock before those of the front axle or axles under the conditions prescribed in D-3.1, with regard to the braking rate and the load respectively. These requirements may be checked on high and low-adhesion road surfaces (about 0.8 and 0.3 maximum) by modulating the service braking control force.

E-4 GENERAL REQUIREMENTS

E-4.1 Any electrical failure or sensor anomaly that affects the system with respect to the functional and performance requirements in this annex, including those in the supply of electricity, the external wiring to the controller(s), the controller(s) (see Note) and the modulator(s) shall be signaled to the driver by a specific optical warning signal. The yellow warning signal specified in 5.2.21.1.2 shall be used for this purpose.

NOTE – The manufacturer shall provide the testing agency with documentation relating to the controller(s) which follows the format set out in Annex G.

E-4.1.1 Sensor anomalies, which cannot be detected under static conditions, shall be detected not later than when the vehicle speed exceed 10 km/h (*see* Note). However, to prevent erroneous fault indication when a sensor is not generating a vehicle speed output, due to non-rotation of a wheel, verification may be delayed but detected not later than when the vehicle speed exceeds 15 km/h.

NOTE – The warning signal may light up again while the vehicle is stationary, provided that it is extinguished before the vehicle speed reaches 10 km/h or 15 km/h, as appropriate, when no defect is present.

E-4.1.2 When the anti-lock braking system is energized with the vehicle stationary, electrically controlled pneumatic modulator valve(s) shall cycle at least once.

E-4.2 In the event of a single electrical functional failure which only affects the anti-lock function, as indicated by the above-mentioned yellow warning signal, the subsequent service braking performance shall not be less than 80 percent of the prescribed performance according to the Type 0 test with the engine disconnected. This corresponds to a stopping distance of $0.1\ v + 0.0075\ v^2$ (m) and a mean fully developed deceleration of 5.15 m/s^2.

E-4.3 The operation of the anti-lock system shall not be adversely affected by magnetic or electrical fields (see Note) (This shall be demonstrated by compliance with AIS-004 (Part 3), as applicable).

NOTE – Until uniform test procedures have been agreed, the manufacturers shall provide the testing agency with their test procedures and results.

E-4.4 A manual device may not be provided to disconnect or change the control mode (*see* Note) of the anti-lock system.

NOTE – It is understood that devices changing the control mode of the anti-lock system are not subject to E-4.4 if in the changed control mode condition all requirements to the category of anti-lock systems, with which the vehicle is equipped, are fulfilled.

E-5 SPECIAL PROVISIONS

E-5.1 Energy Consumption

Vehicles equipped with anti-lock systems shall maintain their performance when the service braking control device is fully applied for long periods. Compliance with this requirement shall be verified by means of the following tests:

E-5.1.1 Test Procedure

E-5.1.1.1 The initial energy level in the energy storage device(s) shall be that specified by the manufacturer. This level shall be at least such as to ensure the efficiency prescribed for service braking when the vehicle is laden. The energy storage device(s) for pneumatic auxiliary equipment shall be isolated.

E-5.1.1.2 From an initial speed of not less than 50 km/h, on a surface with a coefficient of adhesion of 0.3 (*see* Note) or less, the brakes of the laden vehicle shall be fully applied for a time *t*, during which time the energy consumed by the indirectly controlled wheels shall be taken into consideration and all directly controlled wheels shall remain under control of the anti-lock system.

NOTE – Until such test surfaces become generally available, tyres at the limit of wear, and higher values up to 0.4 may be used at the discretion of the testing agency. The actual value obtained and the type of tyres and surface shall be recorded.

E-5.1.1.3 The vehicle's engine shall then be stopped or the supply to the energy transmission storage device(s) cut off.

E-5.1.1.4 The service braking control shall then be fully actuated four times in succession with the vehicle stationary.

E-5.1.1.5 When the brakes are applied for the fifth time, it shall be possible to brake the vehicle with at least the performance prescribed for secondary braking of the laden vehicle.

E-5.1.2 **Additional Requirements**

E-5.1.2.1 The coefficient of adhesion of the road surface shall be measured with the vehicle under test, by the method described in E-7.1.1.

E-5.1.2.2 The braking test shall be conducted with the engine disconnected and idling, and with the vehicle laden.

E-5.1.2.3 The braking time t shall be determined by the formula:

$t = v_{max} \div 7$

(but not less than 15 s)

where t is expressed, in seconds and v_{max} represents the maximum design speed of the vehicle expressed, in km/h, with an upper limit of 120 km/h.

E-5.1.2.4 If the time t cannot be completed in a single braking phase, further phases may be used, up to a maximum of four in all.

E-5.1.2.5 If the test is conducted in several phases, no fresh energy shall be supplied between the phases of the test.

From the second phase, the energy consumption corresponding to the initial brake application may be taken into account, by subtracting one full brake application from the four full applications prescribed in E-5.1.1.4 (and E-5.1.1.5 and E-5.1.2.6) for each of the second, third and fourth phases used in the test prescribed in E-5.1.1 as applicable.

E-5.1.2.6 The performance prescribed in E-5.1.1.5 shall be deemed to be satisfied if, at the end of the fourth application, with the vehicle stationary, the energy level in the storage device(s) is at or above that required for secondary braking with the laden vehicle.

E-5.2 **Utilization of Adhesion**

E-5.2.1 The utilization of adhesion by the anti-lock system takes into account the actual increase in braking distance beyond the theoretical minimum. The anti-lock system shall be deemed to be satisfactory when the condition $\varepsilon \geq 0.75$ is satisfied, where ε represents the adhesion utilized, as defined in E-7.1.2.

E-5.2.2 The adhesion utilization (ε) shall be measured on road surfaces with a coefficient of adhesion of 0.3 (*see* Note) or less, and of about 0.8 (dry road), with an initial speed of 50 km/h. To eliminate the effects

of differential brake temperatures it is recommended that z_{AL} be determined prior to the determination of k.

NOTE – Until such test surfaces become generally available, tyres at the limit of wear, and higher values up to 0.4 may be used at the discretion of the testing agency. The actual value obtained and the type of tyres and surface shall be recorded.

E-5.2.3 The test procedure to determine the coefficient of adhesion (k) and the formulae for calculation of the adhesion utilization (ε) shall be those laid down in E-7.

E-5.2.4 The utilization of adhesion by the anti-lock system shall be checked on complete vehicles equipped with anti-lock systems of categories 1 or 2. In the case of vehicles equipped with category 3 anti-lock systems, only the axle(s) with at least one directly controlled wheel shall satisfy this requirement.

E-5.2.5 The condition $\varepsilon \geq 0.75$ shall be checked with both laden and unladen (*see* Note 1).

The laden test on the high adhesion surface may be omitted if the prescribed force on the control device does not achieve full cycling of the anti-lock system.

For the unladen test, the control force may be increased up to 100 daN if no cycling is achieved with its full force value (*see* Note 2). If 100 daN is insufficient to make the system cycle, then this test may be omitted.

NOTES

1 Until a uniform test procedure is established, the tests required by this paragraph may have to be repeated for vehicles equipped with electrical regenerative braking systems, in order to determine the effect of different braking distribution values provided by automatic functions on the vehicle.

2 'Full force' means the maximum force laid down in Annex B; a higher force may be used if required to activate the anti-lock system.

E-5.3 **Additional Checks**

The following additional checks shall be carried out with the engine disconnected, with the vehicle laden and unladen:

E-5.3.1 The wheels directly controlled by an anti-lock system must not lock when the full force (*see* E-5.2.5, Note 2) is suddenly applied on the control device, on the road surfaces specified in E-5.2.2. As per E-5.2.2, at an initial speed of v = 40 km/h and at a high initial speed v = 0.8 v_{max} ≤ 120 km/h (see Note);

Note: The purpose of these tests is to check that the wheels do not lock and that the vehicle remains stable; it is not necessary, therefore, to make complete stops and bring the vehicle to a halt on the low-adhesion surface.

E-5.3.2 When an axle passes from a high-adhesion surface (k_H) to a low-adhesion surface (k_L), where $k_H \geq 0.5$ and $k_H / k_L \geq 2$, (*see* Note) with the full force (*see* Note 2 below E-5.2.5) applied on the control device, the directly controlled wheels shall not lock. The running

speed and the instant of applying the brakes shall be so calculated that, with the anti-lock system fully cycling on the high-adhesion surface, the passage from one surface to the other is made at high and at low speed, under the conditions laid down in E-5.3.1; (*see* Note below E-5.3.1)

NOTES

k_H is the high-adhesion surface coefficient.
k_L is the low-adhesion surface coefficient.
k_H and k_L are measured as laid down in E-7.

E-5.3.3 When a vehicle passes from a low-adhesion surface (k_L) to a high-adhesion surface (k_H) where $k_H \geq 0.5$ and $k_H / k_L \geq 2$, (*see* Note below E-5.3.2) with the full force (*see* E-5.2.5, Note 2) applied on the control device, the deceleration of the vehicle shall rise to the appropriate high value within a reasonable time and the vehicle shall not deviate from its initial course. The running speed and the instant of applying the brake shall be so calculated that, with the anti-lock system fully cycling on the low-adhesion surface, the passage from one surface to the other occurs at approximately 50 km/h;

E-5.3.4 The provisions of this clause shall only apply to vehicles equipped with anti-lock systems of categories 1 or 2. When the right and left wheels of the vehicle are situated on surfaces with differing coefficients of adhesion (k_H and k_L), where $k_H \geq 0.5$ and $k_H / k_L \geq 2$, (*see* E-5.3.2, Note) the directly controlled wheels shall not lock when the full force (*see* E-5.2.5, Note 2) is suddenly applied on the control device at a speed of 50 km/h;

E-5.3.5 Furthermore, laden vehicles equipped with anti-lock systems of category 1 shall, under the conditions of E-5.3.4 satisfy the prescribed braking rate in E-8.

E-5.3.6 However, in the tests provided in E- 5.3.1, E-5.3.2, E-5.3.3, E-5.3.4 and E-5.3.5, brief periods of wheel-locking shall be allowed. Furthermore, wheel-locking is permitted when the vehicle speed is less than 15 km/h; likewise, locking of indirectly controlled wheels is permitted at any speed, but stability and steer ability shall not be affected and the vehicle shall not exceed a yaw angle of 15° or deviate from a 3.5 m wide lane;

E-5.3.7 During the tests provided in E-5.3.4 and E-5.3.5, steering correction is permitted, if the angular rotation of the steering control is within 120° during the initial 2 s, and not more than 240° in all. Furthermore, at the beginning of these tests the longitudinal median plane of the vehicle shall pass over the boundary between the high and low-adhesion surfaces and during these tests no part of the (outer) tyres shall cross this boundary (*see* E-5.2.5, Note 1).

E-6	SYMBOLS AND DEFINITIONS	
	SYMBOL	**NOTES**
	E	Wheelbase
	ε	The adhesion utilised of the vehicle: quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k)
	ε_i	The ε - value measured on axle i (in the case of a motor vehicle with a Category 3 anti-lock system)
	ε_H	The ε - value on the high-adhesion surface
	ε_L	The ε - value on the low-adhesion surface
	F	Force (N)
	F_{dyn}	Normal reaction of road surface under dynamic conditions with the anti-lock system operative
	F_{idyn}	F_{dyn} on axle i in case of power-driven vehicles
	F_i	Normal reaction of road surface on axle i under static conditions
	F_M	Total normal static reaction of road surface on all wheels of power-driven vehicle
	F_{Mnd} (*see* Note)	Total normal static reaction of road surface on the unbraked and non-driven axles of the power-driven vehicle
	F_{Md} (*see* Note)	Total normal static reaction of road surface on the unbraked and driven axles of the power-driven vehicle
	F_{WM} (*see* Note)	$0.01\ F_{Mnd} + 0.015\ F_{Md}$
	g	Acceleration due to gravity (9.81 m/s^2)
	h	Height of centre of gravity specified by the manufacturer and agreed by the testing agency conducting the approval test
	k	Coefficient of adhesion between tyre and road
	k_f	k-factor of one front axle
	k_H	k-value determined on the high-adhesion surface
	k_i	k-value determined on axle i for a vehicle with a category 3 anti-lock system
	k_L	k-value determined on the low-adhesion surface

E-6	SYMBOLS AND DEFINITIONS	
	SYMBOL	**NOTES**
	k_{lock}	Value of adhesion for 100 percent slip
	k_M	k - factor of the power-driven vehicle
	k_{peak}	Maximum value of the curve 'adhesion versus slip'
	k_r	k - factor of one rear axle
	P	Mass of individual vehicle (kg)
	R	Ratio of k_{peak} to k_{lock}
	t	Time interval (s)
	t_m	Mean value of t
	t_{min}	Minimum value of t
	z	Braking rate
	z_{AL}	Braking rate z of the vehicle with the anti-lock system operative
	z_m	Mean braking rate
	z_{max}	Maximum value of z
	z_{MALS}	z of the power-driven vehicle on a split surface
	NOTE – F_{Mnd} and F_{Md} in case of two-axled motor vehicles: these symbols may be simplified to corresponding F_i - symbols.	
E-7	**UTILIZATION OF ADHESION**	
E-7.1	**Method of Measurement**	
E-7.1.1	**Determination of the coefficient of adhesion (k)**	
E-7.1.1.1	The coefficient of adhesion (k) shall be determined as the quotient of the maximum braking forces without locking the wheels and the corresponding dynamic load on the axle being brakes.	
E-7.1.1.2	The brakes shall be applied on only one axle of the vehicle under test, at an initial speed of 50 km/h. The braking forces shall be distributed between the wheels of the axle to reach maximum performance. The anti-lock system shall be disconnected, or inoperative, between 40 km/h and 20 km/h.	

E-7.1.1.3 A number of tests at increments of line pressure shall be carried out to determine the maximum braking rate of the vehicle (z_{max}).

During each test, a constant input force shall be maintained and the braking rate will be determined by reference to the time taken (t) for the speed to reduce from 40 km/h to 20 km/h using the formula:

$$z = 0.566 \div t$$

z_{max} = maximum value of z ; t is in second.

E-7.1.1.3.1 Wheel lock may occur below 20 km/h.

E-7.1.1.3.2 Starting from the minimum measured value of t, called t_{min}, then select three values of t comprised within t_{min} and 1.05 t_{min} and calculate their arithmetical mean value t_m, then calculate:

$$z_m = 0.566 \div t_m$$

If it is demonstrated that for practical reasons the three values defined above cannot be obtained, then the minimum time t_{min} may be utilized. However, the requirements of E-7.1.3 shall still apply.

E-7.1.1.4 The braking forces shall be calculated from the measured braking rate and the rolling resistance of the unbraked axle which is equal to 0.015 and 0.010 of the static axle load for a driven axle and a non-driven axle, respectively.

E-7.1.1.5 The dynamic load on the axle shall be that given by the formulae in Annex D.

E-7.1.1.6 The value of k shall be rounded to three decimal places.

E-7.1.1.7 Then, the test shall be repeated for the other axle(s) as defined in E-7.1.1.1 to E-7.1.1.6.

E-7.1.1.8 For example, in the case of a two-axle rear-wheel drive vehicle, with the front axle (1) being braked, the coefficient of adhesion (k) is given by:

$$k_f = [(z_m \text{x } P \text{ x } g - 0.015F_2) \div \{F_1 + (h \div E)\, z_m \text{ x } P \text{ x } g\}]$$

NOTE – The other symbols (P, h, E) are defined in Annex D.

E-7.1.1.9 One coefficient will be determined for the front axle k_f and one for the rear axle k_r.

E-7.1.2 **Determination of the adhesion utilized (ε)**

E-7.1.2.1 The adhesion utilized (ε) is defined as the quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k_M), that is.,

$$\varepsilon = z_{AL} \div k_M$$

E-7.1.2.2 From an initial vehicle speed of 55 km/h, the maximum braking rate (z_{AL}) shall be measured with full cycling of the anti-lock braking system and based on the average value of three tests, as in E-7.1.1.3, using the time taken for the speed to reduce from 45 km/h to 15 km/h, according to the following formula:

$$z_{AL} = 0.849 \div t_m$$

E-7.1.2.3 The coefficient of adhesion k_M shall be determined by weighting with the dynamic axle loads according to the following formula:

$$k_M = [\{(k_f \text{ x } F_{fdyn}) + (k_r \text{ x } F_{rdyn})\} \div (P.g)]$$

where

$$F_{fdyn} = [F_f + \{z_{AL} \text{ x } P \text{ x } g \text{ x } (h/E)\}]$$

$$F_{rdyn} = [F_r - \{z_{AL} \text{ x } P \text{ x } g \text{ x } (h/E)\}]$$

E-7.1.2.4 The value of ε shall be rounded to two decimal places.

E-7.1.2.5 In the case of a vehicle equipped with an anti-lock system of categories 1 or 2, the value of z_{AL} shall be based on the whole vehicle, with the anti-lock system in operation, and the adhesion utilized (ε) is given by the same formula quoted in E-7.1.2.1.

E-7.1.2.6 In the case of a vehicle equipped with an anti-lock system of category 3, the value of z_{AL} shall be measured on each axle which has at least one directly controlled wheel. For example, for a two-axle rear-wheel drive vehicle with an anti-lock system acting only on the rear axle (2), the adhesion utilized (ε) is given by:

$$\varepsilon_2 = [(z_{AL} \text{ x } P \text{ x } g - 0.010\, F_1) \div \{k_2 (F_2 - z_{AL} \text{ x } P \text{ x } g \text{ x } (h \div E)\}]$$

This calculation shall be made for each axle having at least one directly controlled wheel.

E-7.1.3 If ε >1.00, the measurements of coefficients of adhesion shall be repeated. A tolerance of 10 percent is accepted.

E-8 PERFORMANCE ON DIFFERING ADHESION SURFACES

E-8.1 The prescribed braking rate referred to in E-5.3.5 may be calculated by reference to the measured coefficient of adhesion of the two surfaces on which this test is carried out. These two surfaces shall satisfy the conditions prescribed in E-5.3.4.

E-8.2 The coefficient of adhesion k_H and k_L of the high and low adhesion surfaces, respectively, shall be determined in accordance with the provisions in E-7.1.1.

E-8.3 The braking rate (z_{MALS}) for laden vehicles shall be:

$$z_{MALS} \geq 0.75 \text{ x } [(4\, k_L + k_H) \div 5] \text{ and } z_{MALS} \geq k_L$$

E-9 **METHOD OF SELECTION OF THE LOW ADHESION SURFACE**

E-9.1 Details of the coefficient of adhesion of the surface selected, as defined in E-5.1.1.2, shall be given to the testing agency.

E-9.1.1 These data shall include a curve of the coefficient of adhesion *versus* slip (from 0 to 100 percent slip) for a speed of approximately 40 km/h.

E-9.1.1.1 The maximum value of the curve will represent k_{peak} and the value at 100 percent slip will represent k_{lock}.

E-9.1.1.2 The ratio R shall be determined as the quotient of the k_{peak} and k_{lock}.

$$R = k_{peak} \div k_{lock}$$

E-9.1.1.3 The value of R shall be rounded to one decimal place.

E-9.1.1.4 The surface to be used shall have a ratio R between 1.0 and 2.0 (*see* Note).

NOTE – Until such test surfaces become generally available, a ratio R up to 2.5 is acceptable, subject to discussion with the testing agency.

E-9.2 Prior to the tests, the testing agency shall ensure that the selected surface meets the specified requirements and shall be informed of the following:

a) Test method to determine R;

b) Type of vehicle; and

c) Axle load and tyres (different loads and different tyres have to be tested and the results shown to the testing agency which will decide if they are representative for the vehicle to be approved).

E-9.2.1 The value of R shall be mentioned in the test report. The calibration of the surface has to be carried out at least once a year with a representative vehicle to verify the stability of R.

ANNEX F

INERTIA DYNAMOMETER TEST METHOD FOR BRAKE LININGS

(*Clause* 6.2)

F-1 GENERAL

F-1.1 The procedure described in this annex may be applied in the event of a modification of vehicle type resulting from the fitting of brake linings of another type to vehicles which have been approved in accordance with this standard.

F-1.2 The alternative types of brake linings shall be checked by comparing their performance with that obtained from the brake linings with which the vehicle was equipped at the time of approval and conforming to the components identified in the relevant information document, a model of which is given in Annex A.

F-1.3 The testing agency responsible for conducting approval tests may at its discretion require comparison of the performance of the brake linings to be carried out in accordance with the relevant provisions contained in Annex B.

F-1.4 Application for approval by comparison shall be made by the vehicle manufacturer or by his duly accredited representative.

F-1.5 In the context of this annex 'vehicle' shall mean the vehicle type approved according to this standard and for which it is requested that the comparison shall be considered satisfactory.

F-2 TEST EQUIPMENT

A dynamometer having the following characteristics shall be used for the tests:

a) It shall be capable of generating the inertia required by F-3.1, and have the capacity to meet the requirements prescribed by B-1.5 with respect to the Type I fade test;

b) Brakes fitted shall be identical with those of the original vehicle type concerned;

c) Air cooling, if provided, shall be in accordance with F-3.4.

d) Instrumentation for the test shall be capable of providing at least the following data;

   1) A continuous recording of disc or drum rotational speed;

   2) Number of revolutions completed during a stop, to resolution not greater than one eighth of a revolution;

   3) Stop time;

   4) A continuous recording of the temperature measured in the centre of the path swept by the lining or at mid-thickness of the disc or drum or lining;

   5) A continuous recording of brake application control line pressure or force;

   6) A continuous recording of brake output torque.

F-3 TEST CONDITIONS

F-3.1 The dynamometer shall be set as close as possible, with ±5 percent tolerance, to the rotary inertia equivalent to that part of the total inertia of the vehicle braked by the appropriate wheel(s) according to the following formula:

$$I = M R^2$$

where

I = rotational inertia, in kgm^2;

R = dynamic tyre rolling radius, in m; and

M = that part of the maximum mass of the vehicle braked by the appropriate wheel(s). In the case of a single-ended dynamometer, this part shall be calculated from the design braking distribution when deceleration corresponds to the appropriate value given in B-2.1.1(A).

F-3.2 The initial rotational speed of the inertia dynamometer shall correspond to the linear speed of the vehicle as prescribed in B-2.1.1(A) and shall be based on the dynamic rolling radius of the tyre.

F-3.3 Brake linings shall be at least 80 percent bedded and shall not have exceeded a temperature of 180°C during the bedding procedure, or alternatively, at the vehicle manufacturer's request, be bedded in accordance with his recommendations.

F-3.4 Cooling air may be used, flowing over the brake in a direction perpendicular to its axis of rotation. The velocity of the cooling air flowing over the brake shall be not greater than 10 km/h. The temperature of the cooling air shall be the ambient temperature.

F-4 TEST PROCEDURE

F-4.1 Five sample sets of the brake lining shall be subjected to the comparison test; they shall be compared with five sets of linings conforming to the original components identified in the information document concerning the first approval of the vehicle type concerned.

F-4.2 Brake lining equivalence shall be based on a comparison of the results achieved using the test procedures prescribed in this annex and in accordance with the following requirements.

F-4.3 **Type 0 Cold Performance Test**

F-4.3.1 Three brake applications shall be made when the initial temperature is below 100°C. The temperature shall be measured in accordance with the provisions of F-2 (d) (4).

F-4.3.2 Brake applications shall be made from an initial rotational speed equivalent to that given in B-2.1.1 (A), and the brake shall be applied to achieve a mean torque equivalent to the deceleration prescribed in that paragraph. In addition, tests shall also be carried out at several rotational speeds, the lowest being equivalent to 30 percent of the maximum speed of the vehicle and the highest being equivalent to 80 percent of that speed.

F-4.3.3 The mean braking torque recorded during the above cold performance tests on the linings being tested for the purpose of comparison shall, for the same input measurement, be within the test limits ±15 percent of the mean braking torque recorded with the brake linings conforming to the component identified in the relevant application for vehicle type approval.

F-4.4 **Type I Test (Fade Test)**

F-4.4.1 **Heating Procedure**

Brake linings shall be tested according to the procedure given in B-1.5.1.

F-4.4.2 **Hot Performance**

F-4.4.2.1 On completion of the tests required under F-4.4.1, the hot braking performance test specified in B-1.5.2 shall be carried out.

F-4.4.2.2 The mean braking torque recorded during the above hot performance tests on the linings being tested for the purpose of comparison shall, for the same input measurement, be within the test limits ±15 percent of the mean braking torque recorded with the brake linings conforming to the component identified in the relevant application for vehicle type approval.

F-5 INSPECTION OF BRAKE LININGS

Brake linings shall be visually inspected on completion of the above tests to check that they are in satisfactory condition for continued use in normal service.

ANNEX G

SPECIAL REQUIREMENTS TO BE APPLIED TO THE SAFETY ASPECTS OF COMPLEX ELECTRONIC VEHICLE CONTROL SYSTEMS

(*Clause* 5.1.3 *and* E-4.1)

G-1 GENERAL

This annex defines the special requirements for documentation, fault strategy and verification with respect to the safety aspects of complex electronic vehicle control systems (*see* G-2.3) as far as this standard is concerned.

This annex may also be called, by special paragraphs in this standard, for safety related functions which are controlled by electronic system(s).

This annex does not specify the performance criteria for 'The system' but covers the methodology applied to the design process and the information which shall be disclosed to the testing agency, for type approval purposes.

This information shall show that 'The system' respects, under normal and fault conditions, all the appropriate performance requirements specified elsewhere in this standard.

G-2 DEFINITIONS

For the purpose of this annex the following definitions shall apply.

G-2.1 **Safety Concept** – It is a description of the measures designed into the system, for example within the electronic units, so as to address system integrity and thereby ensure safe operation even in the event of an electrical failure.

The possibility of a fall-back to partial operation or even to a back-up system for vital vehicle functions may be a part of the safety concept.

G-2.2 **Electronic Control System** – A combination of units, designed to co-operate in the production of the stated vehicle control function by electronic data processing.

Such systems, often controlled by software, are built from discrete functional components such as sensors, electronic control units and actuators and connected by transmission links. They may include mechanical, electro-pneumatic or electro-hydraulic elements.

'The system', referred to herein**,** is the one for which type approval is being sought.

G-2.3 **Complex Electronic Vehicle Control Systems** – Those electronic control systems which are subject to a hierarchy of control in which a controlled function may be over-ridden by a higher level electronic control system/function.

A function which is over-ridden becomes part of the complex system.

G-2.4 **Higher-Level Control** – Systems/functions are those which employ additional processing and/or sensing provisions to modify vehicle behaviour by commanding variations in the normal function(s) of the vehicle control system.

This allows complex systems to automatically change their objectives with a priority which depends on the sensed circumstances.

G-2.5 **Units** – The smallest divisions of system components which shall be considered in this annex, since these combinations of components will be treated as single entities for purposes of identification, analysis or replacement.

G-2.6 **Transmission Links** – The means used for inter-connecting distributed units for the purpose of conveying signals, operating data or an energy supply.

This equipment is generally electrical but may, in some part, be mechanical, pneumatic, hydraulic or optical**.**

G-2.7 **Range of Control** – It refers to an output variable and defines the range over which the system is likely to exercise control.

G-2.8 **Boundary of Functional Operation** – The boundaries of the external physical limits within which the system is able to maintain control.

G-3 DOCUMENTATION

G-3.1 **Requirements**

The manufacturer shall provide a documentation package which gives access to the basic design of 'The system' and the means by which it is linked to other vehicle systems or by which it directly controls output variables.

The function(s) of 'The system' and the safety concept, as laid down by the manufacturer, shall be explained.

Documentation shall be brief, yet provide evidence that the design and development has had the benefit of expertise from all the system fields which are involved.

For periodic technical inspections, the documentation shall describe how the current operational status of 'The system' can be checked.

G-3.1.1 Documentation shall be made available in two parts:

a) The formal documentation package for the approval, containing the material listed in G-3 (with the exception of that of G-3.4.4) which shall be supplied to the testing agency at the time of submission of the type approval application. This will be taken as the basic reference for the verification process set out in G-4.

b) Additional material and analysis data of G-3.4.4, which shall be retained by the manufacturer, but made open for inspection at the time of type approval.

G-3.2 **Description of the Functions of 'The System'**

A description shall be provided which gives a simple explanation of all the control functions of 'The system' and the methods employed to achieve the objectives, including a statement of the mechanism(s) by which control is exercised.

G-3.2.1 A list of all input and sensed variables shall be provided and the working range of these defined.

G-3.2.2 A list of all output variables which are controlled by 'The system' shall be provided and an indication given, in each case, of whether the control is direct or via another vehicle system. The range of control (see G-2.7) exercised on each such variable shall be defined.

G-3.2.3 Limits defining the boundaries of functional operation (see G-2.8) shall be stated where appropriate to system performance.

G-3.3 **System Layout and Schematics**

G-3.3.1 **Inventory of Components**

A list shall be provided; collating all the units of 'The system' and mentioning the other vehicle systems which are needed to achieve the control function in question.

An outline schematic showing these units in combination shall be provided with both the equipment distribution and the interconnections made clear.

G-3.3.2 **Functions of the Units**

The function of each unit of 'The system' shall be outlined and the signals linking it with other units or with other vehicle systems shall be shown. This may be provided by a labeled block diagram or other schematic, or by a description aided by such a diagram.

G-3.3.3 **Interconnections**

Interconnections within 'The system' shall be shown by a circuit diagram for the electric transmission links, by an optical-fibre diagram for optical link by a piping diagram for pneumatic or hydraulic transmission equipment and by a simplified diagrammatic layout for mechanical linkages.

G-3.3.4 **Signal Flow and Priorities**

There shall be a clear correspondence between these transmission links and the signals carried between units.

Priorities of signals on multiplexed data paths shall be stated, wherever priority may be an issue affecting performance or safety as far as this standard is concerned.

G-3.3.5 **Identification of Units**

Each unit shall be clearly and unambiguously identifiable (for example, by marking for hardware and marking or software output for software content) to provide corresponding hardware and documentation association.

Where functions are combined within a single unit or indeed within a single computer, but shown in multiple blocks in the block diagram for clarity and ease of explanation, only a single hardware identification marking shall be used.

The manufacturer shall, by the use of this identification, affirm that the equipment supplied conforms to the corresponding document.

G-3.3.5.1 The identification defines the hardware and software version and, where the latter changes such as to alter the function of the unit as far as this standard is concerned, this identification shall also be changed.

G-3.4 **Safety Concept of the Manufacturer**

G-3.4.1 The manufacturer shall provide a statement which affirms that the strategy chosen to achieve 'The system' objectives will not, under non-fault conditions, prejudice the safe operation of systems which are subject to the prescriptions of this standard.

G-3.4.2 In respect of software employed in 'The system', the outline architecture shall be explained and the design methods and tools used shall be identified. The Manufacturer shall be prepared, if required, to show some evidence of the means by which they determined the realization of the system logic, during the design and development process.

G-3.4.3 The manufacturer shall provide the testing agency with an explanation of the design provisions built into 'The system' so as to generate safe operation under fault conditions. Possible design provisions for failure in 'The system' are for example:

a) Fall-back to operation using a partial system;

b) Change-over to a separate back-up system; and

c) Removal of the high level function.

In case of a failure, the driver shall be warned for example by warning signal or message display. When the system is not deactivated by the driver, for example, by turning the ignition (run) switch to 'off', or by switching off that particular function, if a special switch is provided for that purpose, the warning shall be present as long as the fault condition persists.

G-3.4.3.1 If the chosen provision selects a partial performance mode of operation under certain fault conditions, then these conditions shall be stated and the resulting limits of effectiveness defined.

G-3.4.3.2 If the chosen provision selects a second (back-up) means to realise the vehicle control system objective, the principles of the change-over mechanism, the logic and level of redundancy and any built in back-up checking features shall be explained and the resulting limits of back-up effectiveness defined.

G-3.4.3.3 If the chosen provision selects the removal of the higher level function, all the corresponding output control signals associated with this function shall be inhibited, and in such a manner as to limit the transition disturbance.

G-3.4.4 The documentation shall be supported, by an analysis which shows, in overall terms, how the system will behave on the occurrence of any one of those specified faults which will have a bearing on vehicle control performance or safety.

This may be based on a failure mode and effect analysis (FMEA), a fault tree analysis (FTA) or any similar process appropriate to system safety considerations.

The chosen analytical approach(es) shall be established and maintained by the manufacturer and shall be made open for inspection by the testing agency at the time of the type approval.

G-3.4.4.1 This documentation shall itemize the parameters being monitored and shall set out, for each fault condition of the type defined in G-3.4.4, the warning signal to be given to the driver and/or to service/technical inspection personnel.

G-4 VERIFICATION AND TEST

G-4.1 The functional operation of 'The system' as laid out in the documents required in G-3 shall be tested according to G.4.1.1 and G-4.1.2.

G-4.1.1 **Verification of the function of 'The System'**

As the means of establishing the normal operational levels, verification of the performance of the vehicle system under non-fault conditions shall be conducted against the manufacturer's basic benchmark specification unless this is subject to a specified performance test as part of the approval procedure of this or another standard.

G-4.1.2 **Verification of the Safety Concept of G-3.4**

The reaction of 'The system' shall, at the discretion of the type approval authority, be checked under the influence of a failure in any individual unit by applying corresponding output signals to electrical units or mechanical elements in order to simulate the effects of internal faults within the unit.

The verification results shall correspond with the documented summary of the failure analysis, to a level of overall effect such that the safety concept and execution are confirmed as being adequate.

ANNEX H
COMMITTEE COMPOSITION – AISC Panel

Name	Organization
Convener	
Mr. A. A. Badusha	The Automotive Research Association of India (ARAI)
Members	**Representing**
Mr. K. B. Patil	The Automotive Research Association of India (ARAI)
Dr. N. Karuppaiah	NATRiP
Mr. S. Ravishankar / Mr. D. Balakrishnan / Mr. V. Faustino	Ashok Leyland Technical Centre (SIAM)
Mr. S. V. Suderson/ Mr. C. Dinesh Kumar	Daimler India (SIAM)
Mr. Shailesh Kulkarni	Mahindra and Mahindra Ltd. (SIAM)
Mr. V. G. Kulkarni / Mr. T. Viswanathan	Mahindra and Mahindra Ltd. (SIAM)
Mr. S. M. Panse / Mr. M. V. Shridhare / Mr. Gajanan Salunke	Tata Motors Ltd. (SIAM)
Mr. Suchindran M	Toyota Kirloskar Motor Pvt. Ltd. (SIAM)
Mr. Gururaj Ravi / Mr. Rajesh Vyas / Mr. Raj Kumar Diwedi	Maruti Suzuki India Ltd.(SIAM)
Mr. Rajendra Khile / Mr. Karuppasamy	Renault Nissan Technology and Business Centre (SIAM)
Mr. Mohan Kumar Muthusamy	VE Commercial Vehicles Ltd. (SIAM)
Mr. Makarand Brahme	Volkswagen India Pvt. Ltd. (SIAM)
Mr. Vikrant Lokhande	Volvo Trucks – VECV (SIAM)
Mr. Vishal P. Jain	Isuzu Motors India
Mr. P. Venugopal / Mr. A. Vijayan	Brakes India Ltd.
Mr. S. Balachandran / Mr. D. Prabhakaran / Mr. Sachin Deshmukh	WABCO
Mr. Arun Bisht	Knorr- Bremse India

ANNEX J
COMMITTEE COMPOSITION – AISC

Chairperson	
Mrs. Rashmi Urdhwareshe	Director The Automotive Research Association of India, Pune
Members	**Representing**
Representative from	Ministry of Road Transport and Highways (Dept. of Road Transport and Highways), New Delhi
Representative from	Ministry of Heavy Industries and Public Enterprises (Department of Heavy Industry), New Delhi
Shri S. M. Ahuja	Office of the Development Commissioner, MSME, Ministry of Micro, Small and Medium Enterprises, New Delhi
Shri Shrikant R. Marathe	Former Chairman, AISC
Shri R.R. Singh	Bureau of Indian Standards, New Delhi
Director	Central Institute of Road Transport, Pune
Director	Global Automotive Research Centre, Chennai
Director	International Centre for Automotive Technology, Manesar
Director	Indian Institute of Petroleum, Dehra Dun
Director	Vehicles Research and Development Establishment, Ahmednagar
Director	Indian Rubber Manufacturers Research Association
Representatives from	Society of Indian Automobile Manufacturers
Shri R. P. Vasudevan	Tractor Manufacturers Association, New Delhi
Shri Uday Harite	Automotive Components Manufacturers Association of India, New Delhi

Member Secretary
Shri Vikram Tandon
Dy. General Manager
The Automotive Research Association of India, Pune

* At the time of approval of this Automotive Industry Standard (AIS)

ANNEX K
(*Foreword*)
CLAUSE WISE REFERENCES OF ECE R13H AND THIS STANDARD

Clause No/Annex of ECE (1)	Title (2)	Corresponding Clause/Annex of this standard (3)
1	Scope	1
NA	References	2
2	Definitions	3
3	Application for approval	4
4	Approval	NA
5	Specifications	5
6	Tests	6
7	Modification of vehicle type or braking system and extension of approval	7
8	Conformity of production	NA
9	Penalties for non-conformity of production	NA
10	Production definitely discontinued	NA
11	Names and addresses of testing agency responsible for conducting approval tests, and of administrative departments	NA
Annex 1	Communication concerning the approval or extension or refusal or withdrawal of approval or production definitely discontinued of a vehicle type with regard to braking pursuant to this standard	Annex A
Annex 3	Braking tests and performance of braking systems	Annex B
Annex 3 Appendix 1	Procedure for monitoring the stability of battery charge	Annex B B-4
Annex 4	Provisions relating to energy sources and energy storage devices (energy accumulators)	Annex C
Annex 5	Distribution of braking among the axles of vehicles	Annex D
Annex 5 Appendix 1	Wheel-lock sequence test procedure	Annex D D-7
Annex 5 Appendix 2	Torque wheel test procedure	Annex D D-8
Annex 6	Test requirements for vehicles fitted with anti-lock systems	Annex E
Annex 6	Symbols and definitions	Annex E

Appendix 1		E-6
Annex 6 Appendix 2	Utilization of adhesion	Annex E E-7
Annex 6 Appendix 3	Performance on differing adhesion surfaces	Annex E E-8
Annex 6 Appendix 4	Method of selection of the low adhesion surface	Annex E E-9
Annex 7	Inertia dynamometer test method for brake linings	Annex F
Annex 8	Special requirements to be applied to the safety aspects of complex electronic vehicle control systems	Annex G