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Working Party on Brakes and Running Gear

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Item 3(g) of the provisional agenda

**REGULATIONS Nos. 13 AND 13-H
(Braking)**

Brake Assist System

Proposal for draft amendments to Regulation No. 13-H

Submitted by the experts of the informal working group on Brake Assist Systems ^{*/}

The text reproduced below was prepared by the experts of the informal group on Brake Assist Systems (BAS) in order to insert new provisions on BAS in Regulation No. 13-H. It is based on ECE/TRANS/WP.29/GRRF/2008/2 as amended by informal document No. GRRF-63-46, distributed during the sixty-third session of the Working Party on Brakes and Running Gear (GRRF), and takes into account the comments by the BAS informal group.

^{*/} 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.

A. PROPOSAL

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."

Insert a new paragraph 4.4.5., to read:

- "4.4.5. In the case of a vehicle complying with the BAS requirements of Annex 10, the additional letters 'BAS' shall be placed immediately to the right of the letters mentioned in paragraph 4.4.2., 4.4.3. or 4.4.4."

Insert new paragraphs 12.4. and 12.5., to read (option A or B, to be selected by GRRF/WP.29):

Option A:

- ["12.4. As from [24] months after the date of entry into force of Supplement X to the original version of this Regulation, Contracting Parties applying this Regulation may refuse to grant new approvals if the vehicle type to be approved does not meet the requirements of this Regulation as amended by Supplement X to the 01 series of amendments.
- 12.5. As from [48] months after the date of entry into force of Supplement X to the original version of this Regulation, Contracting Parties applying this Regulation may refuse first national registration if the vehicle does not meet the requirements of this Regulation as amended by Supplement X to the 01 series of amendments."]

Option B:

- ["12.4. As from [24] months after the date of entry into force of Supplement X to the original version of this Regulation, Contracting Parties applying this Regulation may refuse to grant new approvals if the vehicle type to be approved is not fitted with a Brake Assist System meeting the requirements of Annex 10 to this Regulation.

- 12.5. As from [48] months after the date of entry into force of Supplement X to the original version of this Regulation, Contracting Parties applying this Regulation may refuse first national registration of vehicles of this type unless fitted with a Brake Assist System meeting the requirements of Annex 10 to this Regulation."]

Annex 1,

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 Annex 10.
- 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 Annex 10. 2/"

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

Insert a new Annex 10, to read (including its Appendix[ces] 1 [and 2]):

"Annex 10

SPECIAL REQUIREMENTS TO BE APPLIED TO BRAKE ASSIST SYSTEMS,
WHERE FITTED

1. GENERAL

This annex specifies test requirements for vehicles fitted with Brake Assist Systems (BAS) as defined in paragraph 2.23. 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 annex 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 cause full cycling of the ABS.

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

2. GENERAL TEST REQUIREMENTS

2.1. Variables

Whilst performing the tests described in 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 annex 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	± 10 N
Brake temperature	0 – 1,000 °C	± 5 °C
Brake pressure */	0 – 20 MPa */	± 100 kPa */

*/ Applicable as specified in paragraph 3.2.5.

Paragraphs 2.2.3. and 2.2.4. and Appendix 2, to be deleted (option A) or retained (option B), options to be selected by GRRF/WP.29.

[2.2.3. A sampling rate for data acquisition of at least 500 Hz is required.

2.2.4. Further details on analogue and digital data processing of the BAS test procedures are described in Appendix 2 to this annex.]

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.

2.4. Test method

2.4.1. The tests as described in paragraphs 3. and 4. below shall be carried out from a test speed of 100 ± 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 1 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:
- brake line pressure to brake pedal force, where permitted by paragraph 3.2.5., or
 - 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/s² and 5.0 m/s².
- 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 N₁ > 2.5 tonnes], 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 ± 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/s².
- 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. above where:

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

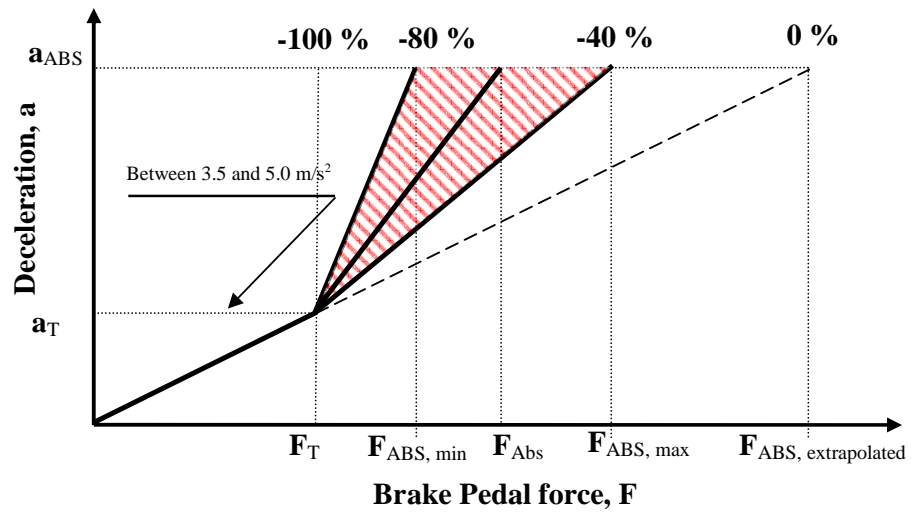


Figure 1a: Pedal force characteristic needed in order to achieve maximum deceleration with category "A" BAS

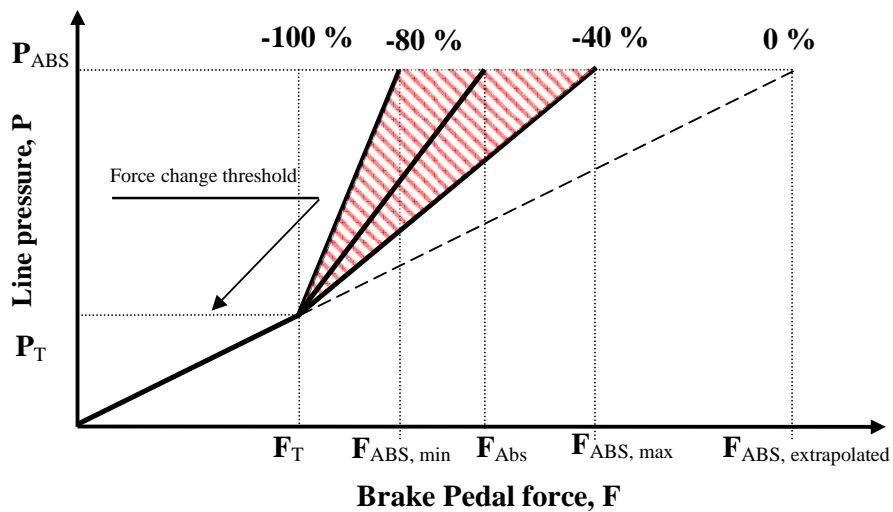


Figure 1b: Pedal force characteristic needed in order to achieve maximum deceleration with category "A" BAS

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

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

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 annex.

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 1 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. above. 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.

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 $F_{\text{ABS, upper}}$ and $F_{\text{ABS, lower}}$. Where $F_{\text{ABS, upper}}$ is $0.7 F_{\text{ABS}}$ and $F_{\text{ABS, lower}}$ is $0.5 F_{\text{ABS}}$.

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

4.3. Data evaluation

The presence of BAS 'B' is proven if a mean deceleration 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.

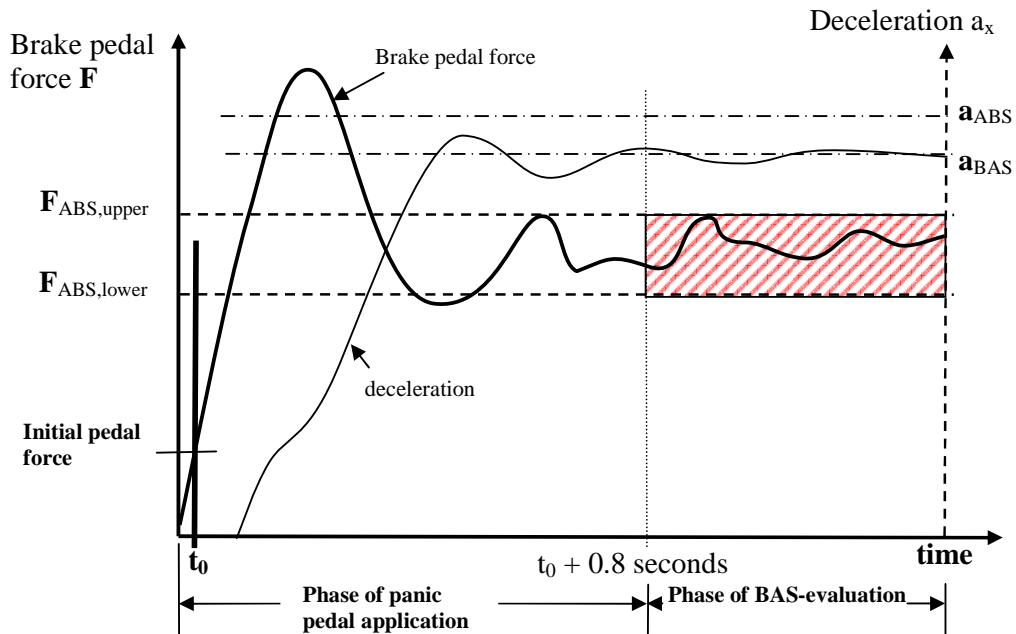


Figure 2: Example of test 2 of a category "B" BAS system

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 annex.

5.2. Data evaluation

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

Annex 10, Appendix 1

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 ± 0.5 s. The deceleration curve, recorded against time, must be within a corridor of ± 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 variance of deceleration increase (see Figure 3).

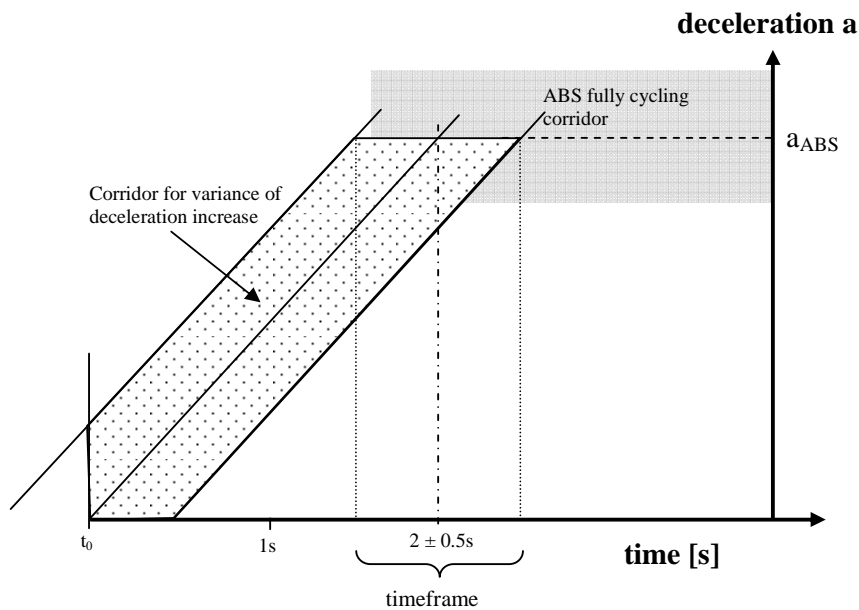


Figure 3: Deceleration corridor for determination of F_{ABS} and a_{ABS}

- 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. 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.
- 1.6. The maximum value for the vehicle deceleration is determined from the "maF curve" and is named as " a_{\max} ".
- 1.7. 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.
- 1.8. The minimum force on the pedal (F_{ABS}) sufficient to achieve the deceleration a_{ABS} is defined as the value of F corresponding to $a = a_{\text{ABS}}$ on the maF curve.

[Annex 10, Appendix 2

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 ± 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 ± 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;
- fmax is the relevant frequency range (30 Hz);
- fo is the filter cut-off frequency;
- fN is the Nyquist or "folding" frequency.

For a fourth order filter

for A = 0.9995: fo = 2.37 · fmax

for A = 0.0005: fS, = 2 · (6.69 · fo), where fS, is the sampling frequency = 2 · fN.

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 fo. 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 Φ 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 μ 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 (± 0.05 per cent) or more and an accuracy of 2 lbs (± 0.1 per cent). 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 $13.4 \cdot f_o$.]"

B. JUSTIFICATION

It is recognised that many drivers do not fully utilize the full capability of a vehicle braking system, in particular in case of emergency. The purpose of a Brake Assist System is to allow real world braking performance to approach the full performance capability of the system. This will have the effect of reducing emergency stopping distances for a large proportion of drivers and thus reduce the number and severity of casualties.

This document introduces provisions for Brake Assist Systems (BAS) to enable manufacturers to declare, and for Contracting Parties to confirm, the presence of a brake assist system on a vehicle covered by this Regulation. It is not intended that this Regulation should mandate the installation of brake assist systems. However, it is envisaged that Contracting Parties wishing to encourage or mandate the use of such systems within their territories (for example, as part of a package of measures to improve the protection of pedestrians) could specify that vehicles are fitted with systems meeting the technical specifications proposed in this document.

The specifications contained within this document reflect systems that are currently available on the market. However, the tests and specifications cannot discriminate between a category B and a category C system. The tests also rely on a declaration from the manufacturer on how the pedal should be pressed to activate their particular BAS. It has, therefore, been requested that information regarding the brake pedal application required to activate BAS (all categories) and all of the input variables to category C systems and their relationships and threshold values be supplied to the Technical Service to monitor the way in which BAS is implemented and to help determine whether further requirements are necessary for these types of system. It is envisaged that in the future the requirements could be further developed to enhance the current performance requirements and allow alternative methods of identifying emergency situations (for example, by using radar technology).
