APTU Uniform Rules (Appendix F to COTIF 1999)

Uniform Technical Prescriptions (UTP) applicable to Rolling Stock, subsystem

FREIGHT WAGONS - (UTP WAG) - ANNEX S

BRAKING

BRAKING PERFORMANCE

Explanatory note:

The texts of this UTP which appear across two columns are identical to corresponding texts of the European Union regulations. Texts which appear in two columns differ; the left-hand column contains the UTP regulations, the right-hand column shows the text in the corresponding EU regulations. The text in the right-hand column is for information only and is not part of the OTIF regulations.

OTIF UTP | *Corresponding text in EU regulations* [1] *EU ref.* [2]

S.1 DETERMINING THE BRAKING POWER OF VEHICLES FITTED WITH UIC AIR BRAKE FOR PASSENGER TRAINS

S.1.1 GENERAL

The braked mass marked on a wagon shall indicate the braking power of this wagon in a 500 m long train that is braked in the P position.

The braked mass of a train of wagons is in principle the sum of the braked mass painted on the vehicles with an active brake.

This braked mass applies to hauled rakes that are ≤ 500 m long and braked in the P position.

S.1.2 DETERMINING THE BRAKING POWER BY CALCULATION

S.1.2.1 Determining the braking power using the factor k

The braked mass B of a wagon shall be determined by calculation providing the following conditions are met:

- maximum speed ≤ 120 km/h,
- the wheels are braked on both sides and have a nominal diameter of 920 to 1 000 mm,
- the brake shoes are made of P10 cast iron,
- the blocks are type Bg (single) or Bgu (tandem),
- force applied by the shoes 5 to 40 kN with Bg and 5 to 55 kN with Bgu blocks.

The braked mass shall be calculated using the following formula:

[1] TSI Freight Wagons – The Annex to the Commission Decision 2006/861/EC published in the EU Official Journal L344 on 08.12.2006 as amended by Commission Decision 2009/107/EC published in EU Official Journal L45 on 14.02.2009.
[2] If no EU reference is indicated, it means that the chapter/section number is the same as in the OTIF text.

Equation (S1): $B[t] = \dfrac{k\,[-] \times \sum F_{dyn}\,[kN]}{9{,}81\ [m/sec^2]}$

where ΣF_{dyn} is the sum of all the forces applied by the shoes whilst the vehicle is moving and k is a dimensionless factor that depends on the type of shoe (Bg or Bgu) and on the contact force of each shoe.

ΣF_{dyn} shall be calculated using the following formula: $\Sigma F_{dyn} = (F_t \times i - i^* \times F_R) \times \eta_{dyn}$

Where:

F_t = Effective force at the brake cylinder [kN], once the recoil of thecylinders and of the rigging has been deducted,

i = Total increment for the brake rigging,

i* = The increment after the central rigging (normally 4 for two-axled wagons and 8 for bogie wagons),

η_{dyn} = Mean efficiency of the rigging whilst the vehicle is moving (mean between two maintenance visits). η_{dyn} can be up to 0.91, depending on the type of rigging.

F_R = Opposing force applied from the regulator (usually 2 kN)

The ‘k’ curves used to calculate the braked mass are given by mathematical formulae of the following type:

Equation (S2): $k = a_0 + a_1 \times F_{dyn} + a_2 \times F_{dyn}^2 + a_3 \times F_{dyn}^3$

where:

	a_0	a_1	a_2	a_3
k_{Bg}	2.145	-5.38×10^{-2}	7.8×10^{-4}	-5.36×10^{-6}
k_{Bgu}	2.137	-5.14×10^{-2}	8.32×10^{-4}	-6.04×10^{-6}

S.1.2.2 Wagons for which the required condition for calculating the braking power according to paragraph S.1.2.1 is not given.

The calculation method described below shall be used to design the brake equipment of wagons with a maximum speed of ≤ 120 km/h. The braked mass that is painted on the wagon shall be determined in tests.

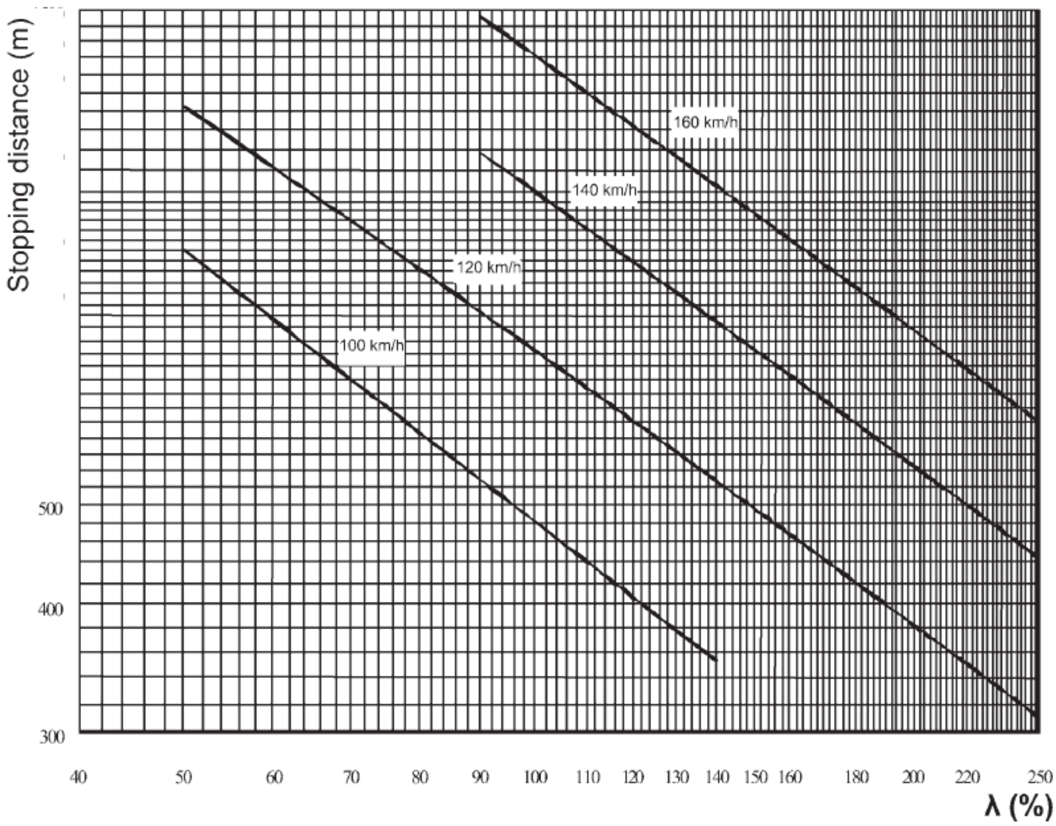
The braked mass is usually calculated in the following two stages:

1. Calculation of the braking distance based on the braking power applied in the various speed ranges.

2. Determination of the braked mass percentage from the calculated braking distance using the assessment graph in Figure S1 (wagon taken in isolation).

Figure S1

Assessment graph



The braking distance shall be calculated step-by-step (chapter S.4.1) or by deceleration stages (chapter S.4.2).

The calculation methods that are indicated apply in principle to a single wagon.

The braking distance shall be calculated for each of the initial speeds given in chapter S.1.3.2 and for the load conditions in chapter S.1.3.2 taking into account:

- the average dynamic efficiency between two maintenance visits,
- a brake cylinder filling time of 4 sec,
- the lowest mean friction characteristic for the friction materials on this type of wagon.

Once the braking distances have been calculated the braked mass shall be pre-determined using the procedure from chapter S.1.3.2, but with the calculated braking distances instead of the mean braking distances measured in tests.

For wagons as described in chapter S.1.2.1 that have a maximum speed of 140 km/h, the braked mass calculated for 120 km/h (cf. chapter S.1.2.1) may also be used for the maximum speed of 140 km/h.

The braked mass may be pre-determined using this calculation procedure, taking into account the following additional points:

- The braking distance shall be calculated for braking from 100, 120, 140 and 160 km/h up to the maximum speed of the wagon;
- Once the braking distances have been calculated, the braked mass shall be pre-determined using the procedure from chapter S.1.3.2, but with the calculated braking distances instead of the mean braking distances measured in tests.

The braked mass that is painted on the wagon shall be determined in tests (chapter S.1.3).

S.1.3 DETERMINING THE BRAKED MASS IN TESTS

This procedure shall be obligatory wherever there is no approved calculation method. The procedure may also be carried out for wagons as described in chapter S.1.2.1 (P10 shoes). If the tests give a braked mass that is higher than the calculated value then the calculated value shall not be changed; if the tests give a braked mass that is lower than the calculated value, the reason for that result shall be determined.

test may be carried out:

- tests with a single vehicle

In these tests the braking distance of the train or wagon shall be measured in an emergency brake application from v_0 on straight and flat track. The braking distance shall be measured from the point where the emergency brake application was initiated.

S.1.3.1 Wagons with a maximum speed of ≤ 120 km/h

S.1.3.1.1 Tests on a single vehicle (slipbrake tests)

The vehicle in question shall be coupled to a locomotive and accelerated up to a speed of v_0. Once that speed has been reached the mechanical coupler shall be uncoupled. An emergency brake application shall be made. The braking distance shall be measured from the point where the emergency brake application was initiated.

S.1.3.1.2 Vehicle composition in the slipbraketest

- One wagon in the case of a basic bogie-wagon;
- A group of three wagons in the case of two-axle wagons;
- A group of two wagons in the case of articulated non-bogie wagons;
- A set of wagons that cannot be split in service.

The slip brake tests shall be carried out at 100 km/h and 120 km/h.

Where an ‘empty-loaded’ changeover device is present, slip brake tests shall be carried out:

- in the ‘empty’ position, around the transition load (providing this is possible with the vehicle type in question). In the case of an automatic ‘empty-loaded’ changeover device, the tests shall also be carried out in the ‘empty’ position around the transition load, but at a load that is far enough below the transition load for the automatic device to be stable in the ‘empty’ position;
- at maximum load, in the ‘loaded’ position.

In the case of vehicles with an automatic, continually operating load changeover device the slip brake tests shall be carried out:

- in the empty state (tare mass), in the ‘empty’ loading position, in order to check that the maximum λ value prescribed has not been exceeded
- with the maximum load (which shall give the maximum braked mass).
- Slip brake tests shall also be carried out to verify the braked mass at the point of maximum energy dissipation.

The general test conditions can be found in chapter S.3.1.

The measured distance shall be corrected for nominal test conditions ($v_{o\ nom}$) using the method given in chapter S.3.2.

From the mean braking distance s (mean of the permissible corrected values), the braked mass percentage of the vehicle shall be determined either from the 120 km/h and/or 100 km/h curves in figure S1 or from the formula in table S1. The resulting minimum braked mass percentage shall be taken.

Table S1

Calculation of λ

$$S = \frac{C}{\lambda + D}$$

$$S = \frac{C}{S} - D$$

V [km/h]	C	D
100	52 840	10
120	83 634	19
140	119 179	19
160	161 280	19

These formulae are valid inside the limits corresponding to the extremities of the curves in Figure S1.

When the braked mass to be painted on the vehicle is determined in tests the test result shall be adjusted for the 'mean' dynamic efficiency between two maintenance visits (0.83 for wagons as described in chapter S.1.2.1).

With P10 shoes the braked mass shall be corrected for the dynamic power at the insert holder using the following method:

a) Determine the efficiency of the brake rigging as accurately as possible whilst the vehicle is running in the test to determine $\eta_{dyn\ test}$.

Where this measurement has not been taken, $\eta_{dyn\ test}$ = 0.91 may be used for new wagons with conventional rigging.

For other vehicles where $\eta_{dyn\ test}$ has not been measured the following may be used:

$$\eta_{dyn\ test} = \frac{1 + \eta_{stat\ test}}{2}$$

This formula may not be applied for ηstat test values of less than 0.6. ηdyn test shall never be higher than 0.91.

b) With B_{test} as the braked mass per insert holder in the test, the equations (1) and (2) above may be used to determine $F_{dyn\ test}$ either by directly reading off the value.

c) The corrected dynamic power is as follows:

$$F_{dyn\ corr} = F_{dyn\ test} \times \frac{0{,}83}{\eta_{dyn\ test}}$$

d) With this value for $F_{dyn\ corr}$ the same tables may be used to determine the corrected braked mass per insert holder, B_{corr}.

S.1.3.2 Wagons with a maximum speed greater than 120 km/h but not exceeding 160 km/h

The method shall be identical to that set down in chapter S.1.3.1 with two additional series of tests, one from 140 km/h and the other from 160 km/h if the wagon is capable of running at 160 km/h.

The measured braking distances shall be corrected for the nominal test conditions ($V_{o\ nom}$) using the method given in chapter S.3.2.

The corrected mean braking distances shall be used to determine 4 values for λ (λ_{100},

λ_{120}, λ_{140}, λ_{160}) from the curves in figure S1 (or from the formulae for these curves — see table S1).

The minimum value shall be taken from λ_{100}, λ_{120}, λ_{140} and λ_{160}.

S.2 DETERMINING THE BRAKING POWER OF WAGONS FITTED WITH A UIC AIR BRAKE FOR FREIGHT TRAINS

The braked mass of wagons in position G shall be deemed to be the same as the braked mass determined in position P.

There shall be no separate assessment of the braking power of wagons in position G.

S.3 EXECUTION OF TESTS

S.3.1 METHOD OF EXECUTION FOR THE TESTS

S.3.1.1 Atmospheric conditions

In order to avoid bad atmospheric conditions affecting the results the tests shall be carried out with minimum wind and dry rail.

S.3.1.2 Number of tests

At least 4 valid tests shall be carried out from which the mean shall then be calculated. All the braking distances obtained shall be corrected according to point 1 of chapter S.3.2.

The mean shall be accepted if it meets the following criteria, which shall be checked simultaneously:

Criterion 1: $\dfrac{\text{Standard deviation of sample } (\sigma_n)}{\text{Mean of sample } (\bar{s})} \leq 3.0\,\%$ and

Criterion 2: $\left|\text{Extreme value } (s_e) - \text{mean } (\bar{s})\right| \leq 1.95 \times \sigma_n$

where s_e is the braking distance furthest from the mean.

If one of the two criteria is not met, then a supplementary test shall be carried out (rejecting the extreme value 's_e' if criterion 2 is not met and $n \geq 5$).

With the new values thus obtained, criteria 1 and 2 shall then be checked where:
s_i = the braking distance measured in test 'i', after correction
$\bar{s}$ = the mean braking distance,
n = the number of tests,
σ_n = the standard deviation of the sample
and

$$\sigma_n = \sqrt{\frac{\sum \left|s_i - \bar{s}\right|^2}{n}}$$

The number of valid tests shall be at least 70 % of the total number of tests performed. The tests taken out in accordance with chapter S.3.2, point 1b, shall not figure in the total number of tests.

If after a total of 10 tests, one of the two criteria is not met, the test series shall be interrupted and the braking system controlled. The test interruption shall be recorded in the test report.

S.3.1.3 Condition of friction components and discs/wheels

Before starting the tests the vehicle's friction components (brake pads/shoes) shall be run in up to at least 70 % coverage.

Shorter braking distances are obtained with 3 to 5 mm wear on cast iron brake shoes. If the tests include braking to a standstill in wet conditions, the leading edge of the pad/shoe shall be run-in in the direction of rotation.

It is recommended that the tests be carried out on block-braked vehicles with wheels (either new or re-profiled) that have been run for at least 1 200 km.

It is recommended that the initial temperature of the discs/wheels be between 50 °C and 60 °C.

S.3.2 METHOD OF EVALUATING THE TEST RESULTS

S.3.2.1 Correcting the braking distances from each test

The braking distance obtained in test 'j' shall be corrected to take into account the following factors:

– nominal speed in relation to the initial speed measured in the test;
– gradient of the test track.

The correction shall be made by applying the following formula:

$$\frac{V_{jnom}^2}{2\times 3.6^2\times s_{jcorr}} = \frac{V_{jmeas}^2}{2\times 3.6^2\times s_{jmeas}} - \frac{g}{\rho}\times\frac{i}{1000}$$

Transformation gives the following:

$$s_{jcorr} = \frac{3.933\times\rho\times V_{jnom}^2}{3.933\times\rho\times V_{jmeas}^2 - i\times s_{jmeas}}\times s_{jmeas}$$

where
s_{jcorr} [m] = corrected braking distance (which corresponds to the nominal speed in test j);
s_{jmeas} [m] = braking distance measured in test j;
V_{jnom} [km/h] = nominal initial speed in test j;
V_{jmeas} [km/h] = initial speed measured in test j;
ρ = coefficient of inertia of the 'rotating masses', which is defined as follows:

$$\rho = 1 + \frac{m_r}{m}$$

where

m = mass of the test train or vehicle,
m_r = equivalent mass of the rotating components.
(Where no exact value is known ρ = 1.15 for locomotives and ρ = 1.04 for coaches shall be used.);

i [mm/m] = mean gradient over s_{jmeas} on the test track, which is positive (+) for an upgrade and negative (-) for a downgrade.

The following two criteria shall be verified to validate the test:

a) 3 mm/m (5 mm/m in exceptional cases)
and
b) $V_{jmeas} - V_{jnom} \leq 4$ km/h

S.3.2.2 Correcting the mean braking distance $\bar{s}$

The mean braking distance $\bar{s}$, obtained in accordance with chapter S.3.1, shall be corrected to take into account the following factors:

a) Dynamic efficiency of the brake rigging tested as compared with the mean in-service value and, for disc brakes, the mean wheel diameter on the vehicles tested as compared to the diameter of the half-worn wheel. For wagons with P10 block brakes and conventional brake rigging the dynamic efficiency shall be corrected using the method set out in S.1.3.1.

The mean braking distance shall be corrected using the following formulae:

$$F_{corr} = F_{test} \times \frac{\eta_m}{\eta_{test}} \times \frac{d_{test}}{d_m}$$

and

$$\bar{s}_{corr} = t_e \times V_{nom} + \frac{F_{test} + W_m}{F_{corr} + W_m} \times \{\bar{s} - V_{nom} \times t_e\}$$

where
$\bar{s}_{corr}$ [m] = corrected mean braking distance;
$\bar{s}$ [m] = mean braking distance in the test;
t_e [s] = equivalent build-up time for the braking power;
V_{nom} [m/s] = nominal initial speed in the test;
d_{test} [mm] = mean wheel diameter on the vehicles tested;
d_m [mm] = diameter of the half-worn wheel;
F_{corr} [kN] = corrected braking power;
F_{test} [kN] = mean braking power in the test;
η_m = efficiency of the brake rigging in average service conditions;
η_{test} = efficiency of the brake rigging in the test;
W_m [kN] = mean resistance to forward motion.

b) Real filling time in relation to the nominal 4 seconds. This correction shall only be applied to tests with a vehicle taken in isolation.

The following correction formula shall be applied:

$$\bar{s}_{corr} = \left(2 - \frac{t_s}{2}\right) \times V_{nom} + \bar{s}$$

where
$\bar{s}_{corr}$ [m] = corrected mean braking distance;
$\bar{s}$ [m] = mean braking distance;
t_s [s] = measured mean filling time for the brake cylinders;

V_{nom} [m/s] = nominal initial speed in the tests.

S.4 EVALUATION OF BRAKE PERFORMANCE BY A CALCULATION

S.4.1 STEP BY STEP CALCULATION

The stop distance calculation can be performed step by step starting with general method based on dynamic equation; the algorithm is defined as follows :

Step 1: $\sum F_i + W_i = m_e \times a_i$

with
ΣF_i = sum of retarding forces of all active brakes
W_i = retarding resistance at time i ;
m_e = equivalent vehicle mass (including rotating masses);
a_i = deceleration at time i.

Step 2: $a_i = \frac{\sum F_i + W_i}{m_e}$

Step 3: $V_{i+1} = V_i - a_i \times \Delta t$

where
Δt = time calculation interval (Δt ≤ 1s);
Δt = time calculation interval (Δt ≤ 1s);
V_i = initial speed of interval Δt;
V_{I+1} = final speed of interval Δt;

Step 4: $V_{mi} = \frac{V_i + V_{i+1}}{2}$

with
V_{mi} = mean speed in time interval Δt.

Step 5: $\Delta s_i = V_{mi} \times \Delta t$

with
Δs_i = running distance during interval Δt.

The distance may also be calculated by use of one of the following two formulas.

Step 5 bis: $\Delta s_i = V_i \times \Delta t - \frac{1}{2} \times a_i \times \Delta t^2$

Step 5 ter: $\Delta s_i = \frac{V^2{}_i - V^2{}_{i+1}}{2 \times a_i}$

On the hypothesis where the brake force is constant on the interval, all the formulas give the same result.

Step 6: $s = \sum (V_{mi} \times \Delta t)$
where s = total stopping distance (down to V = 0).

S.4.2 CALCULATION BY STAGES OF DECELERATION

In the cases when the vehicles are equiped with brakes which established retarding forces are constant by stages in some speed intervals or if one know the mean of this force, the following simplified method is possible:

Step 1: $a_{mi} = \frac{\sum F_{mi} + W_{mi}}{m_e}$

with F_{mi}, W_{mi} and a_{mi} constant values or mean in the speed interval V_i to V_{i+1}

Step 2: $\Delta s_i = \frac{V^2{}_i - V^2{}_{i+1}}{2 \times a_{mi}}$

with Δs_i = running distance in this speed interval.

Step 3: $s = t_e \times V_0 + \sum \Delta s_i$