CITA RECOMMENDATION

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"BRAKE TESTING IN PERIODIC TECHNICAL INSPECTION"

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1. INTRODUCTION

CITA Recommendation No 1 lists the items that should be inspected during periodic technical inspection (PTI), the methods of inspection and the principle reasons for failure. Section 1 covers braking systems.
The purpose of this CITA Recommendation No 8 is to specify in more detail recommended test methods and equipment for assessing the *required safety* of vehicle braking systems.

A general assumption of PTI is that new vehicles comply with legal requirements. The principal aim of PTI is to test whether a vehicle has been properly maintained and is still roadworthy.

This CITA Recommendation is based on the requirements regarding braking systems in European Union directive n° 2014/45/EU[1] on periodic roadworthiness tests for motor vehicles and their trailers. It has been developed by CITA Working Group 1 and takes account of the ISO standard[2] for roller brake testers, the 07 supplement to UNECE Regulation 13.09 concerning reference brake forces for periodic technical inspections, and the outcome of the CITA ECSS Project.

New safety technology by use of electronic controlled systems contribute on a high level to the avoidance of accidents as well as on the avoidance of road fatalities and a reduction of the severity of injuries. The higher the penetration rate of such electronic safety components in vehicles is, the more the users rely on them. Different studies (AUTOFORE; IDELSY; ECSS.) have shown that the defect rate of electronic safety components is like pure mechanical systems. Even if the electronic part of these systems can be controlled by OBD systems, the interface to the pure mechanical system is subject to the usual deterioration. A test of the functionality and performance of these electronic safety systems is necessary and possible. Where appropriate, tests of electronic systems at braking systems are described in this recommendation.

Note that some tests are not mandatory within the European Roadworthiness Package but are best practice of CITA members who conduct these tests.

[1] Directive 2014/45/EU of the European Parliament and of the Council of 3 April 2014 on periodic roadworthiness tests for motor vehicles and their trailers and repealing Directive 2009/40/EC (OJ L 127, 29.4.2014, p. 51)
[2] ISO 21069 -1

2. UNITS – ABBREVIATIONS

UNITS TO RECOMMEND FOR USE ON BRAKE TESTING EQUIPMENT

Measurement	Basic units	Prefix of basic units	Alternative units
Brake force, vertical force	N	daN, kN	kgf, lbF
Air/hydraulic pressure	bar	kPa, MPa	psi
Weight	kg	t	lb
Pedal force	N	daN, kN	kgf, lbF

Note: alternative units can be used when required by national regulations.

ABBREVIATIONS:

ABS	Anti-Lock Brake System
DTC	Diagnostic Trouble Code
EBS	Electronic Brake System
ECSS	Electronically Controlled Safety Systems
EPB	Electronic Parking Brake
ESC	Electronic Stability Control System
GUM	Guide to the Expression of Uncertainty in Measurement
GVM	Gross Vehicle Mass
LSV	Load Sensing Valve
MAM	Maximum Authorised Mass
MI	Malfunction Indicator
MFDD	Mean Fully Developed Deceleration
OBD	On Board Diagnostics
PBT	Plate Brake Tester
PTI	Periodic Technical Inspection
RBT	Roller Brake Tester
RD-method	Belgian calculation method to evaluate brake efficiency for heavy duty vehicles with air brakes
RMS	Root Mean Square
RSI	Road Side inspection
UNECE	United Nations Economic Commission for Europe

3. SCOPE OF INSPECTION

To ensure road safety, braking systems, like other safety relevant vehicle systems, shall be tested for:

- correct installation,
- condition of its parts,
- functioning of pedals, switches, levers, and
- efficiency (performance) of the complete braking system

The tests should be possible without dismantling the parts.

4. INSTALLATION TESTS, CONDITION TESTS

4.1. General requirements

The installation is examined visually and/or manually and/or electronically. During this examination the parts and components are tested for:

- presence,
- correct configuration,
- correct mounting, quantity,
- correct wiring, and
- correct identification marks, if available.

Note:
To keep the safety level of the vehicles, it is recommended that the safety systems installed "End-of-Line" remain in the vehicle during its life time and the presence is tested in the PTI.

The condition is examined visually and/or manually and/or electronically. During this examination the parts and components are tested for:

- damage, corrosion and obsolescence,
- wear and slackness,
- fixing, locking, assembly and installation,
- free and easy movement.

Safety level "End-Of-Line" must remain.

Note:
It is recommended to check vehicles with pneumatic brakes by use of their pressure measuring points. If these test connections are mandatory, their presence and functionality shall be tested. Test connections that are not available can often be easily retrofitted (approval may be necessary according to national legislation). For the equipment with test connections, compliance with the regulations of UNECE R13 is strongly recommended.

4.2. Inspection of installation and condition

The mechanical components of the brakes which can be seen without dismantling are examined visually and/or manually and/or electronically (see 4.1).

For condition tests, these points should be covered:

- Badly chafed rods or levers.
- Frayed or seized cables.
- Badly damaged, corroded, seized or incorrectly fitted rods, levers or linkages.
- Wear in rod or cable ends. Wear in eyes of relay levers.
- Wear in clevis pins, bolts, stationary pins, pivots.
- Absence of locking devices on clevis pins.
- Excessively worn, contaminated, incorrectly adjusted brake linings or pads.
- Fractured, damaged, insecure, misaligned brake drums or discs.
- Any obstruction to free movement in the system.
- Any abnormal movement of levers, rods or cables indicating maladjustment.
- Security of brake back plates or discs (including transmission brakes).
- Examine if there has been any obviously unsafe repair or modification carried out to any of the mechanical components of the brake system.

4.3. Air Brakes

4.3.1. Slack Adjusters

It is not recommended that the function of automatic slack adjusters be tested directly during the PTI.

Instead, they should be checked visually for correct installation (correct angles) and adjustment (amount of slack). In addition, checks should be made for damage, excessive wear or signs of seizure or other defects and that other related components are not missing, disconnected or insecure.

If the checks reveal any defect that would affect the correct functioning of an automatic slack adjuster, the vehicle should be failed.
(For an example: see annex 1)

4.3.2. Mechanically operated LSVs

Check that:
All connections, constructed to move freely, are be able to do so; and the connection cable makes an angle of approximately 90° with a line between the connecting point for cable and lever, and the turning point for the lever (with the lever placed in the mid position, between empty and loaded).

Note:
The LSV may work statically, that is, a change in the lever position during braking does not affect the output pressure of the LSV.

4.4. Hydraulic brakes

4.4.1. Tightness

Check that the hydraulic part of the brake system is tight by firmly depressing the brake. The system/the brake master cylinder shall hold the pressure in both the partial load and the full load positions. The vacuum brake booster under the brake master cylinder support shall be free of brake fluid oil.

The vacuum lines of brake boosters shall be checked for leak-tightness by means of a visual and audible inspection.

4.4.2. Brake fluid test

In case of hydraulic and air over hydraulic brake systems, it is recommended to check the brake fluid reservoir, brake fluid warning lamp and brake fluid level and cleanness. If an appropriate device is available, then also the boiling point of the brake fluid may be checked.

1. Avoid damage and cross contamination.

2. Check the integrity of the brake fluid reservoir. The reservoir cap should be present.

3. Check the level of the brake fluid in the brake fluid reservoir. The brake fluid level shall not be below the MIN mark.

4. If necessary, open the brake fluid reservoir cap and check the condition of the brake fluid visually. Especially check for the presence of impurities, sediments or other contaminations.

5. If necessary, check the function of the brake fluid warning light. On vehicles with the brake fluid level sensor integrated into the reservoir cap, check whether the warning light lights up after removing the cap.

4.5. Electronically controlled systems

4.5.1. Anti-Lock Brake

The following method should be regarded as the minimum standard for the PTI. It is limited to checks which can be carried out easily and without any special vehicle make or model specific equipment. A PTI scan tool can be used to test the installation, function, condition or efficiency.

In case of a trailer, an appropriate testing device is necessary, when there is no truck available with a warning signal (MI) for the trailer ABS.
(For an example: see annex 2)

Status of ABS warning signal (malfunction indicator (MI))

Check that the warning signal starts when the ignition is switched on (this is to check that the warning signal itself is functioning). Check that the warning signal stops in the appropriate manner. These vary from system to system. The warning signal usually stops after a specified time lapse or when the vehicle exceeds a certain "speed threshold". The characteristics of all vehicle types that are likely to be tested should be known. If the warning device stays on, the vehicle should be failed.

Electrical wiring

Check visually for faults, such as damaged wires or connectors that could affect the correct functioning. If there is any damage that could indicate broken electrical connections, the vehicle should be failed.

Wheel speed sensor

Check whether the wheel speed sensors are not missing or damaged.

Hydraulic / pneumatic parts

Using regular methods check hydraulic and pneumatic systems for leaks. Vehicles not meeting normal criteria for leakage rates should be failed.

Mechanical parts

Check visually all accessible mechanical parts. If there is any mechanical defect which is likely to affect the correct functioning of the system, the vehicle should be failed.

4.5.2. Electronic Stability Control

The following method should be regarded as the minimum standard for PTI. It is limited to checks which can be carried out easily and without any special vehicle make or model specific equipment. A PTI scan tool can be used to test the installation, function, condition or efficiency.

Status of ESC warning signal (MI)

Check that the warning signal starts when the ignition is switched on (this is only a warning signal self-test). Check that the warning signal stops in the appropriate manner. The warning signal usually stops after a specified time lapse or when the vehicle exceeds a certain "speed threshold". The characteristics of all the vehicle types likely to be tested should be known. If the warning device stays on, the vehicle should be failed.

Electrical wiring

Check visually for faults, such as damaged wires or connectors that could affect the correct functioning. If there is any damage that could indicate broken electrical connections, the vehicle should be failed.

Wheel speed sensor

Check whether the wheel speed sensors are not missing or damaged.

Hydraulic / pneumatic parts

Using normal methods check hydraulic and pneumatic systems for leaks. Vehicles not meeting normal criteria for leakage rates should be failed.

Mechanical parts

Check visually all accessible mechanical parts. If there is any mechanical defect which is likely to affect the correct functioning of the system, the vehicle should be failed.

4.5.3. Electronic Brake System

The following method should be regarded as the minimum standard for PTI. It is limited to checks which can be carried out easily and without any special vehicle make or model specific equipment. A PTI scan tool can be used to test the installation, function, condition or efficiency.

In case of a trailer, an appropriate testing device is necessary, when there is no truck available with a warning signal (MI) for the trailer EBS.
(For an example: see annex 2)

Status of EBS warning signal (MI)

Check that the warning signal starts when the ignition is switched on (this is only a warning signal self-test). Check that the warning signal stops in the appropriate manner. These vary from system to system. Usually the warning signal goes out after a specified time lapse or when the vehicle exceeds a certain "speed threshold". The characteristics of all the vehicle types likely to be tested should be known. If the warning device stays on, the vehicle should be failed.

Electrical wiring

Check visually for faults, such as damaged wires or connectors that could affect the correct functioning. If there is any damage that could indicate broken electrical connections, the vehicle should be failed.

Wheel speed sensor

Check whether the wheel speed sensors are not missing or damaged.

Hydraulic/pneumatic parts

Using normal methods check hydraulic and pneumatic systems for leaks. Vehicles not meeting normal criteria for leakage rates should be failed.

Mechanical parts

Check visually all accessible mechanical parts. If there is any mechanical defect which is likely to affect the correct functioning of the system, the vehicle should be failed.

4.6. Inertia/Overrun Brakes

Temporarily lift the trailer hitch away from the tow ball, using the jockey wheel (or Jack) to raise the trailer.

Check that all mountings are secure.
Check all cables, rods and linkages for wear, damage and corrosion. Ensure all locking devices are in place and secure.

Check for vertical movement in the actuator draw tube support bearings, check the end float between the brake lever and actuator.

Check that the actuator drawtube weatherproof gaiter is in place, is secure and free from splits, cuts or tears.

Check that the damping device is specified to be used for a trailer of MAM shown on the Trailer Identification Plate.

Parking Brake

Check the parking brake lever pivots for security and movement.

Secondary Attachment

Identify whether a breakaway cable, or secondary coupling is required, and correct type is fitted.

Breakaway Cable

Check cable for corrosion, damage fraying or knotting, check attachment clip operation.
Check cable guides and routing.
Check condition of 'Burst Ring' or alternative managed decoupling device and that it is suitable for the trailer that it is fitted to.

Secondary Coupling

Check cable for corrosion, damage fraying or knotting, check attachment clip operation.
Check cable guides and routing.
Check that the secondary coupling is suitable for the trailer that it is fitted to.

Manual Device.

Check condition of device.

5. FUNCTION TESTS

5.1. Service Brake

5.1.1. General Requirements

The function is examined visually and/or manually and/or electronically. After operating pedals, levers, switches or other operating devices which trigger an operation, this operation must be carried out correctly in terms of time and function.

5.1.2. Air Brakes

5.1.2.1. Method of Test for Load Sensing Valves (LSV)

The LSV test is important and the correct operation of this valve has a great influence on road safety. Due to the great time required for this test, it may not be obligatory for every PTI.

Note:
***Only** applicable for vehicles with LSVs with internal simulation or LSVs fitted with an external 'T bar' simulation valve.*

Note:
Vehicles with an electronic brake system (EBS), where the braking force control is regulated electronically, cannot be tested as described below.

5.1.2.1.1. Pneumatically operated LSVs

As the measuring method consists of checking the actual performance against the data on the LSV plate, an LSV plate with at least the following information must be present:

- The input reference pressure.
- The air suspension bellows pressure and the corresponding output pressure of the LSV for at least 2 values, e.g. empty and the fully laden axle load.

1. *Connection of manometers and pressure reducing valves*

   Connect manometers and pressure reducing valves as follows:

   (a) Trailer or semi-trailer:
   (i) Connect pressure reducing valve and manometer between the connection of the control pressure (yellow) line of the towing vehicle and the semi-trailer.
   (ii) Connect manometer in front of the input of the LSV. (Depending on the location of the pressure measuring point, it can be placed on the output of the trailer brake valve or on the input of the LSV.)

   (b) Towing vehicle:
   (i) Connect manometer in front of the input of the LSV.
   (ii) Connect the pressure reducing valve and manometer between the air pressure reservoir and the simulation input of the LSV.
   (iii) Connect manometer on the output of the LSV.

2. *Input reference pressure*

   (a) Trailer or semi-trailer:
   Set the input reference pressure to the value specified on the LSV plate using pressure reducing valve and manometer. Press the brake pedal fully down and check the

value of the manometer. The Manometer shows the input pressure for the LSV and the difference between manometers and shows the predominance of the trailer brake valve. The input pressure is adjusted using pressure reducing valve until manometer reads the input reference pressure shown on the LSV plate.

(b) Towing vehicle:
The input reference pressure is not regulated by a pressure reducing valve; the brake pedal should be applied until manometer indicates the reference pressure shown on the LSV plate.

3. *Suspension bellows pressure*

Different suspension bellows pressures are simulated by adjusting pressure reducing valve.

4. *Checking the LSV*

The progressive operation of the LSV must be tested by checking three points. It is not sufficient to check only the empty and loaded state points.

Point 1:
Pressure reducing valve is set to simulate a bellows pressure of 0.00 bar.
If one of the two suspension bellows pressures remains present at the LSV, this 'empty condition' pressure will be the first point to check instead of 0.00 bar.
When the input reference pressure is set, the output pressure of the LSV when the brake is applied must be the pressure given on the LSV plate for the empty condition, with some tolerance (e.g. +/- 0.20 bar).

Point 2:
The brakes are released, and the pressure-reducing valve is set to simulate an increase of 0.20 bar in the bellows pressure compared to the empty state.
When the input reference pressure is reset, the output pressure of the LSV must show the expected increase in pressure (e.g. +0.20 bar) compared to the pressure measured at point 1 with some tolerance (e.g. +/- 0.10 bar).

Point 3:
The brakes are released, and the pressure-reducing valve is set to simulate a pressure, which is 0.1 bar lower than the bellows pressure in loaded state. If the input reference pressure is reset, the output pressure for the LSV must show the expected diminution in pressure (e.g. -0.30 bar) compared to the pressure given on the LSV plate for the full laden condition – with some tolerance (e.g. +/- 0.20 bar).

Note:
The LSVs on trailers and semi-trailers work statically; i.e. during braking, the LSV output is not adjusted in response to a change in the control signal (bellows pressure). The brakes must be released before each new suspension bellows pressure is simulated.

5.1.2.1.2. Mechanically operated LSVs

As the measuring method consists of checking the actual performance against the data on the LSV plate, an LSV plate with at least the following information must be present:

- The input reference pressure.
- The spring movement fs in mm. (deflection of the springs in loaded state; information from the axle constructor).
- The lever length L in mm.
- The axle load and the corresponding output pressure of the LSV for at least 2 values, e.g. empty and the fully laden axle load.

1. *Connection of manometers and pressure reducing valves*

   The manometers and the pressure reducing valve should be connected in the same way as for a pneumatic LSV. However, in this case, the suspension bellows pressure cannot be simulated.

2. *Input reference pressure*

   The input reference pressure is set in the same way as with a pneumatically driven LSV.

3. *Checking the LSV*

   Provided the vehicle is submitted empty, when the brakes are fully applied, manometer 5 should show the pressure given on the LSV plate for the empty condition, with some tolerance (e.g. +/- 0.20 bar)
   A check in a simulated loaded condition can only be achieved if the mechanical lever can be adjusted manually or using external load simulation. If the control lever can be moved to the position of maximum load, the accompanying output pressure can be measured and compared with the corresponding value on the LSV plate. For towed vehicles this is usually not possible, leaving only the correct lever length L to be checked against the values given on the LSV plate.

5.1.3. Hydraulic Brakes

If fitted, check the vacuum brake booster as follows: Is the engine turned off, press the brake pedal several times. The brake pedal must be clearly refilled, when starting the engine.

If fitted, check the settings of the braking force controllers and braking force limiters if target values exist (LSV plate) and if test connections are available.

If fitted, check the warning device of the pump und accumulator by fully actuating the service brake four times while the engine is not running; the warning device shall not respond.

Otherwise proceed as with the air braking systems (see point 5.1.2).

5.1.4. Combined Air/Hydraulic Brakes

With combined braking systems, the tests described for air braking systems and hydraulic braking systems in Sections 5.1.2 and 5.1.3 shall be performed accordingly. In addition, the requirements of ISO 21069-2 concerning the testing of air over hydraulic braking systems should be applied.

5.1.5. Inertia / Overrun Brakes

If the actuating device of the parking brake is a ratchet type, check the action of the locking pawl and its release mechanism and ensure that the ratchet does not release unexpectedly when a load is applied to the lever.

Check the following points visually by a road test with watching the retardation from outside:
The brake actuator shall apply smoothly and progressively, and the brake actuator shall release to its original start position smoothly and progressively. If fitted, the application and release shall be under the control of the damping device. The stroke of the drawbar must not exceed about 2/3 of the total overrun travel; this does not apply for the testing of the reversing system.

5.1.6. Recuperation

If a recuperation system is fitted, check the correct function of the warning device and that the warning device displays no malfunction.

If possible, the recuperation should be tested during a test drive with the battery not fully charged. The system must noticeably decelerate the vehicle and the charge indicator (if fitted) displays "charging" when the recuperation is activated.

5.1.7. Other Brake Systems

Other braking systems with different designs must be inspected based on the specifications of the braking systems referred above.

5.2. Parking Brake

Note: A parking brake can be a very vulnerable system, for example a transmission brake of a Land Rover or the small drum brakes of Mercedes Benz, or Iveco Daily. So, it is advisable to test the parking brake with care.

5.2.1. Mechanic Parking Brake

Mechanically actuated parking brakes shall normally be tested on the roller brake tester. The braking power must be graduated and equal on both sides of the vehicle. The difference between right and left shall not be more than 50%, starting from the higher value.

5.2.2. Electric Parking Brake

Electrically actuated parking brakes shall normally be tested on the roller brake tester. The braking power must be graduated and equal on both sides of the vehicle. The difference between right and left should not be more than 50%, starting from the higher value.

An exception can be made, where the EPB switch triggers service brakes via the ESC if wheel speed is detected. In these cases, the maximum permissible right-left deviation may be 95% (not inoperative on one side).

5.3. Retarders

Apart from a check that the retarder control is capable of gradual variation, it is not recommended that the function of retarders is tested at a PTI.

The normal procedure for checking retarders at PTI is a visual check for any problems that could affect its correct functioning and, for systems with on-board diagnostics, that no malfunction signal is activated.

Check visually for mechanical damage to the retarder, for leaks in hydraulic retarders and for damage to the electrical system in electromagnetic retarders.

If there is a malfunction signal or any damage that reduces the retarder's ability to function correctly the vehicle should be failed.

5.4. Electronically controlled systems

A test of these electronic safety systems is possible and would add to road safety.

In the ECSS report (https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/projects_sources/ecss_final_report.pdf ; chapter 5.1.1.2), recommended test methods for brake testing with direct focus on ECSS (ABS, ESC, EBS) have been proposed.

So far, these methods have not been implemented yet.

6. EFFICIENCY TESTS

6.1. Scope of Measurement

PTI must generally be carried out in the condition vehicles are presented by their owners.

Depending on national legislation, it can be required to present vehicles in laden condition.

In most cases, heavy vehicles are presented unloaded or only partially loaded. This means that maximum braking forces can be difficult to establish on a roller brake tester, since the wheels tend to lock before the maximum air pressure in the service line is reached.

There are several basic approaches to overcome this problem. One is to apply an artificial load on the vehicle or the axle.
One other is to extrapolate from air pressure and brake force values registered during roller brake testing in condition as presented.
A third possibility is to use reference brake forces in sense of UNECE R13. With this method one has furthermore an axle-wise test and evaluation of the service brakes.

As well as specifying the test method, the properties of the equipment that is required (air pressure gauges and connectors) are also specified. Via a PTI scan tool an equivalent value for the Brake pressure can be read out as reference value. So, these methods are applicable to heavy vehicles with fully pneumatic braking systems, or mainly pneumatic braking systems where only part of the transmission is hydraulic, and this part does not contain any reduction valves. These methods also apply to hydraulic braked vehicles with ESC-System.

The method takes as a basic presumption that the brake forces increase in direct proportion to the service line air pressure in the relevant range.

6.2. Measurement conditions

6.2.1. Measurement on Roller Brake Tester

There are two kinds of brake tests for testing the braking ratio which relates to the maximum authorised mass. (Most of these methods are described for heavy duty vehicles in ISO 21069):

- By using a laden vehicle which relates to the maximum authorised mass and a direct measurement method e.g.
    - The braking rate is calculated by the direct measurement of the axle brake forces (laden measurement method)
    - Reference braking forces methods without further calculation.
- By using a vehicle which relates not to the maximum authorised mass (because of unladen condition of the vehicle) and an indirect measure method e.g.
    - Reference Brake Forces
    - One-point measurement method
    - Two-point measurement method
    - Multi-point measurement method
    - Reference brake forces used together with one of the methods above
    - Alternative measurement methods e.g. the "RD method" used in Belgium, the two-points measurement used in the Netherlands, the One-point measurement method by using min 1.7 bar (for pneumatic brake systems) brake actuator pressure used in Germany.

6.2.1.1. Laden measurement method

The braking rate shall be determined directly by measuring the braking forces for the vehicle in the laden condition.
The laden braking rate calculation requires no extrapolation, being simply given by the following formula:

$$z_{\mathrm{Mlad}} = \frac{\sum F_{\mathrm{i}}}{F_{\mathrm{Mmax}}}$$

in case of motor vehicle

$$z_{\mathrm{Rlad}} = \frac{\sum F_{\mathrm{i}}}{F_{\mathrm{Rmax}}}$$

in case of towed vehicle

To establish the braking ratio which relates to the maximum authorised mass or, in the case of semi-trailers, to the sum of the authorised axle loads, the test mass should be at least 2/3 of the maximum authorised mass (or sum of the authorised axle loads).

6.2.1.2. Unladen measurement method

By using a not fully laden vehicle, less brake forces and brake actuator pressures are met as by braking with a laden vehicle.

There should always be a minimum test brake cylinder pressure as a minimum test condition. There are different reasons to use a minimum requirement for cylinder pressure:

- Since for an extrapolation method the end point of the measurement should be in the linear behaviour zone of the brake measurement. This linear zone is not ensured beneath braking ratio of 10% of a fully laden vehicle. This means that if the brake actuator pressure is less than 2 bars the brake curve is not yet in his linear part.
- For a correct calculation at least 30% of the design brake actuator pressure shall be achieved by suitable loading of the axle or simulation of load (for pneumatic brake systems). This is not necessary, if the required minimum retardation for the vehicle is reached in extrapolation even with a reduced design brake actuator pressure for the respective axis. In this case, the reduced design brake actuator pressure shall be reduced to the extent that the pressure at which the wheels are blocking is not less than 30% of the reduced brake pressure ($p_{red} = p_{dis}/0.3$).
- To increase the accuracy of the extrapolation methods by heaving a measured pressure as close as possible to the calculated pressure (guaranteed pressure). The Netherlands uses here a minimum of 2.4 bar cylinder pressure.

Higher brake cylinder pressure should be accompanied with a higher weight on the wheels. To obtain maximum braking force there must be enough weight on the wheels, since the brake force on a roller brake tester is equal to the vertical force of the weight multiplied with the friction coefficient between the roller and the tire.

There are different solutions used in national PTI schemes to increase either the friction force (adhesion), either the brake actuator pressure, or both. A short description of these possible tools follows:

1. Presenting the vehicle with a partial load

Customers present their vehicle with a partial load in order to obtain the minimum requirement of the brake actuator pressure to make a valid brake test.

Principle:	The load Sensing Valve (LSV), of the vehicle reacts on the partial load and will send a higher pressure to the axle. Higher load means higher friction forces and thus higher brake forces.
Advantages:	No additional equipment or time needed to perform the brake test;
Disadvantages:	Presenting a vehicle in a laden condition is not always possible e.g. gas tank trucks, milk tank trucks. Also, could it be that a laden vehicle gives problems by the further inspection of the vehicle. Otherwise it could be dangerous for the inspector.
Remarks:	assessment of security of cargo;

2. Chassis load simulation: applied to chassis from top-down

An operator moves the load simulator, based on an electrical pallet truck with a crane with a load arm system mounted on it, to its position (behind or at the side of the vehicle). The simulator is then fixed to the floor via Anchor pins, which are quickly placed into concreted rails systems in the floor. The crane system can then push the chassis down.

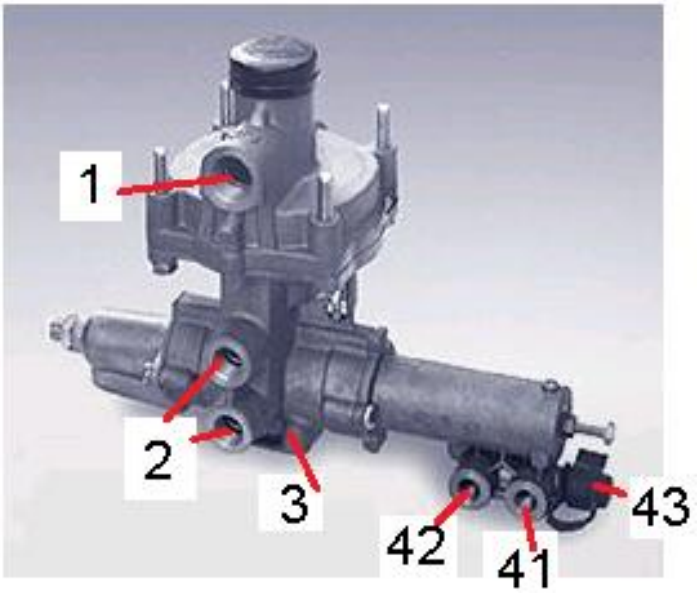
Principle:	By pushing down the chassis, the LSV will react as well as a higher Friction Force will be generated;
Advantages:	Real load simulation – the Load Sensing Valve as well as the suspension system of the vehicle is activated and reacts as a laden vehicle, easy to retrofit.
Disadvantages:	Setup time and space needed, not always possible because the inspection pit.
Remarks:	Only applicable when the vehicle has a load platform.

3. Chassis load simulation: pulling on the chassis of the vehicle

By using a pulling device, the vehicle can be pulled down. Usually there are one or more hydraulic cylinders located in the inspection pit. Each cylinder can be hooked up to the chassis via chains and claws. In many cases, the hydraulic cylinder is mounted on rails and thus movable. In the examination of tandem axles, the claws can stay on the chassis once fitted.
With a remote control to pulling down action is commanded (hydraulic cylinders). Due to the rail system axle by axle can be tested by pulling down and releasing the action and moving to the next axle without any action in the inspection pit.

Principle:	By pulling down the chassis, the LSV will react as well as a higher Friction Force will be generated.
Advantages:	Real load simulation – the Load Sensing Valve as well as the suspension system of the vehicle is activated and reacts as a laden vehicle, easy to retrofit, low-priced; By using rails, it doesn't require to be moved or fitted for each axle on the vehicle.
Disadvantages:	Time intensive because of setup time. There could be danger to damage the chassis.
Remarks:	Sometimes difficult or even impossible to fix installation on the vehicle. *Note:* *To avoid structural damage on vehicle parts, it must be ensured, that the fixing point on the vehicle is capable to bear the necessary forces.*

4. Raise the brake actuator pressure by opening the load sensing valve (LSV)



Example of connections on a pneumatically operated LSV (ISO-8786)
1: supply of energy
2: energy delivery
3: exhaust port
4: control port (device inlet)
41: air suspension
42: air suspension
43: test connection (simulation)

Connect air pressure on the simulation valve of the LSV (connection P43). The P41 and P42 connections of the LVS, the normal pilot pressures of the LSV, are at that moment cut off. The LSV will only react by the pressure from the simulation valve P43. Send a pilot pressure that corresponds to the loaded condition of air spring via the simulation valve P43. The LSV will react as if the vehicle was laden.

Principle:	By simulating the air spring pressure of the laden vehicle via the simulation valve of the LSV, a higher brake actuator pressure can be reached.
Advantages:	Brake system of the vehicle reacts as a loaded vehicle.
Disadvantages:	Setup time, external air pressure needed. No gain in friction Force because of no extra load on the axle.
Remarks:	Not every LSV valve has a simulation valve included; in this case separated simulation valve should be integrated in the brake system of the vehicle. There is no gain in Friction Force, so in combination with a system where a Friction Force gain system (7, 8 or 9) is installed, the best load simulation can be met.

5. Raise the brake actuator pressure by putting the raise/lower valve in the blocked lowering position

Block the Raise/Lower Valve in de lowering position. In certain cases, the Load Sensing Valve will react as if the vehicle is fully laden.

Principle:	The brake- and suspension system of the vehicle can be in certain cases combined as following. The piloting pressure from the Load Sensing Valve is taken on the one hand from the Air Spring pressure and on the other hand from the Levelling Valve. By putting the Raise/Lower Valve in the lowering position, the Levelling Valve will try to send air to the Air Spring in order to put the vehicle higher in the driving condition. The Air Spring will not get this air because on his way, the air is blocked by the Raise/Lower Valve. But by having a connection from the Levelling Valve to the piloting pressure of the LSV, the pressure from the suspension reservoir will be the piloting pressure of the LSV. So, the LSV and the brake system of the vehicle will react as if the vehicle was fully laden.
Advantages:	Brake system of the vehicle reacts as a loaded vehicle; Easy to manage; Fast to use.
Disadvantages:	No gain in Friction Force.
Remarks:	Works only when one of the piloting pressures from the Load Sensing Valve is taken from the Levelling Valve – it is not always clear which vehicle has his LSV and suspension system integrated in this way; There is no gain in Friction Force, so in combination with a system where a Friction Force gain system (7, 8 or 9) is installed, the best load simulation can be met.

6. Raise the brake actuator pressure by disconnecting the EBS

Brake with the contact switched off, or with the EBS alimentation cable disconnected in case of a towed vehicle.

Principle:	When the EBS has no alimentation, certain EBS systems will react, when braking, as if the LSV-function is in a fully laden condition.
Advantages:	Brake system of the vehicle reacts as a loaded vehicle.
Disadvantages:	No gain in Friction Force.
Remarks:	Reaction depends on the EBS system. Not all EBS systems have the same behaviour. There is no gain in Friction Force, so in combination with a system where a Friction Force gain system (7, 8 or 9) is installed, the best load simulation can be met.

7. Conventional axle load simulation: pulling down the axle

Chains or mounting straps are to be fitted to each axle before the brake test. The pulling down of the axle is then done with a fix or movable hydraulic cylinder. Chains or straps are to be removed again before moving the vehicle forward. Operation must be repeated for each axle.

Principle:	Pulling down an axle will create a higher vertical force and thus a higher Friction Force.
Advantages:	Easy installed or retrofitted in inspection pit.
Disadvantages:	Setup time; The use of chains could give a danger to damage the axle or tubes and wires that are fixes on the axle. The maximum pulling force should not exceed 50% of the maximum axle.
Remarks:	Due to the simulated load applied to the axle, the Load Sensing Valve as well as the suspension system of the vehicle is not activated nor tested.

8. Axle load simulation: lifting up the tested axle

This is a load simulation by a lift-able roller set. The brake tester can be raised and controlled via remote control. There are brake testers with horizontal lift-able roller sets and other with inclinable roller sets who turns around a fixed point.

Principle:	Lifting a tandem- or tridem-axle the weight from this group will be transferred to the one lifted axle.*
Advantages:	Quick setup time.

	no connection to the vehicle is required.
Disadvantages:	price; can only be used for tandem- or tridem-axles.
Remarks:	It is recommended not to use the system until the axle is completely lifted from the ground in order not to damage the air spring when he rolls back over his seat by the action lifting down; Due to the simulated load applied to the axle, the Load Sensing Valve as well as the suspension system of the vehicle is not activated nor tested; The vehicle brake system will only react towards the higher mass (higher brake actuator pressure) when on the lifted axle the levelling valve (air suspension) or the mechanical Load Sensing Valve LSV (mechanic suspension) is mounted, in the other cases the gain will be only a higher Friction Force. **Note:* *If the test bench can lift and brake the wheels of an axle one after the others, it is possible to higher the load of the actually measured single wheel with the load from the load of the actually not measured wheel (depending on the stiffness of the chassis). Therefore, it is possible to achieve higher brake forces also on single axle aggregates without the use of any pulling down equipment.*

9. Alternative to the conventional axle load simulation: by fixing the chassis or axle to the floor/pit and lifting the roller brake tester

Chains or straps are to be fitted to the chassis or axle before the brake test. The roller set is then raised. Chains are to be removed again before moving the vehicle forward. Operation must be repeated for each axle.

Principle:	Pulling down an axle will create a higher vertical force and thus a higher Friction Force.
Advantages:	Flexibility by using only the lifting system, or the fixing and lifting system.
Disadvantages:	Costly to install or retrofit.
Remarks:	In some cases, the vehicle frame instead of the axle can be fixed; Due to the simulated load applied to the axle, the Load Sensing Valve as well as the suspension system of the vehicle is not activated nor tested. *Note:* *To avoid structural damage on vehicle parts, it must be ensured, that the fixing point on the vehicle is capable to bear the necessary forces.*

10. Reversed turning brake rolls

In this case, the vehicle is tested wheel by wheel while the rollers from one side turn in opposite direction in comparison with the rollers from the other side. The brake force from the wheel that turns forward is measured. The brake force from the other wheel is measured in a second brake action when the both roller sets turn in the other direction as in the first set.

Principle:	In a normal roller brake tester, the tested axle has the intension to climb up against the second roller. When the axle does this, the commutation roll, will stop the brake tester. Therefore, the second roller is sometimes placed higher. By having reversed turning rolls the axle will be more having the intention to stay in the rollers, and thus a higher brake force than with a normal brake tester can be attaint.
Advantages:	Small gain on brake actuator pressure and corresponding brake force.
Disadvantages:	Brake test must be done wheel per wheel (double time required); brake tester software should be adopted to this test; The gain in a minimum but could be sufficient to get the required brake actuator pressure.
Remarks:	Helpful by testing parking brakes, during the test of the service brake, the vehicle is fixed on the floor, because all wheels brake.

Tools to increase the friction force (adhesion) can be used in combination with those to increase the brake actuator pressure, or visa-versa.

Overview of the different tools used in PTI to increase either the friction force (adhesion), either the brake actuator pressure, or both

		Friction Force	Brake actuator pressure	Setup time
1	Presenting the vehicle with a partial load	++	+	0
2	Chassis load simulation: Applied to chassis from top-down	++	+	++
3	Chassis load simulation: Pulling on the chassis of the vehicle	++	+	++
4	Raise the Brake Actuator Pressure by opening the LSV valve (Load sensing valve)	0	+	++
5	Raise the Brake Actuator Pressure by putting the Raise/lower valve in the blocked lowering position	0	+	+
6	Raise the Brake Actuator Pressure by disconnecting the EBS	0	+	+
7	Conventional Axle Load Simulation: Pulling down the axle	++	0	++
8	Axle load simulation: Lifting up the tested axle	++	0	+
9	Alternative to the Conventional Axle Load Simulation: Pulling down the axle, by fixing the chassis or axle and lifting the roller brake tester	++	+	++
10	Reversed turning brake rolls	+	0	+

Depending on national legislation and boundary conditions, these tools may also be combined.

6.2.1.2.1. One-point calculation

This is an extrapolation method requiring only a single braking force measurement for each wheel/axle. The test shall be carried out with the highest achievable braking forces with the corresponding brake actuator pressure beneath the locking limit of the wheels.
This generates the highest braking forces without too high wheel slip on the rollers.
The one-point measurement is possible since the starting point is standardized at 40 kPa and this assumes a fixed value for all brake threshold pressures. The measured braking forces at each axle shall then be extrapolated to the minimum design pressure p_{Aladi}. The braking rate of the vehicle is given laden by the follow formula:

$$z_{\text{Mlad}} = \frac{\sum F_{\text{Bi}}}{F_{\text{max}}}$$

in case of motor vehicle

$$z_{\text{Rlad}} = \frac{\sum F_{\text{Bi}}}{F_{\text{Rmax}}}$$

in case of towed vehicle

Where : $F_{\text{Bi}} = F_{\text{i}} R_{\text{pi}}$

and : $R_{\text{pi}} = \frac{P_{\text{Aladi}} - 0{,}4}{P_{\text{Ai}} - 0{,}4}$

Note: For a correct calculation the brake actuator pressure reached before blocking the wheels shall correspond to point 6.2.1.2.

6.2.1.2.2. Two-point measurement method

The starting point is not standardized. The braking force shall be measured at a low brake actuator pressure a little above the threshold point where braking force can be measured. The second (main) measurement shall be performed with the highest applicable braking forces with the corresponding brake actuator pressure beneath the locking limit of the wheels.
Again, the measured braking forces at each axle shall be extrapolated to the minimum design pressure.

The laden braking rate is given from:

$$z_{\text{Mlad}} \text{ or } z_{\text{Rlad}}$$

$$F_{\text{Bi}} = F_{\text{Hi}} + R_{\text{Fi}}\left(P_{\text{Aladi}} - P_{\text{AHi}}\right)$$

$$R_{\text{Fi}} = \frac{F_{\text{Hi}} - F_{\text{Li}}}{P_{\text{AHi}} - P_{\text{ALi}}}$$

Note: For a correct calculation the brake actuator pressure reached before blocking the wheels shall correspond to point 6.2.1.2.

6.2.1.2.3. Multi-point measurement method

The laden braking rate may also be achieved by extrapolating multiple measurements of braking forces and actuator pressures using least square numerical methods.

6.2.1.2.4. Reference brake forces

Reference Braking Forces as described in the UNECE R13 mean the braking forces of one axle generated at the circumference of the tyre on a roller brake tester, relative to brake actuator pressure and declared at time of type approval. These are described in detail in points 5.1.4.6. to 5.1.4.7.1. of R13.

The measured braking forces and corresponding actuator pressures shall be compared with the reference braking forces for evaluation purposes.

Note:
For a correct brake testing it might be appropriate to provide a minimum pressure for the reference braking force method, in which the wheels may block at the earliest. In Germany a pressure of 1.7 bar is required. The 1.7 bar does not have to be reached if the reference braking force of 1.7 bar has been already reached at a braking pressure below 1.7 bar.

6.2.1.2.5. RD-method

In Belgium for each vehicle braking forces of one axle generated at the circumference of the tyre on a roller brake tester, relative to brake actuator pressure are calculated for each axle and the vehicle (RD-lines). The calculation considers that the linear behaviour zone of the brake measurement is not covered beneath braking ratio of 10% of a fully laden vehicle and that the distribution of braking among the axles of vehicles.

The measured braking forces and corresponding actuator pressures shall be compared with the calculated RD-lines for evaluation purposes.

6.2.2. Measurement in Road Test

Usually the braking efficiency shall be measured on a roller or plate brake tester. But in the following cases a measurement in a road test is valid:

- Vehicles for which testing on a roller or plate brake tester is not possible for reasons related to the chassis geometry or other vehicle-specific reasons,
- Vehicles designed to have a maximum speed of ≤ 40 km/h,
- Agricultural or forestry vehicles, including any attached machinery, in accordance with Article 2, Points j, k and l of Directive 2003/37/EC (vehicle classes T, R and S),
- Motorcycles with and without sidecars, quads and trikes depending on the type of the braking test device.

When braking on the road, it shall be checked whether the vehicle reaches the prescribed minimum deceleration about permissible total mass.

For the direct determination of the brake efficiency of the vehicle a deceleration recording instrument (decelerometer) shall be used. Only in justified cases (e.g. if correct placement of the brake-measuring device is not possible due to the design of the vehicle, e.g. with motorcycles, or if all braked wheels are locked on a non-slip, dry road surface), then the braking efficiency may be assessed without a recording brake-measuring device; this must be documented in the appropriate inspection report.

For the road test following conditions must be observed:

(1) The test site must be sufficiently secured against the possibility that persons, vehicles, animals etc. enter it. Objects or other obstacles which could endanger the road test must not to be present. No persons are allowed to stay in the intermediate proximity of the vehicle or it´s supposed trajectory during the road test. The surface of the site must be asphalt, concrete (cement) or other material with similar qualities; the site surface must not have considerably worsened adhesive qualities (such as icy, covered with snow etc.) during the test.

(2) It is possible to carry out the road test only after all the other inspection items that are part of the PTI were finished and no defect that could endanger the safety of the test was detected.

(3) During the road test, the vehicle is driven by the inspector or the vehicle´s driver following the inspector's instructions. In that case, the driver must be familiar with the safety of the road test principles.

(4) In case of an air-pressure or combined brake system (air over liquid), the pressure must be supplemented to the level that corresponds with the prescribed working pressure (the required air pressure is in general achieved as soon as the pressure regulator releases the excess pressure).

(5) In case of the T category vehicles with two-pedal service brake handling, the simultaneous operation of both pedals must be secured by a latch. In case of T category vehicles with one-pedal handling, the lever of the hydraulic distributor must be in the central position.

The process of the road test with the use of the decelerometer:

(1) The decelerometer is placed in the vehicle or fastened according to the instructions of use.

(2) The vehicle after setting in motion from the starting point accelerates to the initial speed of measurement. The intensity of the speed of measurement is set according to immediate conditions of measurement and state of the site in a way that the safety of the trial is not endangered and that it is possible to stop the vehicle safely before the trial site ends. It is considered that a speed higher than 20 km.h^{-1} is a sufficient initial speed.

(3) Immediately before starting to brake, the inspector (vehicle driver) turns off the clutch (in case of manual transmission vehicles) and intensively steps on the service brake pedal. While doing that he must pay attention to the fact that the vehicle – as the circumstances allow – braked shortly before the wheel-blocking limit. The vehicle is braked until it stops completely.

(4) Afterwards, the mean fully developed deceleration (MFDD) or the braking ratio gained by the service brake is identified (measured by the deceleration recording device) as well as the possible deviation from the straight drive direction during the braking process.

(5) From the value of the MFDD, the equivalent deceleration value is calculated by the

$$Z = \frac{a}{g} \cdot 100\%$$

relation

(%),

in which the meaning of the symbols is as following:
a – MFDD of the vehicle that was reached by the service brake in (m.s^{-2}),
g – gravitational acceleration (≈ 9,81 m.s^{-2}).

In case the decelerometer directly indicates the deceleration, value this indicated value is used and there is no need to carry out the calculation.

(6) The value of the calculated deceleration or the value of the measured deceleration is compared to the prescribed value for the given vehicle.

Note: Where available, the detection of brake force distribution front/rear and left/right (e.g. by interpretation of the six degrees of freedom), and of reference values should be used.

6.2.3. Measurement on plate brake tester

6.2.3.1. Laden measurement method

The braking rate shall be determined directly by measuring the braking forces for the vehicle in the laden condition.
The laden braking rate calculation requires no extrapolation, being simply given by the following formula:

$$z_{\text{Mlad}} = \frac{\sum F_{\text{i}}}{F_{\text{Mmax}}}$$

in case of motor vehicle

6.2.3.2. Reference brake forces

Reference Braking Forces as described in the UNECE R13 mean the braking forces of one axle generated at the circumference of the tire on a roller brake tester, relative to brake actuator pressure and declared at time of type approval. These are described in detail in points 5.1.4.6. to 5.1.4.7.1. of R13.

The measured braking forces and corresponding actuator pressures shall be compared with the reference braking forces for evaluation purposes.

In Germany, plate brake testers measure the brake force of each wheel and calculate the mean value of brake forces between 5 to 2 km/h.
With a PTI-Scan-Tool, it is possible to read out an equivalent value to brake pressure as reference value.
These measured values must be also calculated to mean value between 5 to 2 km/h.
The calculated mean brake forces and the calculated mean reference value shall be compared with the reference braking forces.

6.3. Assessment of Brake Efficiency

6.3.1. Efficiency

6.3.1.1. Air Brakes

METHOD FOR THE PTI OF BRAKE EFFICIENCY OF HEAVY VEHICLES

To avoid premature locking of the wheels on the roller brake tester, most vehicles will have to be tested fully or partly loaded or with some kind of artificial load.

Premature locking can still occur especially in wet conditions. A "lock allowance" could then be applied in order to avoid failing vehicles with sufficient brake efficiency.

To minimize the risk for tyre damage, ISO standard 21069 point A.1.9.2 should be fulfilled.

Note:

Air pressure gauges should have an adequate resolution and an accuracy in accordance with Standard ISO 21069 point A.3.3. Connectors should correspond to ISO 3584:1984 which specifies the standardized measuring points in the air pressure system of heavy vehicles. Connectors for measuring air pressure at the trailer coupling should also be available.

Note 1: The service line air pressure should be measured as close to the wheel brake cylinders as possible. There should be no reduction valve (e.g. load-sensing valve) between the measuring point and the brake cylinders of the axle to be tested. The load-sensing valve is assumed to function properly; it can be checked separately.

Note 2: PTI-Scan-Tool can read out a comparable signal for the brake pressure as functional signal / reference value.

Note 3: The air pressure may be measured at a point further away from the wheel brake cylinders (e.g. the trailer coupling connections) if the load-sensing valve is set to open fully. Also, if there is an air pressure increasing valve before the trailer coupling, its effect must be considered.

Note 4: The measurement should be based on the highest possible service brake pressures.

1. Reference Brake Forces

a. CONNECT AIR PRESSURE GAUGES AT SUITABLE MEASURING POINTS OR CONNECT PTI-SCAN-TOOL

b. MEASURE BRAKE FORCES AND CORRESPONDING AIR PRESSURE OR USE FUNCTIONAL SIGNAL FOR AIR PRESSURE JUST BEFORE WHEELS LOCK, AXLE BY AXLE

c. EVALUATION OF THE MEASUREMENT

If the measured brake forces are higher or equal to the reference values for the measured pressure / corresponding functional signals for air pressure, the brakes are in proper conditions.

2. Calculation Method (One- or Two- Point)

a. CONNECT AIR PRESSURE GAUGES AT SUITABLE MEASURING POINTS OR CONNECT PTI-SCAN-TOOL

b. MEASURE BRAKE FORCES AND CORRESPONDING AIR PRESSURE OR USE FUNCTIONAL SIGNAL FOR AIR PRESSURE JUST BEFORE WHEELS LOCK, AXLE BY AXLE

Note: If the wheels lock before the air pressure has reached one third of full service line air pressure, or an alternative limit of 2 bar, extrapolation is not advisable and load simulation is advisable.

c. CALCULATION OF MAXIMUM BRAKE FORCES

Calculate maximum brake forces for each axle according to standard ISO 21069 point 4.3.2 and 4.3.3.
For calculation, it can be useful to use a computer or a computer aided roller brake tester, where both brake forces and corresponding air pressures/functional signals for air pressure are registered and processed automatically.

3. <u>Laden measurement method</u>

a. MEASURE BRAKE FORCES JUST BEFORE WHEELS LOCK, AXLE BY AXLE

b. CALCULATION OF MAXIMUM BRAKE FORCES

Sum the brake forces of each axle and relate it to the gross vehicle weight.

6.3.1.2. Hydraulic brakes

1. <u>Reference Brake Forces</u>

a. CONNECT PTI-SCAN-TOOL

Note: PTI-Scan-Tool can read out a comparable signal for the Brake pressure as functional signal / reference value.

b. MEASURE BRAKE FORCES AND USE CORRESPONDING FUNCTIONAL SIGNAL FOR HYDRAULIC PRESSURE JUST BEFORE WHEELS LOCK, AXLE BY AXLE

c. EVALUATION OF THE MEASUREMENT

If the measured brake forces are higher or equal to the reference values for the measured pressure/corresponding functional signals for air pressure, the brakes are in proper conditions.

Additionally, the calculation of the brake force distribution between the axles can easily be done and compared to specified values from the manufacturer.

2. <u>Laden measurement method</u>

Note: In many cases including laden conditions, it could be impossible to achieve high enough values. The reason is that passenger cars normally can be loaded mainly on the rear axle. However, the front axle achieves the higher brake forces on road. To increase the load on the rear axle by loading takes significant time and therefor it does not seem to make sense in all cases.

a. MEASURE BRAKE FORCES JUST BEFORE WHEELS LOCK, AXLE BY AXLE
b. CALCULATION OF MAXIMUM BRAKE FORCES

Sum the brake forces of each axle and relate it to the gross vehicle weight.

6.3.1.3. Inertia/Overrun Brakes

The efficiency of the inertia/overrun brake system shall be tested on a roller brake tester by using the actuation device for the parking brake system. The minimum deceleration specified for parking brake systems or the locking limit shall be achieved.

If the brake test on a roller brake tester does not yield usable measurement results, then an inspection shall be performed during a road test. The use of a recording brake-measuring device is not necessary here. The brake inspection by means of a road test must be documented and substantiated in the inspection report, regardless whether the road test had to be performed due to non-usable measurement results on a braking test bench or for reasons relating to the chassis geometry or for other vehicle-specific reasons.

6.3.2. Distribution of Brake Force Left-Right per Axle

Braking effort from any wheel less than 70% of the maximum effort recorded from another wheel on the same axle should be considered as a reason for failure of the vehicle. Or, in the case of testing on the road, the vehicle deviating excessively from a straight line.

6.3.3. Distribution of Brake Force between the Axles

The correct Brake Force distribution between the brakes of the axles is not only relevant for a short braking distance or the driving stability. It is also very important for the functionality and efficiency of electronic controlled systems, for example ESC. If there are any threshold values from manufacturer or according to national legislation, the vehicle must reach them. If not, the PTI inspector should evaluate this with his technical experience.

6.3.4. Uniformity Fluctuation of Brake Forces

The inspection of uniformity of brake force is usually performed as a part of the brake test. The inspection is carried out by observing the brake force on each wheel placed in the roller brake tester. Measurement is recommended especially when fluctuation of the brake force appears.

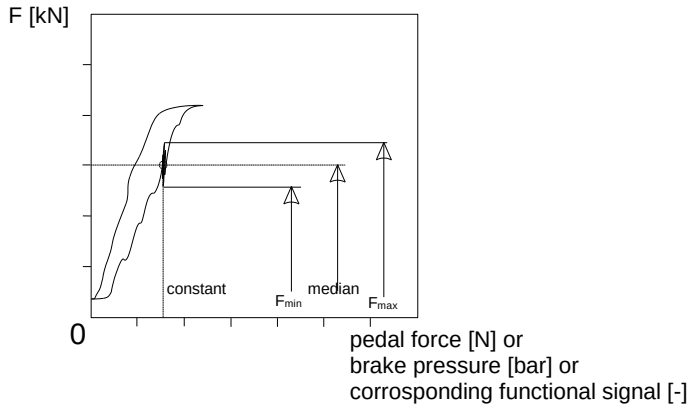
Note: Uniformity of brake force can be measured only by using roller brake tester (RBT).

1. At the moment of fluctuation of the brake force, check the value of pedal force (or brake pressure in case of pure air or air over hydraulic brake system).

2. Hold the pedal force (or brake pressure) at the constant value at which the fluctuation of the brake force was detected.

Note: Some RBT use automatic timer indicating the period when the pedal force should be constant.

3. Measure the maximum and minimum brake force during one-wheel revolution according to the graphical explanation:



4. Compute the percentage of the brake force fluctuation according to the formula:

$$f_F = \pm \frac{F_{max} - F_{min}}{F_{max} + F_{min}} \cdot 100$$

f_F – fluctuation of brake force from the median value (%)
F_{max} – max. value of brake force at the constant pedal force (or brake pressure) during the wheel revolution
F_{min} – min. value of brake force at the constant pedal force (or brake pressure) during the wheel revolution

5. Apply on each wheel (on which fluctuation was detected) and compare results with limit values.

Recommended limit for fluctuation of the brake force is ±10% from the median value (for unladen trailers or semitrailers ±15% is considered as acceptable).

If the fluctuation of the brake force on any wheel exceeds limit value, the vehicle should be failed.

7. EQUIPMENT

7.1. Roller Brake Tester

Note:
Values for roller brake testers for heavy vehicles (≥ 3500 kg GVM) are un-bracketed; those for light vehicles are in brackets.

1. *Brief Description*

Roller brake testers are required on test lanes where heavy vehicles are inspected.

Roller brake testing machines consist of two pairs of rollers on which the road wheels of an axle are placed during test. The braking force produced by the road wheels is converted directly into an indication of braking effort.

2. Required Features

2.1. Allowable load per axle
The maximum allowable axle weight should not be less than 13 000 kg (2500 kg).

2.2. Roller diameter
The diameter of the rollers should not be less than 200 mm (150 mm).

2.3. Roller length
The roller length should not be less than 900 mm (600 mm).

2.4. Distance between the pairs of rollers
The distance between the inside edges of the pairs of rollers should not exceed 1 m (0,9 m).

2.5. Friction coefficient
The friction coefficient should be more than 0.7.

2.6. Start and stop

There must be manual means of starting of the rollers. In countries where automatic means of starting is permitted, this can also be provided.

If there is an automatic start function, there must be a short time lag after the vehicle axle has been placed on the roller tester before the rollers are started.

The rollers must stop automatically when the vehicle axle leaves the roller tester. A manual stop function must also be available.

The rollers must stop automatically if there is a relative difference of speed (slip) between the rollers and vehicle wheels more than 27% ± 3%.

2.7. Accuracy

Roller brake testers for heavy vehicles must fulfil standard ISO 21069 point A.3. Roller brake testers for light vehicles should fulfil these requirements likewise.

(The maximum error at any point must not exceed +/- 5% of the actual value and +/- 3% of the full deflection. The maximum error requirements do not indicate a stricter condition than the resolution requirements below.

When the brake force for each wheel of an axle is the same, the indication from both measuring devices must not differ by more than 2.5% of the highest indication and maximum 1.5% of full-scale deflection.)

2.8. Measurement range and resolution

With analogue display of measured brake forces the range per wheel shall not exceed 45 000 N (7500 N).

The resolution, whether the display is analogue or digital, shall not be less than 100 N in the range up to 5000 N and not less than 500 N above that limit. The display shall be readily visible to the inspector when seated in the driving seat of the vehicle being inspected.

2.9. Point zero

It must be possible to set the zero point of the brake force display without a vehicle axle on the rollers. The roller resistance measured with a vehicle axle on the rollers shall be indicated as a force and not be basis for a new setting of the point zero.

2.10. Calibration

It must be possible to calibrate the roller brake tester over the full measurement range, including the zero reading, with a suitable device with or without rollers turning at idle.

2.11. Testing speed

The testing speed should be in the range 2 km/h to 5 km/h.

2.12. Optional supplementary features

If requested by the purchaser, the following features should be available for the use in conjunction with the roller brake tester.

1. Needle lock or dead-beat pointer. For digital displays a "freeze" function.

2. Provision for the connection of an additional indication unit at up to 20 m distance from the roller unit.

3. Means for changing to a lower measurement range and a smaller distance between the rollers for inspection of lighter vehicles. (Applies to roller brake testers for heavy vehicles).

4. Possibility to run one set of rollers in the opposite direction to the other set of rollers to enable testing of vehicles with multi-axle drive.

5. Automatic stop function triggered when a person is in the pit or close to the rotating rollers.

6. Automatic calculation and indication of imbalance between brake forces of wheels on the same axle.

7. Automatic calculation and indication of brake force variations in one wheel (ovality).

8. Measurement and indication of service line pressure at the trailer coupling or at a measuring point on the vehicles.

9. Recording of brake forces and corresponding service line pressure. Calculation of deceleration at gross vehicle weight (GVW) or at a weight at which the vehicle comes to inspection. Such an option requires possibilities according to point 8.

10. Graphical presentation, axle by axle and for the whole vehicle of the brake applications recorded on the roller brake tester. For the axle by axle presentation an air-pressure to brake force graph is suitable. For the whole vehicle an air-pressure to deceleration graph is recommended.

11. Electronic interfaces to PC to enable further data processing.

7.2. Plate Brake Tester

Note: REQUIREMENTS FOR PLATE BRAKE TESTERS FOR LIGHT VEHICLES
(GVW ≤ 3500 kg GVM).

1. *Brief Description*

A plate brake tester may consist of one or two pairs of measuring plates or a single plate device for motorcycles. Each measuring plate consists of a floor mounted chassis and of a movable upper plate, which moves horizontal in driving direction.

The moving plate with a high friction surface is connected to the chassis via a force transducer, which in turn is connected to the control computer. The control computer outputs the measurement results via a screen or a printout. A vehicle is driven over the plate(s) and the brake force measured by the sensor is recorded with the result displayed on the screen. An option to print the test results is available.

The main advantage of a plate brake tester is that it can be surface mounted with minimal civil engineering requirements.

2. General

The following definitions shall apply in the context of this paragraph:

a. **Plate brake tester:** measuring equipment to test a vehicle's brake efficiency by measuring the wheels' brake force when the vehicle brakes on flat and horizontal measuring plates;
b. **Braking force:** horizontal force, without any peak value at the beginning or end of the test on the measuring plates of the plate brake tester transferred from a vehicle rotating wheel because of the activated brake system. Peak values should be excluded by algorithm defined by national requirements

c. **Resulting measured value:** the value presented as the final outcome of the braking test;
d. **Measuring period:** the period during which there is braking force.

3. Required Features

3.1. Mechanical Parts

The plate brake tester shall consist of two pairs of plates and should be designed to test the brake system of all vehicles with a GVW not exceeding 3500 kg and to withstand a test speed of 10 km/h.

The plates shall have such dimensions and be placed in such a way that it is possible to get a sufficient braking distance for all vehicles that are tested on the plate brake tester. This demand is fulfilled if all wheels get at least 1.3 m braking distance. It should also be possible to measure each wheel on the same axle separately.

The surface of the plates must admit a friction coefficient between plate and tire of at least 0.8 under dry conditions and 0.6 under wet conditions.

3.2. Accuracy

The maximum positive or negative error of the static braking force reading is:

- if the force is 2500 N or lower: 100 N,
- if the force is over 2500 N: 4% of the actual braking force.

If the brake force for each wheel of an axle is the same, the indication from both measuring devices must not differ by more than 2.5% of the highest indication and maximum 1.5% of full-scale deflection.
The resolution shall be equal to or better than 20 N.
If the PBT is equipped with an integrated pedal force meter (PFM). The integrated PFM shall meet the requirements described in the paragraph 8.5 must be equipped with a stop mechanism.
The measurement system must not be influenced by electromagnetic interference. The plate brake tester including all possible peripheral equipment shall comply with the stated accuracy and with the EMC directive 89/336/EEC.

The manufacturer of the tester must state in which temperature range the accuracy is warranted. The temperature range should be stated on the instrument in a visible place (e.g. date plate).

The temperature tests in the stated temperature range are performed according to OIML ID 11.

3.3. Dynamic Test

The measuring plate is pushed (or pulled) loaded with half the maximum load as stated by the manufacturer. The push (or pull) force is recorded and compared with the force recorded by the plate brake tester. During this test the force readings may not exceed 4 times the maximum error. Alternatively, the test is performed by injection of electric signals at an appropriate point of the input circuitry. The maximum error in the time should not exceed 0.1 s. The reaction time of the plate brake tester shall be less than 0.1 s.

The manufacturer must provide a comprehensive instruction manual with adequate information.

3.4. Software

The software must be secure against accidental changing of variables influencing the measured values (e.g. calibration factors) by the user. A security code is an acceptable solution.

3.5. Calculation of the Test Result

The brake force shall be calculated as an RMS (Root Mean Square) brake force.

3.6. Point Zero

It must be possible to set the zero point of the brake force display manually or it must be set automatically.

3.7. Calibration

It must be possible to calibrate the plate brake tester over the full measurement range with a suitable device.

3.8. Measurement Frequency

The measured values that are the basis for the calculated test result shall be collected with a frequency of not less than 100 Hz. Anti-aliasing filters shall be provided.

3.9. Testing Speed

The test speed is approximately 10 km/h, but it could be useful to test also at higher speeds e.g. for testing antilock systems (ABS) where the tester and the facilities are designed for higher speeds.

3.10. Presentation of the test result

The presentation of the final result of the brake test shall include:

- Brake force for each wheel (N);
- Difference between left and right wheel of front and rear axle (%);
- Brake forces versus time for each wheel in a diagram (N/s);
- Brake forces for the parking brake (N).

The results can be presented on a display or as a printout. In the former case the results must remain on the display for at least 15 s.

The results shall be stored until the next test starts.

It is recommended that the computer automatically compares the test results with the legal limits and presents the final result (approved/failed) for:

- Uneven braking effect;
- Deceleration;
- Parking brake.

Note: For these calculations, the vehicle weight is required. It is recommended that there is a built-in weighing device available as a recommended option. If a built-in weighing device is not specified, it must be possible to enter the actual or estimated vehicle weight.

4. Optional Features

The following features should be available for the use in conjunction with the plate brake tester.

4.1. Testing components

4.1.1. The plate brake tester must be a device to reliably and safely simulate static braking force by applying force on the force recording system.

4.1.1.1. The plate brake tester must be equipped with the following testing components:

4.1.1.2. a testing connection which will be used for confirmation of correct operation of the Plate Brake Tester (PBT) during calibration providing the facility to automatically or manually simulate a braking force prior to the measurement;

4.1.1.3. a system that automatically or manually by the user simulates a braking force prior to the measurement.

4.2. usage of functional signal for brake pressure as reference value

4.3. Pedal force meter indicating the maximum pedal force used

5. Education

Users of plate brake testers must have an adequate education and be familiar with the manufacturer's manual.

7.3. Deceleration Recording Device

7.3.1. Use case

'Pendulum' and 'U-tube' decelerometers may be useful for quick checks, but electronic accelerometers are now used with portable data-logging systems;
By recording the instantaneous deceleration as a time series, variation during a brake application can be examined so that in-stop characteristics can be quantified;
Deceleration recording devices without a pitch- correction shall be mounted near to the vehicle's centre of mass to minimize pitch errors caused by weight transfer during braking (or acceleration).

When Roller brake testers or plate brake testers are not suable for availability or if they are not usable according the vehicle characteristics (to large, to heavy, too old…), an alternative solution is available with a deceleration recording device (Service brake and emergency brake).
A road test using a deceleration recording instrument can establish the braking ratio which relates to the maximum authorized mass or, in the case of semi-trailers, to the sum of the authorized axle loads. Vehicles or a trailer with a maximum permissible mass exceeding 3,5 tons has to be inspected following the standards given by ISO 21069 or equivalent methods.
Road tests should be carried out under dry conditions on a flat, straight road.
Deceleration recording device should comply with the following vehicles categories:
(values are mentioned in the directive 2014/45/EU)

- M1, M2
- N1, N2
- O2, O3, O4, semi-trailers and draw-bar trailers
- L (both brakes together): L1, L2e, L3e, L4e, L6e,
- L (rear wheel brake): L5e, L7e
- T5

7.3.2. Main requirements

In order to make sure that the measurement is independent of the positioning of the device inside the vehicle the equipment measurement principle should be based on a 3D sensor technology.
Then the device could be placed wherever on the floor, on the dashboard, on the windscreen at a visible place. Use of suction pad is recommended.
Anyhow the equipment must offer a sound guidance during measurement feature.

Mandatory requirements:

- Measurement range: 0 to 2g (19.6 m/s^2)
- Sampling rate: 10 times per second minimum (50 recommended)
- Maximum error related to the measurement value in the range of 0.2 - 2.0 g: +/- 15%
- Complies with ISO/DTR13487 F
- Complies with EN 17025 standards

Note: Calibration uncertainty according to GUM should not exceed 5%.

Additional options:

- Display the speed during the test
- Acquisition triggering
  - Automatic triggering through detection of a configurable deceleration threshold
  - Or triggering through detection of a threshold on the connected pedometer
- Acquisition stop
  - Automatic stop through detection of a configurable deceleration threshold
  - Or stop through detection of a threshold on the connected pedometer
- Storage capacity: at least 10 test results
- Print out and/or network data result transmission
- Battery autonomy: 50 measurements + 50 printouts (where printer is part of the tool)
- usage of functional signal for brake pressure as reference value
- usage of the six degrees of freedom to judge brake force distribution front/rear and left/right

7.4. Manometers

Note:
The following specified requirements for manometers do not apply for vehicle internal data read out via a vehicle interface (e.g. by a scan tool)

Manometer used in the PTI must comply with national and international regulations and laws for measuring instruments. The following minimum requirements appear to be recommended for Compressed air:

- Measuring range: 0 - 16 bar
- Temperature range for measurements: 0 - 40°C
- Maximum measuring instrument error: +/- 0.16 bar

For hydraulic brake fluids:

- Measuring range: 0 - 200 bar
- Temperature range for measurements: 0 - 40°C
- Maximum measuring instrument error: +/- 2 bar

7.5. PTI Scan Tools

For an effective and efficient inspection of modern vehicle systems (see chapters 4, 5 and 6), the usage of the electronic vehicle interface via a PTI scan tool is necessary.

In the ECSS report the requirements for PTI scan tools have been elaborated.

8. INFORMATION / DATA

In PTI, vehicles are inspected in terms of the installation, condition, function, and the efficiency of its components and systems. For vehicles with electronically controlled safety systems (ECSS), these tests require additional vehicle manufacturer data/information concerning the assessment of these ECSS.

In the ECSS report (https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/projects_sources/ecss_final_report.pdf ; chapter 8.3), the necessary data/information have been elaborated.

For the European Union, there will be two pieces of legislation concerning the obligation of the vehicle manufacturers to deliver the data/information necessary for PTI:

(1) Obligations and requirements concerning delivery of data/information for independent operators, such as PTI, are already defined for M/N vehicles by Regulation (EC) No 715/2007 of the European Parliament and the Council and by Regulation No 595/2009 of the European Parliament and the Council.
Note: for other vehicle categories, comparable legislation exists.

(2) The European Commission is currently adopting an implementing act defining the set of technical information needed on the items to be tested and on the use of the recommended test methods of Annex I of Directive 2014/45/EU.

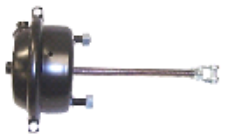
ANNEX 1

Slack Adjusters:

- Incorrect installation;
- Damaged or defective;
- Seized or having abnormal movement.
  Maximum movement for a drum brake:
  From the rest position to the braked position the stroke of compressed air brake cylinders must not be greater than 2/3 of the maximum stroke of the brake cylinder concerned. (See table 1)

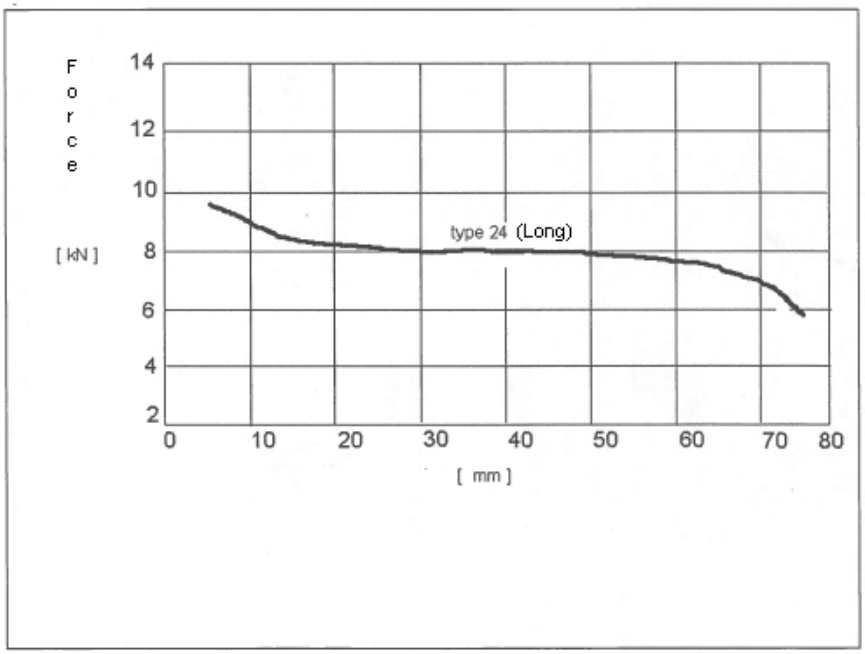
Short stroke version

Type (')	Stroke (mm)	D (mm)	2/3 stroke (mm)
12	45	148	30
16	57	160	38
20	57	172	38
24	57	184	38
30	64	205	43
36	76	230	51



Long stroke version

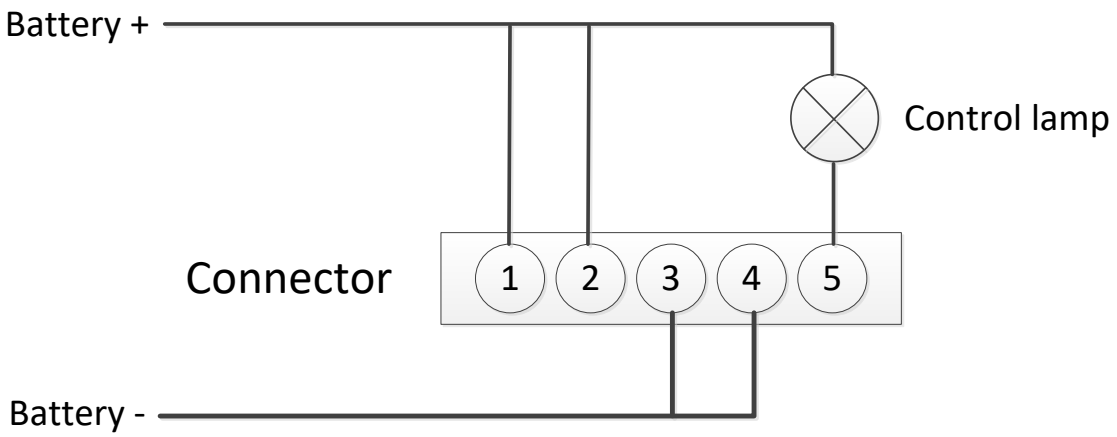
Type (')	Stroke (mm)	D (mm)	2/3 stroke (mm)
12	57	148	38
16	75	160	50
20	75	172	50
24	75	184	50
30	75	205	50
36	76	230	51



ANNEX 2

Example for a testing device to check the control light from a trailer ABS on ISO 7638 connection:

This device can be self-made according to the schedule below.



Battery + = 24 Volt connection
Battery - = Vehicle Mass
Connector = ABS/EBS connector on the trailer
Control Lamp = 24 V light bulb

Usage:

1. The connections 1, 2, 3, 4 and 5 must be combined into the ISO ABS/EBS-connector on the Trailer.
2. Connect the ABS/EBS connector to the Trailer.
3. Connect Battery + to a 24 Volt connection in the vehicle or an external power supply.
4. Connect Battery – to the vehicle mass or an external power supply.
5. The control Lamp must light up for a few seconds:
    a. If the control Lamp goes out the system is OK.
    b. If the control Lamp stays on, there is a DTC in the system.

An example: