The Brake System

Job No. 42—0

A. General

The efficacy and dependability of the brake system of a vehicle are of particular importance for traffic safety. The chief function of the brakes is to absorb the kinetic energy of the moving vehicle. The kinetic energy is converted into heat. The efficacy of a brake system is judged by the mean deceleration attainable. In the relevant German road traffic law the following values are laid down for passenger cars:

Specified mean deceleration — for the service brake: = 2.5 m/sec/sec
for the hand brake: = 1.5 m/sec/sec

The mean deceleration can be computed from the initial velocity of the vehicle and the stopping distance. The stopping distance is the distance the vehicle travels from the moment the brakes are applied until it comes to a stop.

The mean deceleration can, however, also be determined from the initial velocity and the stopping time.

For any given vehicle the stopping distance is dependent on the following factors (assuming that the pedal force applied remains constant):

1. Type and condition of the brake
2. Weight of the vehicle
3. Speed at the moment of brake application (Initial velocity)
4. Condition of the tires
5. Condition of the road surface

Computation of the Stopping Distance

In accordance with basic mechanical formulae, the stopping distance is given by the following equation:

$$s = \frac{v \times t}{2} = \frac{b \times t^2}{b} = \frac{v^2}{2 \times b} \text{ (m)}$$

where

s = stopping distance in m
v = velocity in m/sec
t = stopping time in sec
b = deceleration in m/sec/sec

If the velocity is to be expressed in km/h, the equation is

$$s = \frac{v^2}{26 \times b} \text{ (m)}$$

or for the mean deceleration

$$b = \frac{v^2}{26 \times s} \text{ (m/sec/sec)}$$

The mean deceleration can be determined from the initial velocity and the stopping time by means of the basic equation

$$b = \frac{v}{3.6 \times t} \text{ (m/sec/sec)}$$

The best method of determining the mean deceleration is to measure the stopping distance and to measure the initial velocity with the help of a calibrated speedometer. However, the stopping distance cannot be measured with sufficient accuracy by measuring the tire marks since at the beginning of the braking operation there are no visible tire marks on the road surface. For accurate measurements, therefore, paint markers are used which mark the road surface with a spot of paint at the beginning and at the end of the braking operation.

For practical purposes it is sufficient to determine the mean deceleration by means of a commercial decelerometer. The decelerometer, however, does not indicate the mean deceleration but the maximum deceleration attained during the braking opération. As a rule it can be assumed that when the brakes are fully applied at medium speed (approx. 70 — 80 km/h), the mean deceleration is roughly 0.8 times that of the maximum deceleration indicated by the decelerometer, which means that the indicated value must by multiplied by 0.8.

The specified deceleration values must be attained on a dry level road, at normal pedal load, with the vehicle fully loaded and the brake drums warmed up, (also at maximum speeds) without the vehicle beginning to skid.

Stopping Distance "s" (in m) and Stopping Time "t" (in sec)
on dry concrete roads (freeways) exclusive of the "scare second"

Deceleration	Speed in km/h																					
	40		50		60		70		80		90		100		110		120		130		140	
	s	t	s	t	s	t	s	t	s	t	s	t	s	t	s	t	s	t	s	t	s	t
1.5	41	7.46	64.1	9.3	92.3	11.19	125.6	13	164	14.92	207.7	16.8	256.4	18.6	310.2	20.5	369.2	22.38	433.3	24.2	502.5	26
2	30.8	5.6	48.1	7	69.3	8.4	94.2	9.8	123.2	11.2	156.6	12.6	192.4	14	232.7	15.4	277.2	16.8	325	18.2	376.8	19.6
2.5	24.8	4.48	38.5	5.6	55.8	6.72	75.4	7.6	99.2	8.96	125.1	10.08	154	11.2	186.2	12.3	223.2	13.44	260	14.6	301.6	15.2
3	20.4	3.72	32.1	4.7	45.9	5.58	62.8	6.5	81.6	7.44	103.5	8.4	128.4	9.4	155.1	10.3	183.6	11.16	216.6	12.1	251.2	11.2
3.5	17.6	3.2	27.5	4	39.6	4.8	53.8	5.6	70.4	6.4	89.1	7.2	110	8	133	8.8	158.4	9.6	185.7	10.4	215.2	13
4	15.2	2.8	24	3.5	34.2	4.2	47.1	4.9	60.8	5.6	77.4	6.3	96	7	116.3	7.7	136.8	8.4	162.5	9.1	188.4	9.8
4.5	13.6	2.48	21.4	3.1	30.6	3.72	41.9	4.4	54.4	4.96	69.3	5.58	85.6	6.2	103.4	6.8	122.4	7.44	144.4	8	167.6	8.8
5	12.4	2.24	19.2	2.8	27.9	3.36	37.7	3.9	49.6	4.48	62.1	5.04	76.8	5.6	93.1	6.2	111.6	6.72	130	7.3	150.8	7.8
5.5	11.2	2.04	17.4	2.54	25.2	3.06	34.2	3.6	44.8	4.08	56.7	4.59	69.6	5.08	84.6	5.6	100.8	6.12	118.1	6.6	136.8	7.2
6	10.4	1.86	16	2.3	23.4	2.79	31.4	3.3	41.6	3.72	53.1	4.2	64	4.6	77.6	5.1	93.6	5.58	108.3	6.1	125.6	6.6
6.0	9.6	1.72	14.8	2.15	21.6	2.58	28.9	3	38.4	3.44	48.6	3.87	59.2	4.3	71.6	4.7	86.4	5.16	100	5.6	115.6	6
7	8.8	1.6	13.7	2	19.8	2.4	26.9	2.8	35.2	3.2	44.1	3.6	54.8	4	66.5	4.4	79.2	4.8	92.9	5.2	107.6	5.6

In computing the stopping distances given in the above table, the "scare second" has not been taken into account. Many tests have confirmed the general experience that the driver of a motor vehicle needs just about one second, the so-called "scare second", until he is in a position effectively to brake his vehicle. The "scare second" comprises the recognition time, the reaction time proper, the brake actuating time, and the brake response time. During the whole of this one second the vehicle travels on at undiminished speed. For this reason the actual stopping distance is much longer when the "scare second" is taken into consideration. In the following diagram the stopping distances are given on the basis of one "scare second".

Stopping Distance (Including 1 Scare Second)

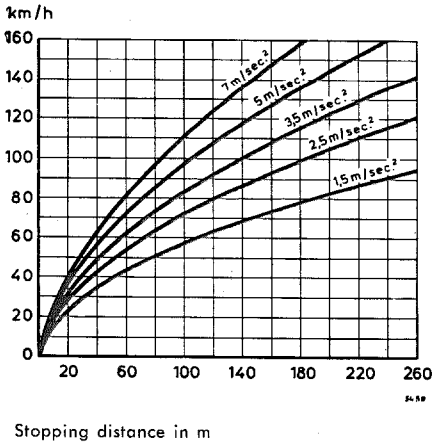

Fig. 42 — 0/1

The deceleration values attained by modern vehicles are considerably higher than the legal minimum values when the cars are braked at medium speeds.
Under very favorable conditions ,the following mean deceleration values can be expected:

dry concrete (freeways)	7 m/sec/sec
dry asphalt and macadam	5 m/sec/sec
wet asphalt and macadam	3.5 m/sec/sec
icy roads	1.5 m/sec/sec

B. Description of the Brake System

a) Vehicle without ATE Power Brake A 50

General:

The service brake is of the hydraulic type. It consists of a brake master cylinder which produces the hydraulic pressure,

the brake wheel cylinders inside the brake drums which transmit this pressure and press the brake shoes against the brake drums,

the network of brake lines and brake hoses which provide the connection between brake master cylinder and brake wheel cylinders, and

the fluid reservoir which maintains a constant volume of brake fluid.

The hydraulic brake operates in accordance with Pascal's Law which states that the pressure exerted on an enclosed liquid is transmitted equally in all directions.

When the brake pedal is depressed, the piston in the brake master cylinder is pushed forward and the displaced brake fluid passes through the brake lines and brake hoses to the brake wheel cylinders. The brake fluid enters the brake wheel cylinders, pushing their pistons outward against the brake shoes and thus forcing these shoes against the brake drums. (For a diagrammatic illustration of the brake system see Fig. 42 — 0/2).