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**ECONOMIC COMMISSION FOR EUROPE**

**INLAND TRANSPORT COMMITTEE**

**World Forum for Harmonization of Vehicle Regulations**

One-hundred-and-forty-eighth session  
Geneva, 23 - 26 June 2009  
Item 4.2.8 of the provisional agenda

**1958 AGREEMENT**

Consideration of draft amendments to existing Regulations

Proposal for Supplement 9 to Regulation No. 13-H  
(Brakes of M<sub>1</sub> and N<sub>1</sub> vehicles)

Submitted by the Working Party on Brakes and Running Gear \*/

The text reproduced below was adopted by the Working Party on Brakes and Running Gear (GRRF) at its sixty-fifth session. It is based on ECE/TRANS/WP.29/GRRF/2008/15, as reproduced in GRRF-25-23-Rev.1. It is submitted to the World Forum for Harmonization of Vehicle Regulations (WP.29) and to the Administrative Committee (AC.1) for consideration (ECE/TRANS/WP.29/GRRF/65, para. 13).

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\*/ In accordance with the programme of work of the Inland Transport Committee for 2006-2010 (ECE/TRANS/166/Add.1, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance performance of vehicles. The present document is submitted in conformity with that mandate.

Insert new paragraphs 2.34. to 2.34.3., to read:

- "2.34. "Brake Assist System (BAS)" means a function of the braking system that deduces an emergency braking event from a characteristic of the driver's brake demand and, under such conditions:
- (a) assists the driver to deliver the maximum achievable braking rate, or
  - (b) is sufficient to cause full cycling of the Anti-lock Braking System.
- 2.34.1. "Category A Brake Assist System" means a system which detects an emergency braking condition based on the brake pedal force applied by the driver;
- 2.34.2. "Category B Brake Assist System" means a system which detects an emergency braking condition based on the brake pedal speed applied by the driver;
- 2.34.3. "Category C Brake Assist System" means a system which detects an emergency braking condition based on multiple criteria, one of which must be the rate at which the brake pedal is applied."

Amend paragraphs 4.4.3 and 4.4.4., to read:

- "4.4.3. In the case of a vehicle complying with the Electronic Stability Control and Brake Assist System requirements of Annex 9 to this Regulation, the additional letters "ESC" shall be placed immediately to the right of the letter 'R' mentioned in paragraph 4.4.2.
- 4.4.4. In the case of vehicles complying with the Vehicle Stability Function requirements of Annex 21 to Regulation No. 13 and the Brake Assist System requirements of Annex 9 to this Regulation, the additional letters "VSF" shall be placed immediately to the right of the letter 'R' mentioned in paragraph 4.4.2."

Amend paragraph 5.2.24., to read:

- "5.2.24. Subject to the requirements of paragraphs 12.2. to 12.3., any vehicle fitted with an ESC system complying with the definition of paragraph 2.25. shall meet the equipment, performance and test requirements contained in Part A of Annex 9 to this Regulation."

Amend paragraphs 12.2. to 12.4., to read:

- "12.2. As from 1 November 2011, Contracting Parties applying this Regulation may refuse to grant national or regional type approval if the vehicle type does not meet the requirements of this Regulation as amended by Supplement 9 and is not fitted with an Electronic Stability Control System and a Brake Assist System, both meeting the requirements of Annex 9 to this Regulation.

- 12.3. As from 1 November 2013, Contracting Parties applying this Regulation may refuse first national registration of a vehicle which does not meet the requirements of this Regulation as amended by Supplement 9 and is not fitted with an Electronic Stability Control System and a Brake Assist System, both meeting the requirements of Annex 9 to this Regulation.
- 12.4. As from the official date of entry into force of Supplement 9 to the original version of this Regulation, Contracting Parties applying this Regulation:
- (a) shall not refuse to grant approval under this Regulation to a vehicle complying with the requirements as amended by Supplement 9 to the original version of this Regulation.
- (b) shall refuse to grant approval under this Regulation as amended by Supplement 7 to the original version of this Regulation."

Annex 1,

Amend item 21. , amend to read:

- "21. The vehicle is equipped ....
- If yes: The ESC system has been tested according to and fulfils  
the requirements of Annex 9.....Yes / No
- or: The vehicle ...
- ....Yes / No"

Insert new items 22. to 22.1.3., to read:

- "22. The vehicle is / is not 2/ fitted with a Brake Assist System meeting the requirements of Part B of Annex 9.
- 22.1. Category of Brake Assist System A / B / C 2/
- 22.1.1. For category A systems, define the force threshold at which the ratio between pedal force and brake pressure increases; 2/
- 22.1.2. 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); 2/
- 22.1.3. For category C systems, define the input variables affecting the decision to activate the Brake Assist System, the relationship between them and the pedal application required to activate the Brake Assist System for the tests described in Part B of Annex 9. 2/"

Items 22. to 31. (former), renumber as items 23. to 32.

Annex 2.

Model A, amend the last sentence of the text beneath the example of approval mark, to read:

"The additional marking "ESC" indicates that the vehicle meets the Electronic Stability Control and Brake Assist System requirements of Annex 9 to this Regulation."

Annex 9.

The Title, amend to read:

"Annex 9

ELECTRONIC STABILITY CONTROL AND BRAKE ASSIST SYSTEMS"

After the title, insert a new section heading, to read:

"A. REQUIREMENTS FOR ELECTRONIC STABILITY CONTROL SYSTEMS,  
WHERE FITTED."

Paragraph 1, amend to read.

"1. GENERAL REQUIREMENTS

Vehicles equipped ...specified in paragraph 5. of this section."

Footnote 2, amend the end of the footnote, to read:

".. stipulated under paragraph 5. of this section"

Paragraph 3.6.4., amend to read:

"3.6.4. The requirement of paragraph 3.6.2.7. of this section does not apply to tell-tales shown in a common space."

Paragraph 3.6.5., amend to read:

"3.6.5. The manufacturer ...would meet paragraphs 3., 3.1., 3.2. and 3.3. of this section at that level of ESC function."

After Paragraph 5.11.9, insert a new section B, to read:

"B. SPECIAL REQUIREMENTS TO BE APPLIED TO BRAKE ASSIST SYSTEMS,  
WHERE FITTED

1. GENERAL

The following requirements apply to vehicles fitted with Brake Assist Systems (BAS) as defined in paragraph 2.34. of this Regulation and declared in the Communication of Annex 1, paragraph 22. of this Regulation.

In addition to the requirements of this annex, Brake Assist Systems shall also be subject to any relevant requirements contained elsewhere within this Regulation.

In addition to the requirements of this annex, vehicles with BAS shall also be equipped with ABS in accordance with Annex 6.

1.1. General performance characteristics for category "A" BAS systems

When an emergency condition has been sensed by a relative high pedal force, the additional pedal force to cause full cycling of the ABS shall be reduced compared to the pedal force required without the BAS system in operation.

Compliance with this requirement is demonstrated if the provisions of paragraphs 3.1. to 3.3. of this section are met.

1.2. General performance characteristics for category "B" and category "C" BAS systems

When an emergency condition has been sensed, at least by a very fast application of the pedal, the BAS system shall raise the pressure to deliver the maximum achievable braking rate or cause full cycling of the ABS.

Compliance with this requirement is demonstrated if the provisions of paragraphs 4.1. to 4.3. of this section are met.

2. GENERAL TEST REQUIREMENTS

2.1. Variables

Whilst performing the tests described in part B of this annex, the following variables shall be measured:

2.1.1. Brake pedal force,  $F_p$  ;

2.1.2. Vehicle velocity,  $v_x$  ;

2.1.3. Vehicle deceleration,  $a_x$  ;

- 2.1.4. Brake temperature,  $T_d$  ;
- 2.1.5. Brake pressure,  $P$ , where applicable;
- 2.1.6. Brake pedal travel,  $S_p$ , measured at the centre of the pedal plate or at a position on the pedal mechanism where the displacement is proportional to the displacement at the centre of the pedal plate allowing simple calibration of the measurement.

## 2.2. Measuring equipment

2.2.1. The variables listed in paragraph 2.1. of this section shall be measured by means of appropriate transducers. Accuracy, operating ranges, filtering techniques, data processing and other requirements are described in ISO Standard 15037-1: 2006.

2.2.2. Accuracy of pedal force and disc temperature measurements shall be as follows:

Variable range system	Typical operating range of the transducers	Recommended maximum recording errors
Pedal force	0 to 2,000 N	$\pm 10$ N
Brake temperature	0 – 1,000 °C	$\pm 5$ °C
Brake pressure */	0 – 20 MPa */	$\pm 100$ kPa */

\*/ Applicable as specified in paragraph 3.2.5.

2.2.3. Details on analogue and digital data processing of the BAS test procedures are described in Appendix 5 to this annex. A sampling rate for data acquisition of at least 500 Hz is required.

2.2.4. Alternative measuring methods to those referred to in paragraph 2.2.3. may be allowed, provided they demonstrate at least an equivalent level of precision.

## 2.3. Test conditions

2.3.1. Test vehicle loading condition: The vehicle shall be unladen. There may be, in addition to the driver, a second person on the front seat who is responsible for noting the results of the tests.

2.3.2. Braking tests shall be carried out on a dry surface affording good adhesion.

## 2.4. Test method

2.4.1. The tests as described in paragraphs 3. and 4. of this section shall be carried out from a test speed of  $100 \pm 2$  km/h. The vehicle shall be driven at the test speed in a straight line.

- 2.4.2. The average temperature of the brakes shall be in accordance with paragraph 1.4.1.1. of Annex 3.
- 2.4.3. For the tests the reference time,  $t_0$ , is defined as the moment when the brake pedal force reaches 20 N.

Note: For vehicles equipped with a brake system assisted by an energy source, the applied pedal force necessary depends on the energy level that exists in the energy storage device. Therefore, sufficient energy level shall be ensured at the beginning of the test.

3. Assessment of the presence of a category "A" BAS

A category "A" BAS shall meet the test requirements contained in paragraphs 3.1. and 3.2.

3.1. Test 1: Reference test to determine  $F_{ABS}$  and  $a_{ABS}$ .

3.1.1. The reference values  $F_{ABS}$  and  $a_{ABS}$  shall be determined in accordance with the procedure described in Appendix 4 to this annex.

3.2. Test 2: For activation of BAS

3.2.1. Once an emergency braking condition has been detected, systems sensitive to pedal force shall show a significant increase in the ratio of:

- (a) brake line pressure to brake pedal force, where permitted by paragraph 3.2.5., or
- (b) vehicle deceleration to brake pedal force.

3.2.2. The performance requirements for a category "A" BAS are met if a specific brake application characteristic can be defined that exhibits a decrease of between 40 per cent and 80 per cent in required brake pedal force for  $(F_{ABS} - F_T)$  compared to  $(F_{ABS, extrapolated} - F_T)$ .

3.2.3.  $F_T$  and  $a_T$  are threshold force and threshold deceleration as shown in Figure 1. The values of  $F_T$  and  $a_T$  shall be supplied to the Technical Service at the time of submission of the type-approval application. The value of  $a_T$  shall be between 3.5 m/s<sup>2</sup> and 5.0 m/s<sup>2</sup>.

3.2.4. A straight line is drawn from the origin through the point  $F_T, a_T$  (as shown in Figure 1a). The value of brake pedal force "F", at the point of intersection between this line and a horizontal line defined by  $a=a_{ABS}$ , is defined as  $F_{ABS, extrapolated}$ :

$$F_{ABS, extrapolated} = \frac{F_T \cdot a_{ABS}}{a_T}$$

3.2.5. As an alternative, which can be selected by the manufacturer, in the case of vehicles of category  $N_1$ , or  $M_1$  derived from those  $N_1$  vehicles, with a gross vehicle mass

GVM > 2,500 kg, the pedal force figures for  $F_T$ ,  $F_{ABS,min}$ ,  $F_{ABS,max}$  and  $F_{AB,extrapolated}$  may be derived from the brake line pressure response characteristic instead of the vehicle deceleration characteristic. This shall be measured as the brake pedal force is increasing.

- 3.2.5.1. The pressure, at which ABS cycling commences, shall be determined by making five tests from  $100 \pm 2$  km/h in which the brake pedal is applied up to the level which produces ABS operation and the five pressures at which this occurs as determined from front wheel pressure records, shall be recorded and the mean value obtained as  $P_{ABS}$ .
- 3.2.5.2. The threshold pressure  $P_T$  shall be stated by the manufacturer and correspond to a deceleration in the range of  $2.5 - 4.5$  m/s<sup>2</sup>.
- 3.2.5.3. Figure 1b shall be constructed in the manner set out in paragraph 3.2.4., but using line pressure measurements to define the parameters set out in paragraph 3.2.5. of this section where:

$$F_{ABS,extrapolated} = \frac{F_T \cdot P_{ABS}}{P_T}$$

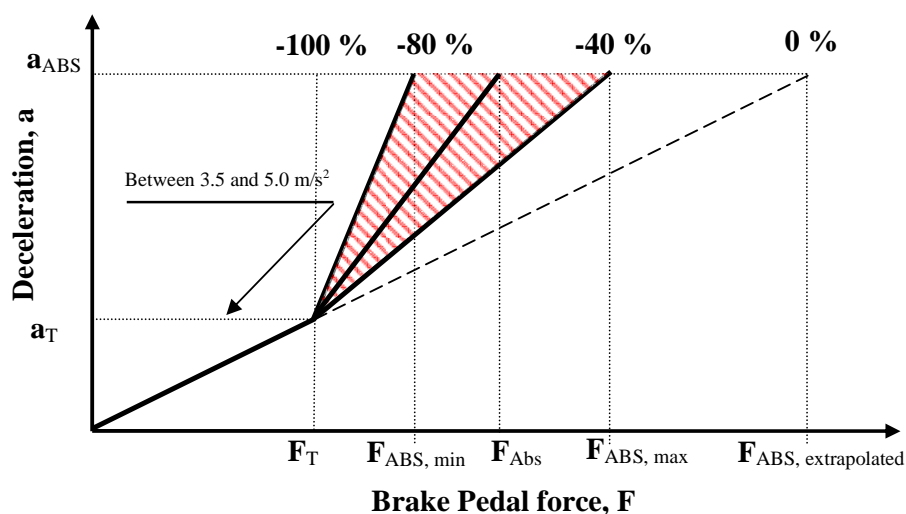


Figure 1a: Pedal force characteristic needed in order to achieve maximum deceleration with category "A" BAS



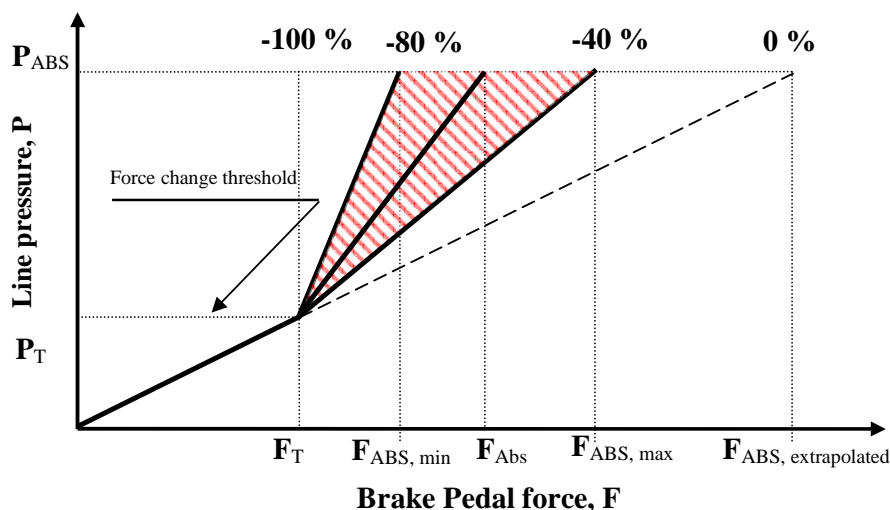


Figure 1b: Pedal force characteristic needed in order to achieve maximum deceleration with category "A" BAS

### 3.3. Data evaluation

The presence of a category "A" BAS is proven if

$$F_{ABS,min} \leq F_{ABS} \leq F_{ABS,max}$$

where:

$$F_{ABS,max} - F_T \leq (F_{ABS,extrapolated} - F_T) \cdot 0.6$$

and

$$F_{ABS,min} - F_T \geq (F_{ABS,extrapolated} - F_T) \cdot 0.2$$

## 4. ASSESSMENT OF THE PRESENCE OF A CATEGORY "B" BAS

A category "B" BAS shall meet the test requirements contained within paragraphs 4.1. and 4.2. of this section.

### 4.1. Test 1: Reference test to determine $F_{ABS}$ and $a_{ABS}$ .

4.1.1. The reference values  $F_{ABS}$  and  $a_{ABS}$  shall be determined in accordance with the procedure described in Appendix 4 to this annex.

### 4.2. Test 2: For activation of BAS

The vehicle shall be driven in a straight line at the test speed specified in paragraph 2.4. of this section. The driver shall apply the brake pedal quickly according to Figure 2, simulating emergency braking so that BAS is activated and ABS is fully cycling.

In order to activate BAS the brake pedal shall be applied as specified by the car manufacturer. The manufacturer shall notify the Technical Service of the required brake pedal input at the time of submission of the application for type-approval. It shall be demonstrated to the satisfaction of the Technical Service that the BAS activates under the conditions specified by the manufacturer in accordance with paragraph 22.1.2. or 22.1.3 of Annex 1.

After  $t = t_0 + 0.8$  s and until the vehicle has slowed down to a speed of 15 km/h, the brake pedal force shall be maintained in a corridor between  $F_{ABS, upper}$  and  $F_{ABS, lower}$ , where  $F_{ABS, upper}$  is  $0.7 F_{ABS}$  and  $F_{ABS, lower}$  is  $0.5 F_{ABS}$ .

The requirements are also considered to be met if, after  $t = t_0 + 0.8$  s, the pedal force falls below  $F_{ABS, lower}$  provided the requirement of paragraph 4.3. is fulfilled.

#### 4.3. Data evaluation

The presence of BAS 'B' is demonstrated if a mean deceleration ( $a_{BAS}$ ) of at least  $0.85 \cdot a_{ABS}$  is maintained from the time when  $t = t_0 + 0.8$  s to the time when the vehicle speed has been reduced to 15 km/h.

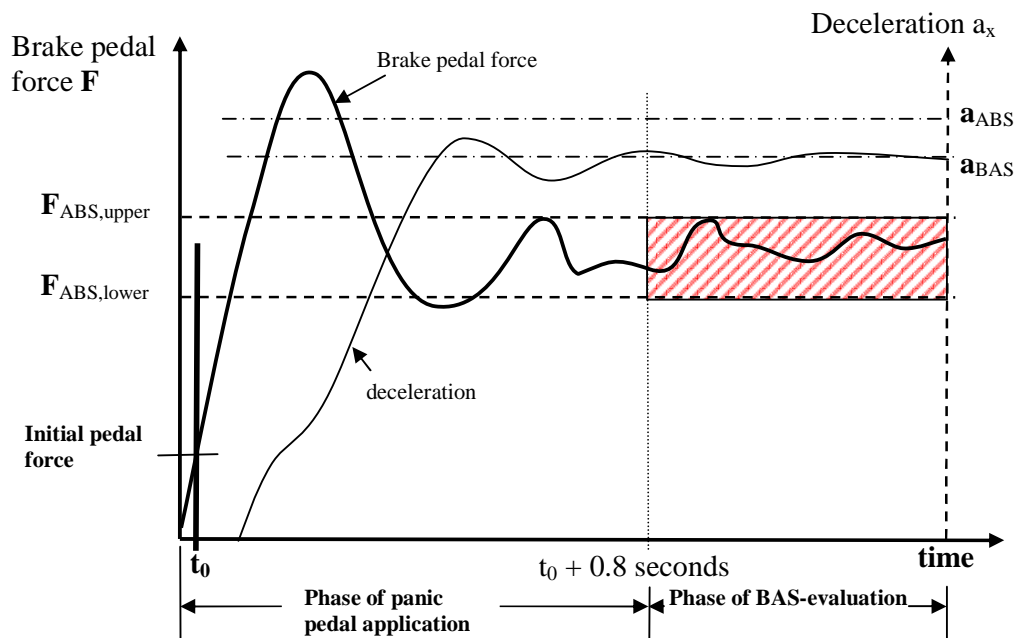


Figure 2: Example of test 2 of a category "B" BAS system

5. ASSESSMENT OF THE PRESENCE OF A CATEGORY "C" BAS

5.1. A category "C" BAS shall meet the test requirements of paragraphs 4.1. and 4.2. of this section.

5.2. Data evaluation

A category "C" BAS shall meet the requirements of paragraph 4.3. of this section."

Insert new Appendices 4 and 5, to read:

"Annex 9 - Appendix 4

METHOD FOR DETERMINATION OF  $F_{ABS}$  AND  $a_{ABS}$

- 1.1. The brake pedal force  $F_{ABS}$  is the minimum pedal force that has to be applied for a given vehicle in order to achieve maximum deceleration which indicates that ABS is fully cycling.  $a_{ABS}$  is the deceleration for a given vehicle during ABS deceleration as defined in paragraph 1.7.
- 1.2. The brake pedal shall be applied slowly (without activating the BAS in the case of category B or category C systems) providing a constant increase of deceleration until ABS is fully cycling (Figure 3).
- 1.3. The full deceleration must be reached within the timeframe of  $2.0 \pm 0.5$  s. The deceleration curve, recorded against time, must be within a corridor of  $\pm 0.5$  s around the centre line of the deceleration curve corridor. The example in Figure 3 has its origin at the time  $t_0$  crossing the  $a_{ABS}$  line at 2 seconds. Once full deceleration has been achieved the pedal travel  $S_p$  shall not be decreased for at least 1 s. The time of full activation of the ABS system is defined as the time when pedal force  $F_{ABS}$  is achieved. The measurement shall be within the corridor for variation of increase in deceleration (see Figure 3).

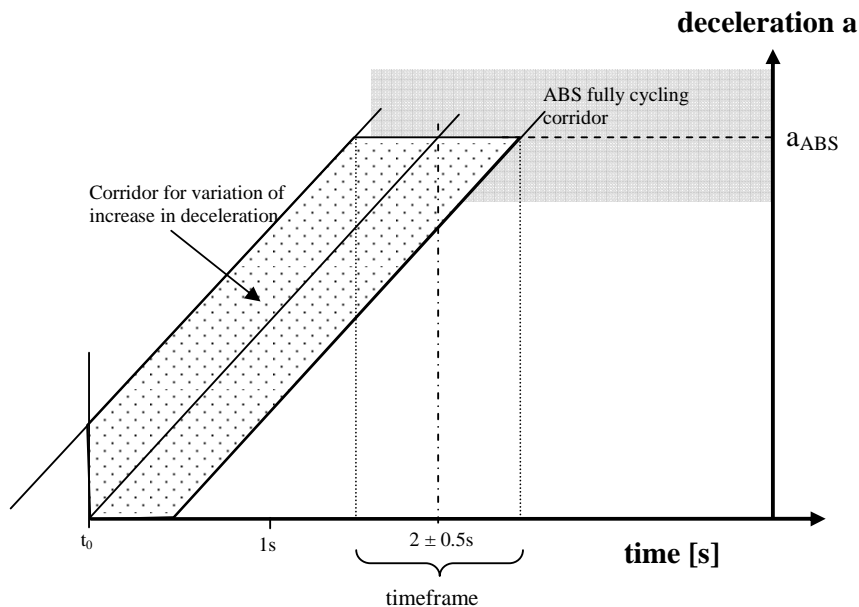


Figure 3: Deceleration corridor for determination of  $F_{ABS}$  and  $a_{ABS}$

- 1.4. Five tests meeting the requirements of paragraph 1.3. shall be carried out. For each of these valid tests the vehicle deceleration shall be plotted as a function of the recorded

brake pedal force. Only data recorded at speeds above 15 km/h shall be taken for the calculations described in the following paragraphs.

- 1.5. For the determination of  $a_{ABS}$  and  $F_{ABS}$ , a low pass filter of 2 Hz for vehicle deceleration as well as pedal force shall be applied.
- 1.6. The five individual "deceleration versus brake pedal force" curves are averaged by calculating the mean deceleration of the five individual "deceleration vs. brake pedal force" curves at increments of 1 N pedal force. The result is the mean deceleration versus brake pedal force curve, which will be referred to as the "maF curve" in this appendix.
- 1.7. The maximum value for the vehicle deceleration is determined from the "maF curve" and is named as " $a_{max}$ ".
- 1.8. All values of the "maF curve" that are above 90 per cent of this deceleration value " $a_{max}$ " are averaged. This value of "a" is the deceleration " $a_{ABS}$ " referred to in this annex.
- 1.9. The minimum force on the pedal ( $F_{ABS}$ ) sufficient to achieve the deceleration  $a_{ABS}$  is defined as the value of F corresponding to  $a = a_{ABS}$  on the maF curve.

Annex 9 - Appendix 5

(see paragraph 2.2.3. of section B of this annex)

DATA PROCESSING FOR THE BAS

1. ANALOGUE DATA PROCESSING

The bandwidth of the entire, combined transducer/recording system shall be no less than 30 Hz.

In order to execute the necessary filtering of signals, low-pass filters with order 4 or higher shall be employed. The width of the pass band (from 0 Hz to frequency  $f_0$  at -3 dB) shall not be less than 30 Hz. Amplitude errors shall be less than  $\pm 0.5$  per cent in the relevant frequency range of 0 Hz to 30 Hz. All analogue signals shall be processed with filters having sufficiently similar phase characteristics to ensure that time delay differences due to filtering lie within the required accuracy for time measurement.

NOTE: During analogue filtering of signals with different frequency contents, phase shifts can occur. Therefore, a data processing method, as described in paragraph 2. of this appendix, is preferable.

2. DIGITAL DATA PROCESSING

2.1. General consideration

Preparation of analogue signals includes consideration of filter amplitude attenuation and sampling rate to avoid aliasing errors, and filter phase lags and time delays. Sampling and digitising considerations include pre-sampling amplification of signals to minimize digitising errors; number of bits per sample; number of samples per cycle; sample and hold amplifiers; and time-wise spacing of samples. Considerations for additional phaseless digital filtering include selection of pass bands and stop bands and the attenuation and allowable ripple in each; and correction of filter phase lags. Each of these factors shall be considered in order to achieve a relative overall data acquisition accuracy of  $\pm 0.5$  per cent.

2.2. Aliasing errors

In order to avoid uncorrectable aliasing errors, the analogue signals shall be appropriately filtered before sampling and digitising. The order of the filters used and their pass band shall be chosen according to both the required flatness in the relevant frequency range and the sampling rate.

The minimum filter characteristics and sampling rate shall be such that:

- (a) Within the relevant frequency range of 0 Hz to  $f_{max} = 30$  Hz the attenuation is less than the resolution of the data acquisition system; and

- (b) At one-half the sampling rate (i.e. the Nyquist or "folding" frequency) the magnitudes of all frequency components of signal and noise are reduced to less than the system resolution.

For 0.05 per cent resolution the filter attenuation shall be less than 0.05 per cent in the frequency range between 0 and 30 Hz, and the attenuation shall be greater than 99.95 per cent at all frequencies greater than one-half the sampling frequency.

NOTE: For a Butterworth filter the attenuation is given by:

$$A^2 = \frac{1}{1 + \left(\frac{f_{\max}}{f_0}\right)^{2n}} \quad \text{and} \quad A^2 = \frac{1}{1 + \left(\frac{f_N}{f_0}\right)^{2n}}$$

where:

- n is the order to filter;
- $f_{\max}$  is the relevant frequency range (30 Hz);
- $f_0$  is the filter cut-off frequency;
- $f_N$  is the Nyquist or "folding" frequency.

For a fourth order filter

for  $A = 0.9995$ :  $f_0 = 2.37 \cdot f_{\max}$

for  $A = 0.0005$ :  $f_s = 2 \cdot (6.69 \cdot f_0)$ , where  $f_s$  is the sampling frequency  $= 2 \cdot f_N$ .

### 2.3. Filter phase shifts and time delays for anti-aliasing filtering

Excessive analogue filtering shall be avoided, and all filters shall have sufficiently similar phase characteristics to ensure that time delay differences are within the required accuracy for the time measurement. Phase shifts are especially significant when measured variables are multiplied together to form new variables, because while amplitudes multiply, phase shifts and associated time delays add. Phase shifts and time delays are reduced by increasing  $f_0$ . Whenever equations describing the pre-sampling filters are known, it is practical to remove their phase shifts and time delays by simple algorithms performed in the frequency domain.

NOTE: In the frequency range in which the filter amplitude characteristics remain flat, the phase shift  $\Phi$  of a Butterworth filter can be approximated by

$$\Phi = 81 \cdot (f/f_0) \text{ degrees for second order}$$

$$\Phi = 150 \cdot (f/f_0) \text{ degrees for fourth order}$$

$$\Phi = 294 \cdot (f/f_0) \text{ degrees for eighth order}$$

The time delay for all filter orders is:  $t = (\Phi/360) \cdot (1/f_0)$

### 2.4. Data sampling and digitising

At 30 Hz the signal amplitude changes by up to 18 per cent per millisecond. To limit dynamic errors caused by changing analogue inputs to 0.1 per cent, sampling or

digitising time shall be less than 32  $\mu$ s. All pairs or sets of data samples to be compared shall be taken simultaneously or over a sufficiently short time period.

## 2.5. System requirements

The data system shall have a resolution of 12 bits ( $\pm 0.05$  per cent) or more and an accuracy of  $\pm 0.1$  per cent (2 lbs). Anti-aliasing filters shall be of order 4 or higher and the relevant data range  $f_{\max}$  shall be 0 Hz to 30 Hz.

For fourth order filters the pass-band frequency  $f_o$  (from 0 Hz to frequency  $f_o$ ) shall be greater than  $2.37 \cdot f_{\max}$  if phase errors are subsequently adjusted in digital data processing, and greater than  $5 \cdot f_{\max}$  otherwise. For fourth order filters the data sampling frequency  $f_s$  shall be greater than  $13.4 \cdot f_o$ ."

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- or: The vehicle ...
- ....Yes / No"

Insert new items 22. to 22.1.3., to read:

- "22. The vehicle is / is not 2/ fitted with a Brake Assist System meeting the requirements of Part B of Annex 9.
- 22.1. Category of Brake Assist System A / B / C 2/
- 22.1.1. For category A systems, define the force threshold at which the ratio between pedal force and brake pressure increases; 2/
- 22.1.2. 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); 2/
- 22.1.3. For category C systems, define the input variables affecting the decision to activate the Brake Assist System, the relationship between them and the pedal application required to activate the Brake Assist System for the tests described in Part B of Annex 9. 2/"

Items 22. to 31. (former), renumber as items 23. to 32.

Annex 2.

Model A, amend the last sentence of the text beneath the example of approval mark, to read:

"The additional marking "ESC" indicates that the vehicle meets the Electronic Stability Control and Brake Assist System requirements of Annex 9 to this Regulation."

Annex 9,

The Title, amend to read:

"Annex 9

ELECTRONIC STABILITY CONTROL AND BRAKE ASSIST SYSTEMS"

After the title, insert a new section heading, to read:

"A. REQUIREMENTS FOR ELECTRONIC STABILITY CONTROL SYSTEMS,  
WHERE FITTED."

Paragraph 1, amend to read.

"1. GENERAL REQUIREMENTS

Vehicles equipped ...specified in paragraph 5. of this section."

Footnote 2, amend the end of the footnote, to read:

".. stipulated under paragraph 5. of this section"

Paragraph 3.6.4., amend to read:

"3.6.4. The requirement of paragraph 3.6.2.7. of this section does not apply to tell-tales shown in a common space."

Paragraph 3.6.5., amend to read:

"3.6.5. The manufacturer ...would meet paragraphs 3., 3.1., 3.2. and 3.3. of this section at that level of ESC function."

After Paragraph 5.11.9, insert a new section B, to read:

"B. SPECIAL REQUIREMENTS TO BE APPLIED TO BRAKE ASSIST SYSTEMS,  
WHERE FITTED

1. GENERAL

The following requirements apply to vehicles fitted with Brake Assist Systems (BAS) as defined in paragraph 2.34. of this Regulation and declared in the Communication of Annex 1, paragraph 22. of this Regulation.

In addition to the requirements of this annex, Brake Assist Systems shall also be subject to any relevant requirements contained elsewhere within this Regulation.

In addition to the requirements of this annex, vehicles with BAS shall also be equipped with ABS in accordance with Annex 6.

1.1. General performance characteristics for category "A" BAS systems

When an emergency condition has been sensed by a relative high pedal force, the additional pedal force to cause full cycling of the ABS shall be reduced compared to the pedal force required without the BAS system in operation.

Compliance with this requirement is demonstrated if the provisions of paragraphs 3.1. to 3.3. of this section are met.

1.2. General performance characteristics for category "B" and category "C" BAS systems

When an emergency condition has been sensed, at least by a very fast application of the pedal, the BAS system shall raise the pressure to deliver the maximum achievable braking rate or cause full cycling of the ABS.

Compliance with this requirement is demonstrated if the provisions of paragraphs 4.1. to 4.3. of this section are met.

2. GENERAL TEST REQUIREMENTS

2.1. Variables

Whilst performing the tests described in part B of this annex, the following variables shall be measured:

2.1.1. Brake pedal force,  $F_p$  ;

2.1.2. Vehicle velocity,  $v_x$  ;

2.1.3. Vehicle deceleration,  $a_x$  ;

- 2.1.4. Brake temperature,  $T_d$  ;
- 2.1.5. Brake pressure,  $P$ , where applicable;
- 2.1.6. Brake pedal travel,  $S_p$ , measured at the centre of the pedal plate or at a position on the pedal mechanism where the displacement is proportional to the displacement at the centre of the pedal plate allowing simple calibration of the measurement.

## 2.2. Measuring equipment

2.2.1. The variables listed in paragraph 2.1. of this section shall be measured by means of appropriate transducers. Accuracy, operating ranges, filtering techniques, data processing and other requirements are described in ISO Standard 15037-1: 2006.

2.2.2. Accuracy of pedal force and disc temperature measurements shall be as follows:

Variable range system	Typical operating range of the transducers	Recommended maximum recording errors
Pedal force	0 to 2,000 N	$\pm 10$ N
Brake temperature	0 – 1,000 °C	$\pm 5$ °C
Brake pressure */	0 – 20 MPa */	$\pm 100$ kPa */

\*/ Applicable as specified in paragraph 3.2.5.

2.2.3. Details on analogue and digital data processing of the BAS test procedures are described in Appendix 5 to this annex. A sampling rate for data acquisition of at least 500 Hz is required.

2.2.4. Alternative measuring methods to those referred to in paragraph 2.2.3. may be allowed, provided they demonstrate at least an equivalent level of precision.

## 2.3. Test conditions

2.3.1. Test vehicle loading condition: The vehicle shall be unladen. There may be, in addition to the driver, a second person on the front seat who is responsible for noting the results of the tests.

2.3.2. Braking tests shall be carried out on a dry surface affording good adhesion.

## 2.4. Test method

2.4.1. The tests as described in paragraphs 3. and 4. of this section shall be carried out from a test speed of  $100 \pm 2$  km/h. The vehicle shall be driven at the test speed in a straight line.

- 2.4.2. The average temperature of the brakes shall be in accordance with paragraph 1.4.1.1. of Annex 3.
- 2.4.3. For the tests the reference time,  $t_0$ , is defined as the moment when the brake pedal force reaches 20 N.

Note: For vehicles equipped with a brake system assisted by an energy source, the applied pedal force necessary depends on the energy level that exists in the energy storage device. Therefore, sufficient energy level shall be ensured at the beginning of the test.

3. Assessment of the presence of a category "A" BAS

A category "A" BAS shall meet the test requirements contained in paragraphs 3.1. and 3.2.

3.1. Test 1: Reference test to determine  $F_{ABS}$  and  $a_{ABS}$ .

3.1.1. The reference values  $F_{ABS}$  and  $a_{ABS}$  shall be determined in accordance with the procedure described in Appendix 4 to this annex.

3.2. Test 2: For activation of BAS

3.2.1. Once an emergency braking condition has been detected, systems sensitive to pedal force shall show a significant increase in the ratio of:

- (a) brake line pressure to brake pedal force, where permitted by paragraph 3.2.5., or
- (b) vehicle deceleration to brake pedal force.

3.2.2. The performance requirements for a category "A" BAS are met if a specific brake application characteristic can be defined that exhibits a decrease of between 40 per cent and 80 per cent in required brake pedal force for  $(F_{ABS} - F_T)$  compared to  $(F_{ABS, extrapolated} - F_T)$ .

3.2.3.  $F_T$  and  $a_T$  are threshold force and threshold deceleration as shown in Figure 1. The values of  $F_T$  and  $a_T$  shall be supplied to the Technical Service at the time of submission of the type-approval application. The value of  $a_T$  shall be between 3.5 m/s<sup>2</sup> and 5.0 m/s<sup>2</sup>.

3.2.4. A straight line is drawn from the origin through the point  $F_T, a_T$  (as shown in Figure 1a). The value of brake pedal force "F", at the point of intersection between this line and a horizontal line defined by  $a=a_{ABS}$ , is defined as  $F_{ABS, extrapolated}$ :

$$F_{ABS, extrapolated} = \frac{F_T \cdot a_{ABS}}{a_T}$$

3.2.5. As an alternative, which can be selected by the manufacturer, in the case of vehicles of category  $N_1$ , or  $M_1$  derived from those  $N_1$  vehicles, with a gross vehicle mass

GVM > 2,500 kg, the pedal force figures for  $F_T$ ,  $F_{ABS,min}$ ,  $F_{ABS,max}$  and  $F_{AB,extrapolated}$  may be derived from the brake line pressure response characteristic instead of the vehicle deceleration characteristic. This shall be measured as the brake pedal force is increasing.

- 3.2.5.1. The pressure, at which ABS cycling commences, shall be determined by making five tests from  $100 \pm 2$  km/h in which the brake pedal is applied up to the level which produces ABS operation and the five pressures at which this occurs as determined from front wheel pressure records, shall be recorded and the mean value obtained as  $P_{ABS}$ .
- 3.2.5.2. The threshold pressure  $P_T$  shall be stated by the manufacturer and correspond to a deceleration in the range of  $2.5 - 4.5$  m/s<sup>2</sup>.
- 3.2.5.3. Figure 1b shall be constructed in the manner set out in paragraph 3.2.4., but using line pressure measurements to define the parameters set out in paragraph 3.2.5. of this section where:

$$F_{ABS,extrapolated} = \frac{F_T \cdot P_{ABS}}{P_T}$$

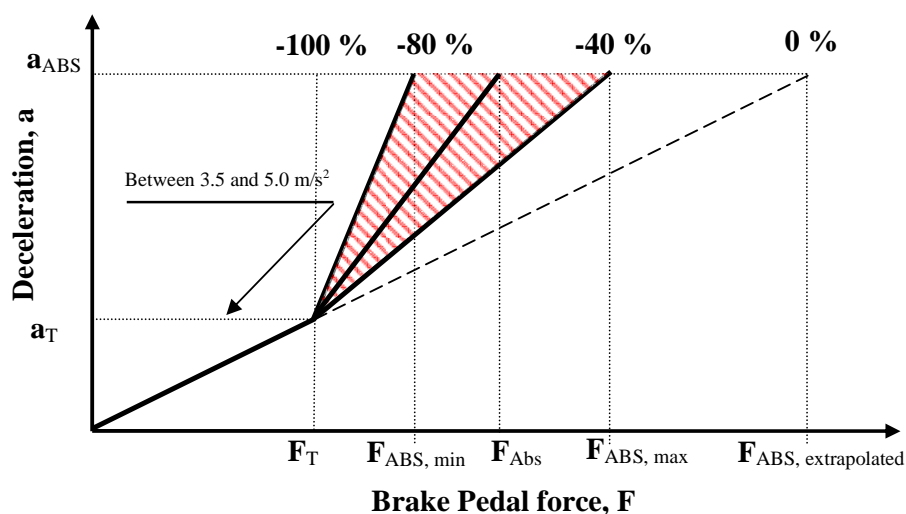


Figure 1a: Pedal force characteristic needed in order to achieve maximum deceleration with category "A" BAS



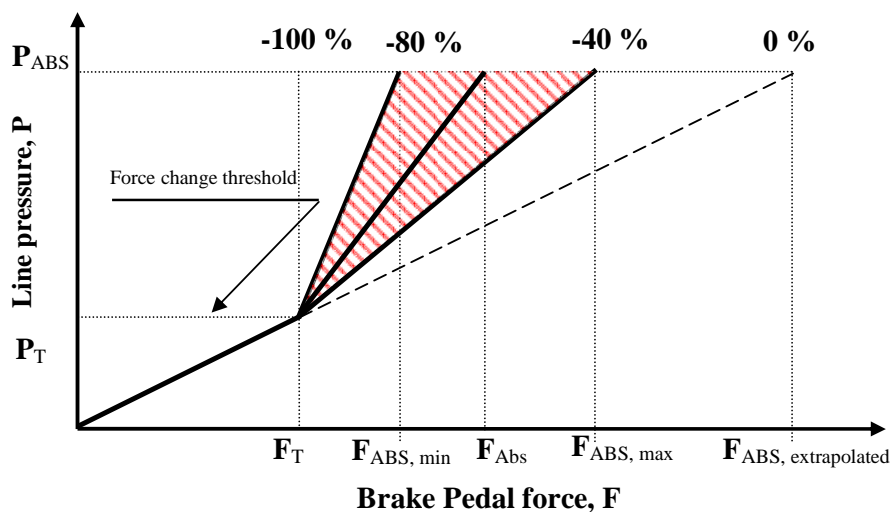


Figure 1b: Pedal force characteristic needed in order to achieve maximum deceleration with category "A" BAS

### 3.3. Data evaluation

The presence of a category "A" BAS is proven if

$$F_{ABS,min} \leq F_{ABS} \leq F_{ABS,max}$$

where:

$$F_{ABS,max} - F_T \leq (F_{ABS,extrapolated} - F_T) \cdot 0.6$$

and

$$F_{ABS,min} - F_T \geq (F_{ABS,extrapolated} - F_T) \cdot 0.2$$

## 4. ASSESSMENT OF THE PRESENCE OF A CATEGORY "B" BAS

A category "B" BAS shall meet the test requirements contained within paragraphs 4.1. and 4.2. of this section.

### 4.1. Test 1: Reference test to determine $F_{ABS}$ and $a_{ABS}$ .

4.1.1. The reference values  $F_{ABS}$  and  $a_{ABS}$  shall be determined in accordance with the procedure described in Appendix 4 to this annex.

### 4.2. Test 2: For activation of BAS

The vehicle shall be driven in a straight line at the test speed specified in paragraph 2.4. of this section. The driver shall apply the brake pedal quickly according to Figure 2, simulating emergency braking so that BAS is activated and ABS is fully cycling.

In order to activate BAS the brake pedal shall be applied as specified by the car manufacturer. The manufacturer shall notify the Technical Service of the required brake pedal input at the time of submission of the application for type-approval. It shall be demonstrated to the satisfaction of the Technical Service that the BAS activates under the conditions specified by the manufacturer in accordance with paragraph 22.1.2. or 22.1.3 of Annex 1.

After  $t = t_0 + 0.8$  s and until the vehicle has slowed down to a speed of 15 km/h, the brake pedal force shall be maintained in a corridor between  $F_{ABS, upper}$  and  $F_{ABS, lower}$ , where  $F_{ABS, upper}$  is  $0.7 F_{ABS}$  and  $F_{ABS, lower}$  is  $0.5 F_{ABS}$ .

The requirements are also considered to be met if, after  $t = t_0 + 0.8$  s, the pedal force falls below  $F_{ABS, lower}$  provided the requirement of paragraph 4.3. is fulfilled.

#### 4.3. Data evaluation

The presence of BAS 'B' is demonstrated if a mean deceleration ( $a_{BAS}$ ) of at least  $0.85 \cdot a_{ABS}$  is maintained from the time when  $t = t_0 + 0.8$  s to the time when the vehicle speed has been reduced to 15 km/h.

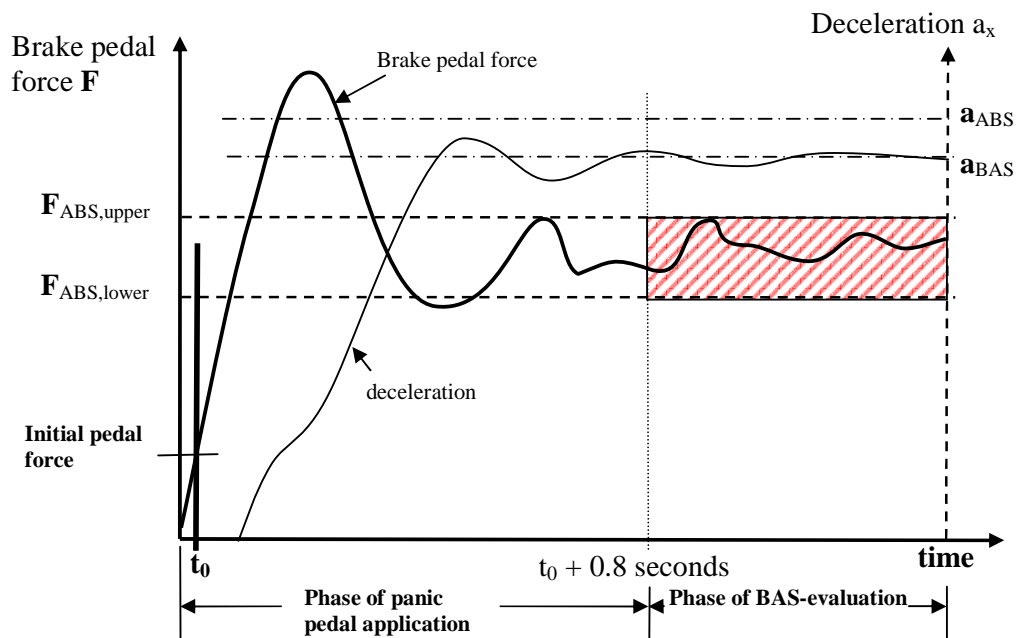


Figure 2: Example of test 2 of a category "B" BAS system

5. ASSESSMENT OF THE PRESENCE OF A CATEGORY "C" BAS

5.1. A category "C" BAS shall meet the test requirements of paragraphs 4.1. and 4.2. of this section.

5.2. Data evaluation

A category "C" BAS shall meet the requirements of paragraph 4.3. of this section."

Insert new Appendices 4 and 5, to read:

"Annex 9 - Appendix 4

METHOD FOR DETERMINATION OF  $F_{ABS}$  AND  $a_{ABS}$

- 1.1. The brake pedal force  $F_{ABS}$  is the minimum pedal force that has to be applied for a given vehicle in order to achieve maximum deceleration which indicates that ABS is fully cycling.  $a_{ABS}$  is the deceleration for a given vehicle during ABS deceleration as defined in paragraph 1.7.
- 1.2. The brake pedal shall be applied slowly (without activating the BAS in the case of category B or category C systems) providing a constant increase of deceleration until ABS is fully cycling (Figure 3).
- 1.3. The full deceleration must be reached within the timeframe of  $2.0 \pm 0.5$  s. The deceleration curve, recorded against time, must be within a corridor of  $\pm 0.5$  s around the centre line of the deceleration curve corridor. The example in Figure 3 has its origin at the time  $t_0$  crossing the  $a_{ABS}$  line at 2 seconds. Once full deceleration has been achieved the pedal travel  $S_p$  shall not be decreased for at least 1 s. The time of full activation of the ABS system is defined as the time when pedal force  $F_{ABS}$  is achieved. The measurement shall be within the corridor for variation of increase in deceleration (see Figure 3).

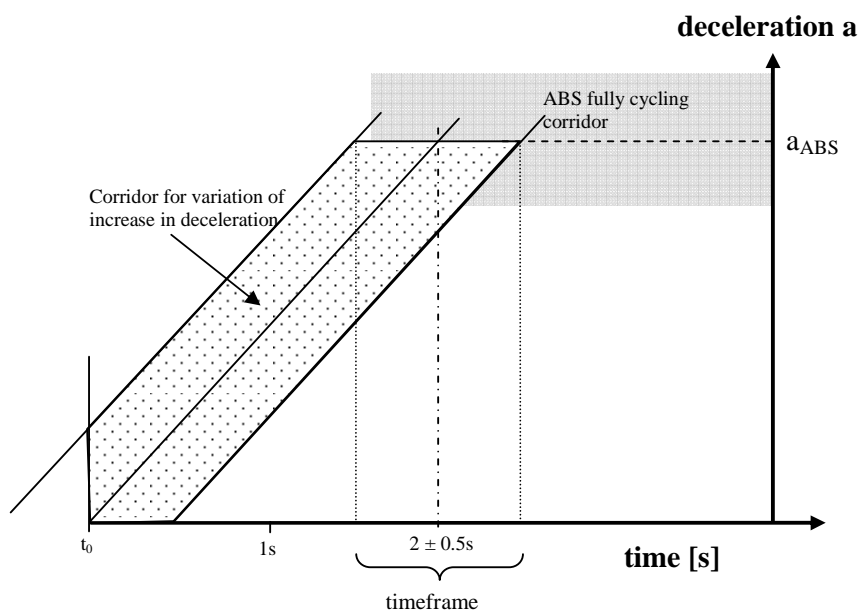


Figure 3: Deceleration corridor for determination of  $F_{ABS}$  and  $a_{ABS}$

- 1.4. Five tests meeting the requirements of paragraph 1.3. shall be carried out. For each of these valid tests the vehicle deceleration shall be plotted as a function of the recorded

brake pedal force. Only data recorded at speeds above 15 km/h shall be taken for the calculations described in the following paragraphs.

- 1.5. For the determination of  $a_{ABS}$  and  $F_{ABS}$ , a low pass filter of 2 Hz for vehicle deceleration as well as pedal force shall be applied.
- 1.6. The five individual "deceleration versus brake pedal force" curves are averaged by calculating the mean deceleration of the five individual "deceleration vs. brake pedal force" curves at increments of 1 N pedal force. The result is the mean deceleration versus brake pedal force curve, which will be referred to as the "maF curve" in this appendix.
- 1.7. The maximum value for the vehicle deceleration is determined from the "maF curve" and is named as " $a_{max}$ ".
- 1.8. All values of the "maF curve" that are above 90 per cent of this deceleration value " $a_{max}$ " are averaged. This value of "a" is the deceleration " $a_{ABS}$ " referred to in this annex.
- 1.9. The minimum force on the pedal ( $F_{ABS}$ ) sufficient to achieve the deceleration  $a_{ABS}$  is defined as the value of F corresponding to  $a = a_{ABS}$  on the maF curve.

Annex 9 - Appendix 5

(see paragraph 2.2.3. of section B of this annex)

DATA PROCESSING FOR THE BAS

1. ANALOGUE DATA PROCESSING

The bandwidth of the entire, combined transducer/recording system shall be no less than 30 Hz.

In order to execute the necessary filtering of signals, low-pass filters with order 4 or higher shall be employed. The width of the pass band (from 0 Hz to frequency  $f_0$  at -3 dB) shall not be less than 30 Hz. Amplitude errors shall be less than  $\pm 0.5$  per cent in the relevant frequency range of 0 Hz to 30 Hz. All analogue signals shall be processed with filters having sufficiently similar phase characteristics to ensure that time delay differences due to filtering lie within the required accuracy for time measurement.

NOTE: During analogue filtering of signals with different frequency contents, phase shifts can occur. Therefore, a data processing method, as described in paragraph 2. of this appendix, is preferable.

2. DIGITAL DATA PROCESSING

2.1. General consideration

Preparation of analogue signals includes consideration of filter amplitude attenuation and sampling rate to avoid aliasing errors, and filter phase lags and time delays. Sampling and digitising considerations include pre-sampling amplification of signals to minimize digitising errors; number of bits per sample; number of samples per cycle; sample and hold amplifiers; and time-wise spacing of samples. Considerations for additional phaseless digital filtering include selection of pass bands and stop bands and the attenuation and allowable ripple in each; and correction of filter phase lags. Each of these factors shall be considered in order to achieve a relative overall data acquisition accuracy of  $\pm 0.5$  per cent.

2.2. Aliasing errors

In order to avoid uncorrectable aliasing errors, the analogue signals shall be appropriately filtered before sampling and digitising. The order of the filters used and their pass band shall be chosen according to both the required flatness in the relevant frequency range and the sampling rate.

The minimum filter characteristics and sampling rate shall be such that:

- (a) Within the relevant frequency range of 0 Hz to  $f_{max} = 30$  Hz the attenuation is less than the resolution of the data acquisition system; and

- (b) At one-half the sampling rate (i.e. the Nyquist or "folding" frequency) the magnitudes of all frequency components of signal and noise are reduced to less than the system resolution.

For 0.05 per cent resolution the filter attenuation shall be less than 0.05 per cent in the frequency range between 0 and 30 Hz, and the attenuation shall be greater than 99.95 per cent at all frequencies greater than one-half the sampling frequency.

NOTE: For a Butterworth filter the attenuation is given by:

$$A^2 = \frac{1}{1 + \left(\frac{f_{\max}}{f_0}\right)^{2n}} \quad \text{and} \quad A^2 = \frac{1}{1 + \left(\frac{f_N}{f_0}\right)^{2n}}$$

where:

n is the order to filter;

$f_{\max}$  is the relevant frequency range (30 Hz);

$f_0$  is the filter cut-off frequency;

$f_N$  is the Nyquist or "folding" frequency.

For a fourth order filter

for A = 0.9995:  $f_0 = 2.37 \cdot f_{\max}$

for A = 0.0005:  $f_s = 2 \cdot (6.69 \cdot f_0)$ , where  $f_s$  is the sampling frequency =  $2 \cdot f_N$ .

### 2.3. Filter phase shifts and time delays for anti-aliasing filtering

Excessive analogue filtering shall be avoided, and all filters shall have sufficiently similar phase characteristics to ensure that time delay differences are within the required accuracy for the time measurement. Phase shifts are especially significant when measured variables are multiplied together to form new variables, because while amplitudes multiply, phase shifts and associated time delays add. Phase shifts and time delays are reduced by increasing  $f_0$ . Whenever equations describing the pre-sampling filters are known, it is practical to remove their phase shifts and time delays by simple algorithms performed in the frequency domain.

NOTE: In the frequency range in which the filter amplitude characteristics remain flat, the phase shift  $\Phi$  of a Butterworth filter can be approximated by

$$\Phi = 81 \cdot (f/f_0) \text{ degrees for second order}$$

$$\Phi = 150 \cdot (f/f_0) \text{ degrees for fourth order}$$

$$\Phi = 294 \cdot (f/f_0) \text{ degrees for eighth order}$$

The time delay for all filter orders is:  $t = (\Phi/360) \cdot (1/f_0)$

### 2.4. Data sampling and digitising

At 30 Hz the signal amplitude changes by up to 18 per cent per millisecond. To limit dynamic errors caused by changing analogue inputs to 0.1 per cent, sampling or

digitising time shall be less than 32  $\mu$ s. All pairs or sets of data samples to be compared shall be taken simultaneously or over a sufficiently short time period.

## 2.5. System requirements

The data system shall have a resolution of 12 bits ( $\pm 0.05$  per cent) or more and an accuracy of  $\pm 0.1$  per cent (2 lbs). Anti-aliasing filters shall be of order 4 or higher and the relevant data range  $f_{\max}$  shall be 0 Hz to 30 Hz.

For fourth order filters the pass-band frequency  $f_o$  (from 0 Hz to frequency  $f_o$ ) shall be greater than  $2.37 \cdot f_{\max}$  if phase errors are subsequently adjusted in digital data processing, and greater than  $5 \cdot f_{\max}$  otherwise. For fourth order filters the data sampling frequency  $f_s$  shall be greater than  $13.4 \cdot f_o$ ."

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**ECONOMIC COMMISSION FOR EUROPE**

**INLAND TRANSPORT COMMITTEE**

**World Forum for Harmonization of Vehicle Regulations**

One-hundred-and-forty-eighth session  
Geneva, 23 - 26 June 2009  
Item 4.2.8 of the provisional agenda

**1958 AGREEMENT**

Consideration of draft amendments to existing Regulations

Proposal for Supplement 9 to Regulation No. 13-H  
(Brakes of M<sub>1</sub> and N<sub>1</sub> vehicles)

Submitted by the Working Party on Brakes and Running Gear \*/

The text reproduced below was adopted by the Working Party on Brakes and Running Gear (GRRF) at its sixty-fifth session. It is based on ECE/TRANS/WP.29/GRRF/2008/15, as reproduced in GRRF-25-23-Rev.1. It is submitted to the World Forum for Harmonization of Vehicle Regulations (WP.29) and to the Administrative Committee (AC.1) for consideration (ECE/TRANS/WP.29/GRRF/65, para. 13).

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\*/ In accordance with the programme of work of the Inland Transport Committee for 2006-2010 (ECE/TRANS/166/Add.1, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance performance of vehicles. The present document is submitted in conformity with that mandate.

Insert new paragraphs 2.34. to 2.34.3., to read:

- "2.34. "Brake Assist System (BAS)" means a function of the braking system that deduces an emergency braking event from a characteristic of the driver's brake demand and, under such conditions:
- (a) assists the driver to deliver the maximum achievable braking rate, or
  - (b) is sufficient to cause full cycling of the Anti-lock Braking System.
- 2.34.1. "Category A Brake Assist System" means a system which detects an emergency braking condition based on the brake pedal force applied by the driver;
- 2.34.2. "Category B Brake Assist System" means a system which detects an emergency braking condition based on the brake pedal speed applied by the driver;
- 2.34.3. "Category C Brake Assist System" means a system which detects an emergency braking condition based on multiple criteria, one of which must be the rate at which the brake pedal is applied."

Amend paragraphs 4.4.3 and 4.4.4., to read:

- "4.4.3. In the case of a vehicle complying with the Electronic Stability Control and Brake Assist System requirements of Annex 9 to this Regulation, the additional letters "ESC" shall be placed immediately to the right of the letter 'R' mentioned in paragraph 4.4.2.
- 4.4.4. In the case of vehicles complying with the Vehicle Stability Function requirements of Annex 21 to Regulation No. 13 and the Brake Assist System requirements of Annex 9 to this Regulation, the additional letters "VSF" shall be placed immediately to the right of the letter 'R' mentioned in paragraph 4.4.2."

Amend paragraph 5.2.24., to read:

- "5.2.24. Subject to the requirements of paragraphs 12.2. to 12.3., any vehicle fitted with an ESC system complying with the definition of paragraph 2.25. shall meet the equipment, performance and test requirements contained in Part A of Annex 9 to this Regulation."

Amend paragraphs 12.2. to 12.4., to read:

- "12.2. As from 1 November 2011, Contracting Parties applying this Regulation may refuse to grant national or regional type approval if the vehicle type does not meet the requirements of this Regulation as amended by Supplement 9 and is not fitted with an Electronic Stability Control System and a Brake Assist System, both meeting the requirements of Annex 9 to this Regulation.

- 12.3. As from 1 November 2013, Contracting Parties applying this Regulation may refuse first national registration of a vehicle which does not meet the requirements of this Regulation as amended by Supplement 9 and is not fitted with an Electronic Stability Control System and a Brake Assist System, both meeting the requirements of Annex 9 to this Regulation.
- 12.4. As from the official date of entry into force of Supplement 9 to the original version of this Regulation, Contracting Parties applying this Regulation:
- (a) shall not refuse to grant approval under this Regulation to a vehicle complying with the requirements as amended by Supplement 9 to the original version of this Regulation.
- (b) shall refuse to grant approval under this Regulation as amended by Supplement 7 to the original version of this Regulation."

Annex 1,

Amend item 21. , amend to read:

- "21. The vehicle is equipped ....
- If yes: The ESC system has been tested according to and fulfils  
the requirements of Annex 9.....Yes / No
- or: The vehicle ...
- ....Yes / No"

Insert new items 22. to 22.1.3., to read:

- "22. The vehicle is / is not 2/ fitted with a Brake Assist System meeting the requirements of Part B of Annex 9.
- 22.1. Category of Brake Assist System A / B / C 2/
- 22.1.1. For category A systems, define the force threshold at which the ratio between pedal force and brake pressure increases; 2/
- 22.1.2. 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); 2/
- 22.1.3. For category C systems, define the input variables affecting the decision to activate the Brake Assist System, the relationship between them and the pedal application required to activate the Brake Assist System for the tests described in Part B of Annex 9. 2/"

Items 22. to 31. (former), renumber as items 23. to 32.

Annex 2.

Model A, amend the last sentence of the text beneath the example of approval mark, to read:

"The additional marking "ESC" indicates that the vehicle meets the Electronic Stability Control and Brake Assist System requirements of Annex 9 to this Regulation."

Annex 9,

The Title, amend to read:

"Annex 9

ELECTRONIC STABILITY CONTROL AND BRAKE ASSIST SYSTEMS"

After the title, insert a new section heading, to read:

"A. REQUIREMENTS FOR ELECTRONIC STABILITY CONTROL SYSTEMS,  
WHERE FITTED."

Paragraph 1, amend to read.

"1. GENERAL REQUIREMENTS

Vehicles equipped ...specified in paragraph 5. of this section."

Footnote 2, amend the end of the footnote, to read:

".. stipulated under paragraph 5. of this section"

Paragraph 3.6.4., amend to read:

"3.6.4. The requirement of paragraph 3.6.2.7. of this section does not apply to tell-tales shown in a common space."

Paragraph 3.6.5., amend to read:

"3.6.5. The manufacturer ...would meet paragraphs 3., 3.1., 3.2. and 3.3. of this section at that level of ESC function."

After Paragraph 5.11.9, insert a new section B, to read:

"B. SPECIAL REQUIREMENTS TO BE APPLIED TO BRAKE ASSIST SYSTEMS,  
WHERE FITTED

1. GENERAL

The following requirements apply to vehicles fitted with Brake Assist Systems (BAS) as defined in paragraph 2.34. of this Regulation and declared in the Communication of Annex 1, paragraph 22. of this Regulation.

In addition to the requirements of this annex, Brake Assist Systems shall also be subject to any relevant requirements contained elsewhere within this Regulation.

In addition to the requirements of this annex, vehicles with BAS shall also be equipped with ABS in accordance with Annex 6.

1.1. General performance characteristics for category "A" BAS systems

When an emergency condition has been sensed by a relative high pedal force, the additional pedal force to cause full cycling of the ABS shall be reduced compared to the pedal force required without the BAS system in operation.

Compliance with this requirement is demonstrated if the provisions of paragraphs 3.1. to 3.3. of this section are met.

1.2. General performance characteristics for category "B" and category "C" BAS systems

When an emergency condition has been sensed, at least by a very fast application of the pedal, the BAS system shall raise the pressure to deliver the maximum achievable braking rate or cause full cycling of the ABS.

Compliance with this requirement is demonstrated if the provisions of paragraphs 4.1. to 4.3. of this section are met.

2. GENERAL TEST REQUIREMENTS

2.1. Variables

Whilst performing the tests described in part B of this annex, the following variables shall be measured:

2.1.1. Brake pedal force,  $F_p$  ;

2.1.2. Vehicle velocity,  $v_x$  ;

2.1.3. Vehicle deceleration,  $a_x$  ;

- 2.1.4. Brake temperature,  $T_d$  ;
- 2.1.5. Brake pressure,  $P$ , where applicable;
- 2.1.6. Brake pedal travel,  $S_p$ , measured at the centre of the pedal plate or at a position on the pedal mechanism where the displacement is proportional to the displacement at the centre of the pedal plate allowing simple calibration of the measurement.

## 2.2. Measuring equipment

2.2.1. The variables listed in paragraph 2.1. of this section shall be measured by means of appropriate transducers. Accuracy, operating ranges, filtering techniques, data processing and other requirements are described in ISO Standard 15037-1: 2006.

2.2.2. Accuracy of pedal force and disc temperature measurements shall be as follows:

Variable range system	Typical operating range of the transducers	Recommended maximum recording errors
Pedal force	0 to 2,000 N	$\pm 10$ N
Brake temperature	0 – 1,000 °C	$\pm 5$ °C
Brake pressure */	0 – 20 MPa */	$\pm 100$ kPa */

\*/ Applicable as specified in paragraph 3.2.5.

2.2.3. Details on analogue and digital data processing of the BAS test procedures are described in Appendix 5 to this annex. A sampling rate for data acquisition of at least 500 Hz is required.

2.2.4. Alternative measuring methods to those referred to in paragraph 2.2.3. may be allowed, provided they demonstrate at least an equivalent level of precision.

## 2.3. Test conditions

2.3.1. Test vehicle loading condition: The vehicle shall be unladen. There may be, in addition to the driver, a second person on the front seat who is responsible for noting the results of the tests.

2.3.2. Braking tests shall be carried out on a dry surface affording good adhesion.

## 2.4. Test method

2.4.1. The tests as described in paragraphs 3. and 4. of this section shall be carried out from a test speed of  $100 \pm 2$  km/h. The vehicle shall be driven at the test speed in a straight line.

- 2.4.2. The average temperature of the brakes shall be in accordance with paragraph 1.4.1.1. of Annex 3.
- 2.4.3. For the tests the reference time,  $t_0$ , is defined as the moment when the brake pedal force reaches 20 N.

Note: For vehicles equipped with a brake system assisted by an energy source, the applied pedal force necessary depends on the energy level that exists in the energy storage device. Therefore, sufficient energy level shall be ensured at the beginning of the test.

3. Assessment of the presence of a category "A" BAS

A category "A" BAS shall meet the test requirements contained in paragraphs 3.1. and 3.2.

3.1. Test 1: Reference test to determine  $F_{ABS}$  and  $a_{ABS}$ .

3.1.1. The reference values  $F_{ABS}$  and  $a_{ABS}$  shall be determined in accordance with the procedure described in Appendix 4 to this annex.

3.2. Test 2: For activation of BAS

3.2.1. Once an emergency braking condition has been detected, systems sensitive to pedal force shall show a significant increase in the ratio of:

- (a) brake line pressure to brake pedal force, where permitted by paragraph 3.2.5., or
- (b) vehicle deceleration to brake pedal force.

3.2.2. The performance requirements for a category "A" BAS are met if a specific brake application characteristic can be defined that exhibits a decrease of between 40 per cent and 80 per cent in required brake pedal force for  $(F_{ABS} - F_T)$  compared to  $(F_{ABS, extrapolated} - F_T)$ .

3.2.3.  $F_T$  and  $a_T$  are threshold force and threshold deceleration as shown in Figure 1. The values of  $F_T$  and  $a_T$  shall be supplied to the Technical Service at the time of submission of the type-approval application. The value of  $a_T$  shall be between 3.5 m/s<sup>2</sup> and 5.0 m/s<sup>2</sup>.

3.2.4. A straight line is drawn from the origin through the point  $F_T, a_T$  (as shown in Figure 1a). The value of brake pedal force "F", at the point of intersection between this line and a horizontal line defined by  $a=a_{ABS}$ , is defined as  $F_{ABS, extrapolated}$ :

$$F_{ABS, extrapolated} = \frac{F_T \cdot a_{ABS}}{a_T}$$

3.2.5. As an alternative, which can be selected by the manufacturer, in the case of vehicles of category  $N_1$ , or  $M_1$  derived from those  $N_1$  vehicles, with a gross vehicle mass

GVM > 2,500 kg, the pedal force figures for  $F_T$ ,  $F_{ABS,min}$ ,  $F_{ABS,max}$  and  $F_{AB,extrapolated}$  may be derived from the brake line pressure response characteristic instead of the vehicle deceleration characteristic. This shall be measured as the brake pedal force is increasing.

- 3.2.5.1. The pressure, at which ABS cycling commences, shall be determined by making five tests from  $100 \pm 2$  km/h in which the brake pedal is applied up to the level which produces ABS operation and the five pressures at which this occurs as determined from front wheel pressure records, shall be recorded and the mean value obtained as  $P_{ABS}$ .
- 3.2.5.2. The threshold pressure  $P_T$  shall be stated by the manufacturer and correspond to a deceleration in the range of  $2.5 - 4.5$  m/s<sup>2</sup>.
- 3.2.5.3. Figure 1b shall be constructed in the manner set out in paragraph 3.2.4., but using line pressure measurements to define the parameters set out in paragraph 3.2.5. of this section where:

$$F_{ABS,extrapolated} = \frac{F_T \cdot P_{ABS}}{P_T}$$

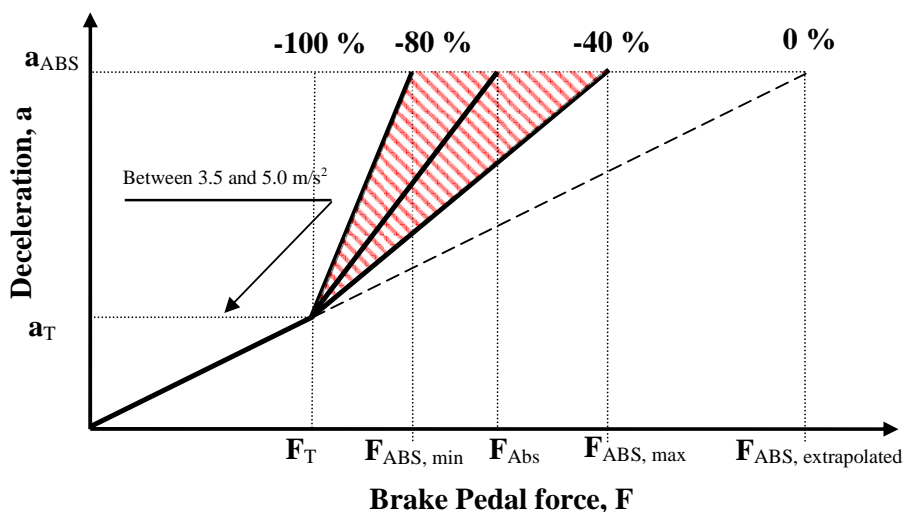


Figure 1a: Pedal force characteristic needed in order to achieve maximum deceleration with category "A" BAS



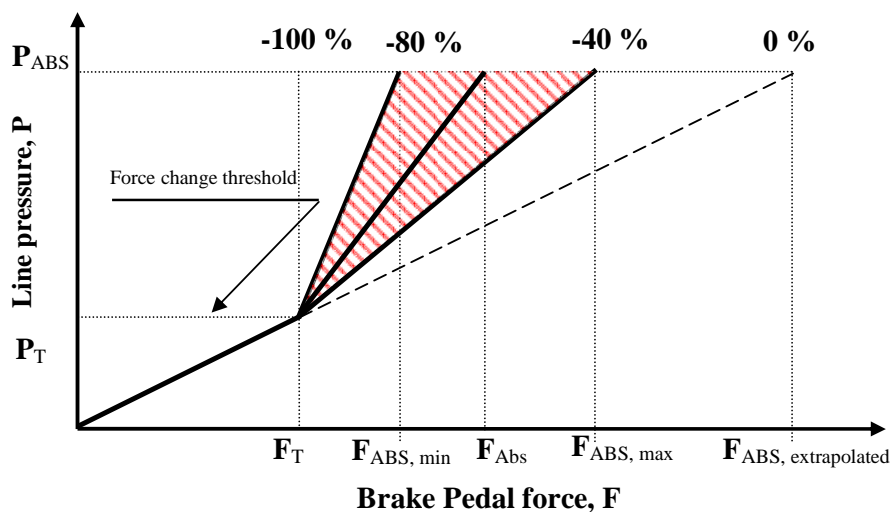


Figure 1b: Pedal force characteristic needed in order to achieve maximum deceleration with category "A" BAS

### 3.3. Data evaluation

The presence of a category "A" BAS is proven if

$$F_{ABS,min} \leq F_{ABS} \leq F_{ABS,max}$$

where:

$$F_{ABS,max} - F_T \leq (F_{ABS,extrapolated} - F_T) \cdot 0.6$$

and

$$F_{ABS,min} - F_T \geq (F_{ABS,extrapolated} - F_T) \cdot 0.2$$

## 4. ASSESSMENT OF THE PRESENCE OF A CATEGORY "B" BAS

A category "B" BAS shall meet the test requirements contained within paragraphs 4.1. and 4.2. of this section.

### 4.1. Test 1: Reference test to determine $F_{ABS}$ and $a_{ABS}$ .

4.1.1. The reference values  $F_{ABS}$  and  $a_{ABS}$  shall be determined in accordance with the procedure described in Appendix 4 to this annex.

### 4.2. Test 2: For activation of BAS

The vehicle shall be driven in a straight line at the test speed specified in paragraph 2.4. of this section. The driver shall apply the brake pedal quickly according to Figure 2, simulating emergency braking so that BAS is activated and ABS is fully cycling.

In order to activate BAS the brake pedal shall be applied as specified by the car manufacturer. The manufacturer shall notify the Technical Service of the required brake pedal input at the time of submission of the application for type-approval. It shall be demonstrated to the satisfaction of the Technical Service that the BAS activates under the conditions specified by the manufacturer in accordance with paragraph 22.1.2. or 22.1.3 of Annex 1.

After  $t = t_0 + 0.8$  s and until the vehicle has slowed down to a speed of 15 km/h, the brake pedal force shall be maintained in a corridor between  $F_{ABS, upper}$  and  $F_{ABS, lower}$ , where  $F_{ABS, upper}$  is  $0.7 F_{ABS}$  and  $F_{ABS, lower}$  is  $0.5 F_{ABS}$ .

The requirements are also considered to be met if, after  $t = t_0 + 0.8$  s, the pedal force falls below  $F_{ABS, lower}$  provided the requirement of paragraph 4.3. is fulfilled.

#### 4.3. Data evaluation

The presence of BAS 'B' is demonstrated if a mean deceleration ( $a_{BAS}$ ) of at least  $0.85 \cdot a_{ABS}$  is maintained from the time when  $t = t_0 + 0.8$  s to the time when the vehicle speed has been reduced to 15 km/h.

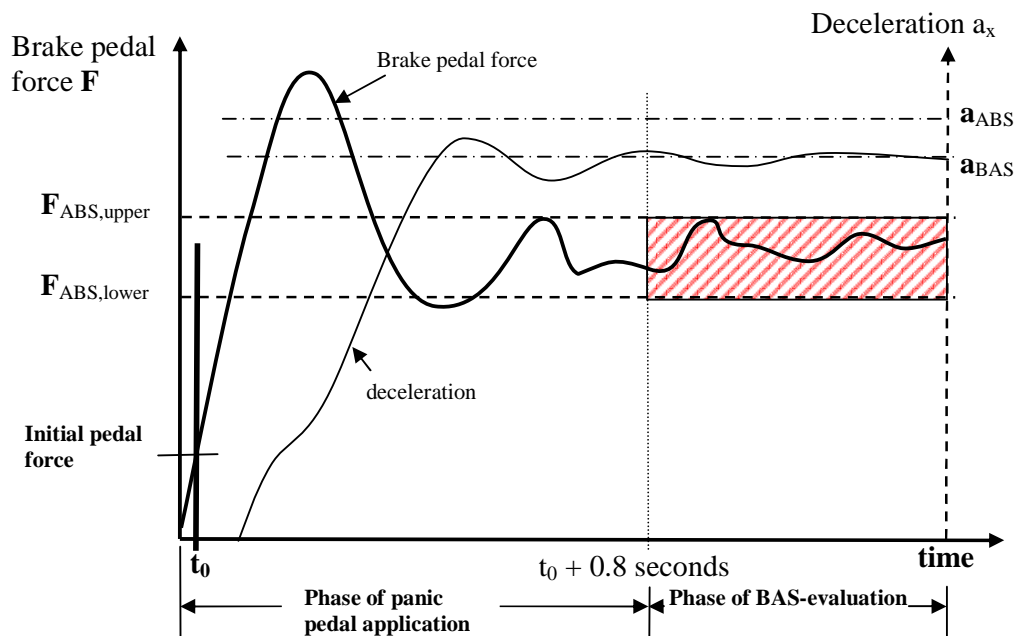


Figure 2: Example of test 2 of a category "B" BAS system

5. ASSESSMENT OF THE PRESENCE OF A CATEGORY "C" BAS

5.1. A category "C" BAS shall meet the test requirements of paragraphs 4.1. and 4.2. of this section.

5.2. Data evaluation

A category "C" BAS shall meet the requirements of paragraph 4.3. of this section."

Insert new Appendices 4 and 5, to read:

"Annex 9 - Appendix 4

METHOD FOR DETERMINATION OF  $F_{ABS}$  AND  $a_{ABS}$

- 1.1. The brake pedal force  $F_{ABS}$  is the minimum pedal force that has to be applied for a given vehicle in order to achieve maximum deceleration which indicates that ABS is fully cycling.  $a_{ABS}$  is the deceleration for a given vehicle during ABS deceleration as defined in paragraph 1.7.
- 1.2. The brake pedal shall be applied slowly (without activating the BAS in the case of category B or category C systems) providing a constant increase of deceleration until ABS is fully cycling (Figure 3).
- 1.3. The full deceleration must be reached within the timeframe of  $2.0 \pm 0.5$  s. The deceleration curve, recorded against time, must be within a corridor of  $\pm 0.5$  s around the centre line of the deceleration curve corridor. The example in Figure 3 has its origin at the time  $t_0$  crossing the  $a_{ABS}$  line at 2 seconds. Once full deceleration has been achieved the pedal travel  $S_p$  shall not be decreased for at least 1 s. The time of full activation of the ABS system is defined as the time when pedal force  $F_{ABS}$  is achieved. The measurement shall be within the corridor for variation of increase in deceleration (see Figure 3).

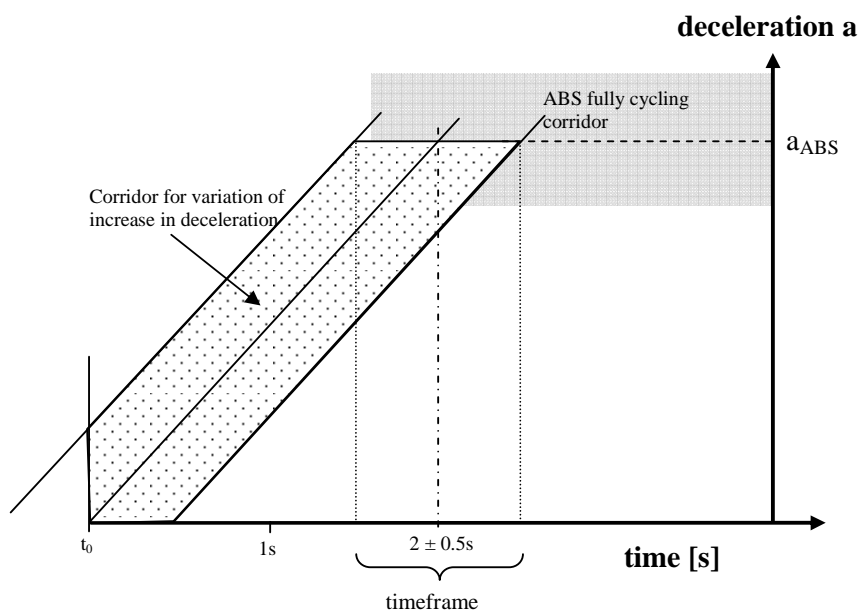


Figure 3: Deceleration corridor for determination of  $F_{ABS}$  and  $a_{ABS}$

- 1.4. Five tests meeting the requirements of paragraph 1.3. shall be carried out. For each of these valid tests the vehicle deceleration shall be plotted as a function of the recorded

brake pedal force. Only data recorded at speeds above 15 km/h shall be taken for the calculations described in the following paragraphs.

- 1.5. For the determination of  $a_{ABS}$  and  $F_{ABS}$ , a low pass filter of 2 Hz for vehicle deceleration as well as pedal force shall be applied.
- 1.6. The five individual "deceleration versus brake pedal force" curves are averaged by calculating the mean deceleration of the five individual "deceleration vs. brake pedal force" curves at increments of 1 N pedal force. The result is the mean deceleration versus brake pedal force curve, which will be referred to as the "maF curve" in this appendix.
- 1.7. The maximum value for the vehicle deceleration is determined from the "maF curve" and is named as " $a_{max}$ ".
- 1.8. All values of the "maF curve" that are above 90 per cent of this deceleration value " $a_{max}$ " are averaged. This value of "a" is the deceleration " $a_{ABS}$ " referred to in this annex.
- 1.9. The minimum force on the pedal ( $F_{ABS}$ ) sufficient to achieve the deceleration  $a_{ABS}$  is defined as the value of F corresponding to  $a = a_{ABS}$  on the maF curve.

Annex 9 - Appendix 5

(see paragraph 2.2.3. of section B of this annex)

DATA PROCESSING FOR THE BAS

1. ANALOGUE DATA PROCESSING

The bandwidth of the entire, combined transducer/recording system shall be no less than 30 Hz.

In order to execute the necessary filtering of signals, low-pass filters with order 4 or higher shall be employed. The width of the pass band (from 0 Hz to frequency  $f_0$  at -3 dB) shall not be less than 30 Hz. Amplitude errors shall be less than  $\pm 0.5$  per cent in the relevant frequency range of 0 Hz to 30 Hz. All analogue signals shall be processed with filters having sufficiently similar phase characteristics to ensure that time delay differences due to filtering lie within the required accuracy for time measurement.

NOTE: During analogue filtering of signals with different frequency contents, phase shifts can occur. Therefore, a data processing method, as described in paragraph 2. of this appendix, is preferable.

2. DIGITAL DATA PROCESSING

2.1. General consideration

Preparation of analogue signals includes consideration of filter amplitude attenuation and sampling rate to avoid aliasing errors, and filter phase lags and time delays. Sampling and digitising considerations include pre-sampling amplification of signals to minimize digitising errors; number of bits per sample; number of samples per cycle; sample and hold amplifiers; and time-wise spacing of samples. Considerations for additional phaseless digital filtering include selection of pass bands and stop bands and the attenuation and allowable ripple in each; and correction of filter phase lags. Each of these factors shall be considered in order to achieve a relative overall data acquisition accuracy of  $\pm 0.5$  per cent.

2.2. Aliasing errors

In order to avoid uncorrectable aliasing errors, the analogue signals shall be appropriately filtered before sampling and digitising. The order of the filters used and their pass band shall be chosen according to both the required flatness in the relevant frequency range and the sampling rate.

The minimum filter characteristics and sampling rate shall be such that:

- (a) Within the relevant frequency range of 0 Hz to  $f_{max} = 30$  Hz the attenuation is less than the resolution of the data acquisition system; and

- (b) At one-half the sampling rate (i.e. the Nyquist or "folding" frequency) the magnitudes of all frequency components of signal and noise are reduced to less than the system resolution.

For 0.05 per cent resolution the filter attenuation shall be less than 0.05 per cent in the frequency range between 0 and 30 Hz, and the attenuation shall be greater than 99.95 per cent at all frequencies greater than one-half the sampling frequency.

NOTE: For a Butterworth filter the attenuation is given by:

$$A^2 = \frac{1}{1 + \left(\frac{f_{\max}}{f_0}\right)^{2n}} \quad \text{and} \quad A^2 = \frac{1}{1 + \left(\frac{f_N}{f_0}\right)^{2n}}$$

where:

n is the order to filter;

$f_{\max}$  is the relevant frequency range (30 Hz);

$f_0$  is the filter cut-off frequency;

$f_N$  is the Nyquist or "folding" frequency.

For a fourth order filter

for A = 0.9995:  $f_0 = 2.37 \cdot f_{\max}$

for A = 0.0005:  $f_s = 2 \cdot (6.69 \cdot f_0)$ , where  $f_s$  is the sampling frequency =  $2 \cdot f_N$ .

### 2.3. Filter phase shifts and time delays for anti-aliasing filtering

Excessive analogue filtering shall be avoided, and all filters shall have sufficiently similar phase characteristics to ensure that time delay differences are within the required accuracy for the time measurement. Phase shifts are especially significant when measured variables are multiplied together to form new variables, because while amplitudes multiply, phase shifts and associated time delays add. Phase shifts and time delays are reduced by increasing  $f_0$ . Whenever equations describing the pre-sampling filters are known, it is practical to remove their phase shifts and time delays by simple algorithms performed in the frequency domain.

NOTE: In the frequency range in which the filter amplitude characteristics remain flat, the phase shift  $\Phi$  of a Butterworth filter can be approximated by

$$\Phi = 81 \cdot (f/f_0) \text{ degrees for second order}$$

$$\Phi = 150 \cdot (f/f_0) \text{ degrees for fourth order}$$

$$\Phi = 294 \cdot (f/f_0) \text{ degrees for eighth order}$$

The time delay for all filter orders is:  $t = (\Phi/360) \cdot (1/f_0)$

### 2.4. Data sampling and digitising

At 30 Hz the signal amplitude changes by up to 18 per cent per millisecond. To limit dynamic errors caused by changing analogue inputs to 0.1 per cent, sampling or

digitising time shall be less than 32  $\mu$ s. All pairs or sets of data samples to be compared shall be taken simultaneously or over a sufficiently short time period.

## 2.5. System requirements

The data system shall have a resolution of 12 bits ( $\pm 0.05$  per cent) or more and an accuracy of  $\pm 0.1$  per cent (2 lbs). Anti-aliasing filters shall be of order 4 or higher and the relevant data range  $f_{\max}$  shall be 0 Hz to 30 Hz.

For fourth order filters the pass-band frequency  $f_o$  (from 0 Hz to frequency  $f_o$ ) shall be greater than  $2.37 \cdot f_{\max}$  if phase errors are subsequently adjusted in digital data processing, and greater than  $5 \cdot f_{\max}$  otherwise. For fourth order filters the data sampling frequency  $f_s$  shall be greater than  $13.4 \cdot f_o$ ."

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