# TB

RAILWAY INDUSTRIAL STANDARD OF THE

PEOPLE'S REPUBLIC OF CHINA

ICS 45.060.01
S 33

# TB/T 2841-2010

Replacing TB/T 2841-2005

# Air spring for railway vehicle

铁道车辆空气弹簧



**Issued on: April 27, 2010** **Implemented on: October 01, 2010**

**Issued by: Ministry of Railways of the People's Republic of China**

# Table of Contents

# Foreword

This Standard non-equivalently adopts EN 13597-2003 “Railway applications - Rubber suspension components - Rubber diaphragms for pneumatic suspension springs”. Compared with EN 13597-2003, the main differences are as follows:

- ADD requirements and methods for rigidity, height, creep, high and low temperature tests of auxiliary spring;
- ADD vertical fatigue test requirements and methods of air spring for swing hanger bogie;
- ADD horizontal fatigue test requirements and methods of air spring for bolster bogie;
- ADD vertical damping coefficient test methods of air spring with orifice;
- AMEND preparation method of test samples for environment endurance test of air spring;
- ADD requirements and methods of low temperature air tightness.

This Standard replaces TB/T 2841-2005 “Air spring for railway vehicle". Compared with TB/T 2841-2005, the main changes are as follows:

- ADD requirements and methods for rigidity, height, creep, high and low temperature tests of auxiliary spring;
- ADD property parameters requirements of the ultimate pressure withstand capability of air spring, the maximum physical dimensions, load capacity at different height; AMEND test methods of main property parameters;
- AMEND items and methods of environment endurance test of air spring.

Annex A of this Standard is informative while Annexes B and C are normative.

This Standard was proposed and shall be under jurisdiction of Qingdao Sifang Rolling Stock Research Institute Co., Ltd.

Main drafting organizations of this Standard: Qingdao Sifang Rolling Stock Research Institute Co., Ltd., Zhuzhou Times Material Technology Co., Ltd. AND Locomotive and Car Research Institute of China Academy of Railway Sciences.

Main drafters of this Standard: Cheng Haitao, Wang Fusheng, Fang Kejuan, Du Shang, Wang Liming, Wang Jin, Chen Canhui and Yuan Liangming.

The previous editions replaced by this Standard are as follows:

- TB/T 2841-1997;

- TB/T 2481-2005.

# Air spring for railway vehicle

## 1 Scope

This Standard specifies the terms, symbols and coordinate system definition, product property requirements, inspection test method, inspection rules, marking, packaging, storage and transportation of air spring for railway vehicle.

This Standard does not describe those components that may influence air spring properties, such as air supply system of air duct, control valve or auxiliary chamber.

This Standard is applicable to newly-made air spring for railway passenger vehicles and CRH (China Railway High-speed) vehicles. Air spring for metro vehicles, urban rail vehicles, mono-rail vehicles, magnetic suspension vehicles and other kinds of rail vehicles can use this Standard as reference.

## 2 Normative references

The provisions in following documents become the provisions of this Standard through reference in this Standard. For dated references, the subsequent amendments (excluding corrections) or revisions do not apply to this Standard, however, parties who reach an agreement based on this Standard are encouraged to study if the latest versions of these documents are applicable. For undated references, the latest edition of the referenced document applies.

GB/T 528-2009 Rubber, vulcanized or thermoplastic - Determination of tensile stress-strain properties (ISO 37:2005, IDT)

GB/T 531.1-2008 Rubber vulcanized or thermoplastic - Determination of indentation hardness - Part 1: Duromerer method (Shore hardness) (ISO 7619-1:2004, IDT)

GB/T 532-2008 Rubber vulcanized or thermoplastic - Determination of adhesion to textile fabric (eqv ISO 36:2005)

GB/T 533-2008 Rubber vulcanized or thermoplastic - Determination of density (ISO 2781:2007, IDT)

GB/T 1682-1994 Rubber, vulcanized - Determination of low-temperature brittleness (single test piece method) (eqv ISO 812:1991)

GB/T 1690-2006 Rubber vulcanized or thermoplastic - Determination of the effect of liquids (ISO 1817:2005, MOD)

GB/T 2941-2006 Rubber - General procedures for preparing and conditioning test pieces for physical test methods (ISO 23529:2004, IDT)

GB/T 3512-2001 Rubber, vulcanized or thermoplastic - Accelerated ageing and heat resistance tests - Air-oven method (eqv ISO 188:1998)

GB/T 7759-1996 Rubber, Vulcanized or thermoplastic - Determination of compression set at ambient elevated or low temperatures (eqv ISO 815:1991)

GB/T 9867-2008 Rubber vulcanized or thermoplastic - Determination of abrasion resistance using a rotating cylindrical drum device (ISO 4649:2002, IDT)

GB/T 11211-2009 Rubber vulcanized or thermoplastic - Determination of adhesion to metal - Two-plate method (ISO 814:2007, IDT)

GB/T 13642-1992 Rubber, vulcanized - Resistance to ozone ageing - Dynamic strain test method (neq ISO 1431 -2:1982)

GB/T 13934-2006 Rubber, vulcanized or thermoplastic - Determination of flex cracking and crack growth (De Mattia) (ISO 132:1999, MOD)

GB/T 17200-2008 Technical specification for tensile compression and flexural testing machines for rubber and plastics (constant rate of traverse) (ISO 5893:2002, IDT)

TB/T 2843-2007 General technical specification for elastic parts for railways

# 3 Terms, symbols and coordinate-system definitions

## 3.1 Terms

The following terms are applicable to this Standard.

### 3.1.1 Diaphragm

#### 3.1.1.1 Diaphragm

The major bearing and vibration attenuation component of air spring. Its structure is shown in Figure 1. Different diaphragm types refer to Annex A.

An important component of auxiliary spring which usually consists of metal vulcanized with rubber.

#### 3.1.5.3 Support rim

A component performs functions of supporting diaphragm, transmitting load and providing installation space for wearing plate and is between rubber metal spring and airbag, which is usually metal or metal vulcanized with rubber.

### 3.1.6 Design height

Working height in technical specification. It is the installation space of air spring in vertical direction. Properties at height is used as reference to assessing spring performance. This height is also the initial point for calculating vertical deflection and compressing is negative while straining is positive.

Note: Technical specification is the technical document provided by customer and approved through specified procedure.

### 3.1.7 Design state

Working state of air spring at load of vehicle weight.

### 3.1.8 Design pressure

Pressure of air spring when it is loaded with empty vehicle at design height.

### 3.1.9 Effective area

Effective active area of pressure for air spring when is inflated.

### 3.1.10 Auxiliary chamber

Separate chamber used to decreasing vertical rigidity of air spring and is connected with diaphragm.

### 3.1.11 Max outside diameter

Periphery diameter of diaphragm in inflated state at maximum vertical load.

### 3.1.12 Air gap

Height difference between bottom surface of top plate of air spring and top surface of auxiliary spring under design pressure.

## 3.2 Symbols

Symbols used in this Standard are listed in Table 1.

**Table 1 Symbols**

- Requirements for test items and methods (such as test requirements of functional parameters concerning rigidity, load capacity; the type test items which shall be performed).

### 4.2 Documents required to be provided by supplier

The supplier shall provide at least the following documents to customer:

- Documents approved by customer (outline and report of type test, outline and report of routine tests, instructions of assembly, manual of operation and maintenance and so on);

- The general drawing with the maximum physical dimensions included (when air spring has the maximum vertical working load).

## 5 Operation environment temperature

The operation environment temperature of air spring is -40°C ~ +50°C.

## 6 Product property requirements

### 6.1 Environment adaptability

#### 6.1.1 General principles

Properties of rubber material of diaphragm shall meet requirements of 6.1.2 ~ 6.1.6. Properties of rubber material of other parts shall meet requirements of 6.1.2 and 6.1.5.

#### 6.1.2 Low temperature endurance property

The test shall be performed according to 7.2.1; the brittleness temperature shall not be higher than -45°C.

#### 6.1.3 Ozone resistance property

The test shall be performed according to 7.2.2; there shall not have cracks on both side of rubber sheet.

#### 6.1.4 Oil resistance property

The test shall be performed according to 7.2.3; the weight variation per area unit $\Delta m_A$ shall not be higher than 230g/m$^2$.

#### 6.1.5 Cleaner resistance property

The test shall be performed according to 7.2.4; the sample hardness variation shall not exceed $\pm 5H_A$.

Customer shall provide the detailed information of cleaner.

#### 6.1.6 Abrasion resistance property

The test shall be performed according to 7.2.5; the volume of sample shall not be decreased by more than 200 $mm^3$.

### 6.2 Appearance and basic requirements

#### 6.2.1 Appearance in free state

The appearance of all components of air spring shall meet the following requirements:

a) The cords of diaphragm shall not be exposed. The inner and outer surface shall have no bubbles, cracks, damage and other impurities mixed in rubber. The matching face shall have no defects such as rubber voids, bubbles or impurities. The marks shall be clear;

b) For the top plate, support rim and rubber metal spring with vulcanized rubber, their rubber surface shall be smooth and have no impurities mixture or adhesion, no defects such as scars, cracks, bubbles or peels. For the metal top plate, support rim and clamping ring without vulcanized rubber, their surface shall have no burrs and visible casting pores. The metal materials surface which may rust shall have anti-corrosive treatment. The marks shall be clear.

#### 6.2.2 The appearance in maximum horizontal displacement state

The diaphragm shall have no wrinkles or delamination when ultimate deformation test is carried out for air spring according to 7.3.2 while slight wave shape is permitted to appear when horizontal displacement is the greatest. Gas tightness test shall be performed; the pressure decrease compared with the value in no horizontal displacement state shall not exceed 10kPa.

#### 6.2.3 Adhesion strength of cord plies

CARRY out adhesion strength test of cord plies according to 7.3.3; the result shall not be lower than 6 N/mm.

#### 6.2.4 Appearance at maximum vertical working load

CARRY out inflation test of air spring at ultimate vertical working load according to 7.3.4. The diaphragm shall have no destructive state such as laceration or cracks.

#### 6.2.5 Gas tightness

CARRY out gas tightness test at normal and low temperature according to 7.3.5; the pressure decrease shall not exceed 10kPa.

For the air spring achieving self-sealed state between top plate and diaphragm through

pressure, normal temperature and low temperature gas tightness test shall be included in type tests, and only normal temperature test shall be included in routine tests; for the air spring with top plate and diaphragm connected by clamping ring, only normal temperature gas tightness test shall be included in both type tests and routine tests.

**6.2.6 Fatigue test**

Fatigue test shall be carried out according to 7.3.6; the qualification judgment criteria after test is as follows. If any of the following requirements is not met, then it is judged as unqualified:

- The inner and outer surface of diaphragm shall have no defects such as break-off, bumps or ply cord exposure, and shall have no cord plies delamination;

- The outer surface of diaphragm shall have no cracks when half fatigue test cycles is completed. The crack length on inner and outer surface shall not exceed 10mm after all the fatigue test cycles is finished;

- The inner and outer surface of diaphragm shall have no fractured cords and bead core;

- The auxiliary spring shall have no metal fracture defects;

- The peeling depth of joints between spring rubber and metal shall not exceed 2mm;

- The normal temperature gas tightness of air spring shall meet requirements of 6.2.5;

- The load capacity, vertical rigidity, horizontal rigidity and maximum physical dimensions shall meet requirements of technical specification;

- The burst pressure of air spring shall meet requirements of 6.2.7;

- The adhesion strength between cord plies of diaphragm shall meet requirements of 6.2.3.

**6.2.7 Burst pressure**

Burst test shall be carried out according to 7.3.7; the burst pressure $P_B$ shall not be lower than 3 times of the maximum working pressure while the minimum value shall not be lower than 1.6Mpa.

**6.3 Physical dimensions**

**6.3.1 Physical dimensions of new product**

The test shall be carried out according to 7.4.1. The physical dimensions of new product means the maximum diameter *D* of air spring diaphragm and the gap *H* between bottom of diaphragm and bottom surface of auxiliary spring along with

The rigidity properties expressed in numerical manner include:

a) Nominal rigidity value

It includes nominal rigidity and upper as well as lower tolerances. Annex C gives the tolerance range.

b) Rigidity limits

This rigidity has no tolerance range and consists of upper and lower limits.

The curve figure types include:

- $K_s$-$a$ curve;

- $K_s$-$F$ curve;

- $K_{dyn}$-$f$ curve.

The space range of air spring and its interface with vehicle body and bogie will influence its rigidity property. Interface and space range shall be specified in technical specification; the typical air spring types are shown in Annex A.

**6.4.1.2 Vertical static rigidity**

The test shall be carried out according to 7.5.1.2.2; the results shall meet requirements of technical specification. The following parameters shall be also included in test report:

- Vertical vibration amplitude ($a$);

- Vertical load ($F$);

- Installation height of air spring ($H_t$);

- Volume of auxiliary chamber ($V_{AUX}$).

**6.4.1.3 Horizontal static rigidity**

The test shall be performed according to 7.5.1.2.3 and the results shall meet requirements of technical specification. The following parameters shall be also included in test report:

- Vertical vibration amplitude ($a$);

- Vertical load ($F$);

- Installation height of air spring ($H_t$).

**6.4.1.4 Torsion static rigidity**

The test shall be performed according to 7.5.1.2.4; the results shall meet requirements of technical specification. The following parameters shall be also included in test report:

- Torsion amplitude (*a*);
- Vertical load (*F*);
- Installation height of air spring ($H_t$).

#### 6.4.1.5 Vertical dynamic rigidity

The test shall be performed according to 7.5.1.3.2; the results shall meet requirements of technical specification. The following parameters shall be also included in test report:

- Vertical vibration amplitude (*a*);
- Vertical load (*F*);
- Installation height of air spring ($H_t$);
- Volume of auxiliary chamber ($V_{AUX}$);
- Frequency (*f*).

#### 6.4.1.6 Horizontal dynamic rigidity

The test shall be performed according to 7.5.1.3.3; the results shall meet requirements of technical specification. The following parameters shall be also included in test report:

- Horizontal vibration amplitude (*a*);
- Vertical load (*F*);
- Installation height of air spring ($H_t$);
- Frequency.

#### 6.4.1.7 Torsion dynamic rigidity

The test shall be performed according to 7.5.1.3.4; the results shall meet requirements of technical specification. The following parameters shall be also included in test report:

- Torsion amplitude (*a*);
- Vertical load (*F*);
- Installation height of air spring ($H_t$);
- Torsion frequency (*f*).

Where

$$F_0 < F_1 < F_2 < F_M$$

Requirements of vertical load displacement property of auxiliary spring shall be specified in technical specification. Requirements of vertical load displacement characteristic of auxiliary spring after creep and high temperature aging can be also be determined by customer as required. The tolerance limits are listed in Annex C.

**6.5.3 Vertical dynamic rigidity of auxiliary spring**

The test shall be performed according to 7.6.3; the result shall meet requirements of technical specification.

Vertical dynamic rigidity has three expressing manners and any one of them can be used:

a) Rigidity $K_{dyn}$ - displacement amplitude $a$

The technical specification shall specify test frequency and displacement amplitude while the test report shall provide test result of rigidity $K_{dyn}$ - displacement amplitude $a$.

b) Rigidity $K_{dyn}$ - load amplitude $\Delta F$

The technical specification shall specify test frequency and load amplitude while the test report shall provide test result of rigidity $K_{dyn}$ - load amplitude $\Delta F$.

c) Rigidity $K_{dyn}$ - test frequency $f$

The technical specification shall specify test load and test frequency while the test report shall provide test result of rigidity $K_{dyn}$ - test frequency $f$.

The vertical rigidity requirements in technical specification can be provided as enveloping lines or as numerical values.

**6.5.4 Static creep of auxiliary spring**

The test shall be performed according to 7.6.4. Static creep represents static displacement of auxiliary spring in specified time and at static load $F_c$. The technical specification shall specify the following parameters:

- Permitted static creep in specified time (the unit is millimeter per 6 years);

- Static load $F_c$.

The static creep shall meet limits requirements of technical specification. The relative variation of vertical rigidity before and after creep shall meet requirements of Annex C.

#### 6.5.5 Adhesion strength of auxiliary spring

The test shall be performed according to 7.6.5. Adhesion strength of auxiliary spring means inspecting the surface condition of auxiliary spring at straining and shearing load. It is a no-destructive test and the result shall meet the following requirements:

- There shall not have defects such as laceration and cracks between rubber and metal of auxiliary spring;

- There shall not have tension fracture on parts of rubber surface.

#### 6.5.6 High temperature aging test of auxiliary spring

The test shall be performed according to 7.6.6. High temperature aging test of auxiliary spring means inspecting whether there is damage on surface of auxiliary spring and whether vertical rigidity variation exceeds specified range after placing the auxiliary spring in high temperature environment for a period. The result shall meet the following requirements:

- There shall not have defects such as laceration and peels between rubber and metal of auxiliary spring;

- Vertical rigidity variation before and after high temperature aging test shall meet limit requirements of Annex C.

#### 6.5.7 Low temperature property test of auxiliary spring

The test shall be performed according to 7.6.7. Low temperature property test means performing rigidity test and identifying whether the vertical variation exceeds limits after placing the auxiliary spring in low temperature for a period. The result shall meet the following requirements:

- There shall not have defects such as laceration and peels between rubber and metal of auxiliary spring;

- Vertical rigidity variation before and after low temperature performance test shall meet limit requirements of Annex C.

### 6.6 Friction pair property

#### 6.6.1 Friction factor

The test shall be performed according to 7.7.1. Customer shall specify limits of friction factor in the technical specification. The friction factor between top plate and wearing plate of air spring shall not be higher than limits in technical specification. This test is only applicable to air spring used for bolster-less bogies.

#### 6.6.2 Friction fatigue property

The test shall be performed according to 7.7.2. After the fatigue test is finished, inspect the top and bottom surface of friction pair; both shall have no wearing groove. The left wearing height of lower one of friction pair shall not be lower than 2/3 of the original design value. When the friction pair on the top plate and the top plate is not an integral one, the friction pair and the top plate shall be firmly connected and are not loose while there shall not have loose welding. The fixing bolt of wearing plate and lower one of friction pair shall be intact and shall not be loose or sheared. The friction factor test shall be performed after fatigue test; the value shall meet requirements of technical specification. This test is only applicable to air spring used for bolster-less bogies.

# 7 Inspection test method

## 7.1 Summary

### 7.1.1 The general test conditions

The test shall be performed at specified test temperature.

When test items in 7.3.1 ~ 7.5.4 (excluding 7.3.3) and 7.7.1 ~ 7.7.2 are performed, the contact area between top plate and test platform shall not be less than that with actual vehicle and the friction factor shall simulate actual condition as far as possible.

Some of the tests mentioned above are dangerous; protective measures shall be adopted to ensure test personnel safety.

### 7.1.2 Test equipment

The accuracy of sensor for pressure measurement shall be ±2kPa. When tests in 7.3.2 ~ 7.7.2 (excluding 7.3.3 and 7.3.7) are performed, upper limit of test load shall be within 20% ~ 100% of test equipment's measurement range; error of test equipment shall be ±1% of indicating value. For test in 7.3.3, the accuracy of elongation dynamometer shall reach class 2 specified in GB/T 17200-2008. The permitted control error of load, displacement and frequency of fatigue test equipment shall be within ±5% of specified value.

### 7.1.3 Preparation of test sample pieces or sample sheets

Vulcanized sample shall be used for tests in 7.2.1, 7.2.2 and 7.2.4. For tests in 7.2.3, 7.2.5 and 7.3.3, the sample shall be obtained from diaphragm after fatigue test (7.3.6) and burst test (7.3.7) are carried out. The sampling area is shown in Annex B.

Tests in 7.3.2 ~ 7.5.4 (excluding 7.3.3) are applicable to the whole air spring. For the test in 7.3.7, rigidity support can be used to replace auxiliary spring if the burst force is not affected. Tests in 7.6.1 ~ 7.6.7 are applicable to auxiliary spring. Tests in 7.7.1 ~ 7.7.2 are applicable to top plate and friction pair of auxiliary spring while the airbag can be removed.

For the property test in 7.3.2 ~ 7.6.7 (excluding 7.3.3), samples shall be place in environment with constant temperature (23±2)°C for 24 h.

**7.2 Environment adaptability test method**

**7.2.1 Low temperature endurance test of rubber**

Low temperature endurance test of rubber shall be performed according to GB/T 1682-1994. RECORD the highest temperature when impact damage occurs.

**7.2.2 Ozone resistance property**

Ozone resistance property shall be performed according to GB/T 13642-1992. Continuous dynamic straining test shall be adopted, which is detailed as follows:

- Dynamic elongation is 0% ~ 20%; frequency is 0.5 Hz;
- The dimensions of samples are as follows:

  Thickness: (2.0±0.2) mm;

  Width: the minimum value is 10 mm;

  Length: (100±10) mm. The active length between clamping shall not be less than 40mm.

- Ozone concentration: $(50\pm5)\times10^{-8}$;
- Temperature: (40±2)°C.

There shall not have less than 3 samples;

INSPECT cracks on both surfaces of sample after continuous dynamic straining test is carried out for 168 h.

**7.2.3 Oil resistance property**

Oil resistance property test shall be performed according to GB/T 1690-2006. The test samples are got from diaphragm wall and have the same thickness as diaphragm wall. The outer surface of sample is in contact with oil and the detailed conditions are as follows:

- Oil: IRM902;
- Temperature: (70±1)°C;
- Soaking time: $72^{0}_{-2}$ h.

There shall have 3 samples. Adjustment shall be carried out at standard laboratory

temperature specified by GB/T 1690-2006 for at least 24 h.

MEASURE the weight variation $\Delta m_A$ per area unit.

**7.2.4 Cleaner resistance property**

Cleaner resistance property test shall be performed according to GB/T 1690-2006 and the detailed conditions are as follows:

- Cleaner: 5% oxalic acid solution;

- Temperature: (50±1)°C;

- Soaking time: $72^{0}_{-2}$ h.

OVERLAY 3 samples and measure Shore A hardness before and after test according to GB/T 531.1-2008.

**7.2.5 Abrasion resistance property**

Abrasion resistance property test shall be performed according to GB/T 9867-2008 and the details are as follows:

The samples are cylinder and the diameter is (16±0.2) mm. The thickness is at least 6 mm. If the thickness is less than 6 mm, treatment shall be performed according to method in 6.1 of GB/T 9867-2008.

There shall have 3 samples; adjustment shall be carried out at standard laboratory temperature specified by GB/T 2941-2006 for at least 24 h.

TEST the outer layer rubber of diaphragm for the samples; the sample is invalid if ply is reached due to wearing and re-test shall be performed.

MEASURE rubber density according to GB/T 533-2008.

**7.3 Appearance and basic function test methods**

**7.3.1 Appearance inspection**

For component or air spring, no matter it is in inflated state after assembly, inspection shall be performed by visual observation at normal temperature.

**7.3.2 Appearance inspection at maximum horizontal displacement**

Air spring is in inflated state at normal temperature and meets the following requirements:

- Test height shall not exceed design height $H_T$;

- Vertical load of air spring shall not exceed $F_J$=0.7$F_0$. RECORD the pressure when there is no horizontal displacement after load is stable;

- Air spring has the maximum horizontal displacement $d_M$.

MAINTAIN the state for 1 min ~ 3 min after air spring reaches the maximum horizontal displacement $d_M$. INSPECT appearance of the whole air spring, especially check whether there is wrinkles on diaphragm. RECORD the pressure at the maximum horizontal displacement when the inspection is finished.

When the air spring is installed on test platform before test, if the designed radius rigidity is symmetric, installation can be carried out randomly, and installation in actual vehicle direction is not necessary. If the designed radius rigidity is asymmetric, test shall be performed in multiple directions which shall be specified in technical specification.

**7.3.3 Adhesion strength of cord plies**

Adhesion strength test of cord plies shall be performed according to GB/T 532-2008.

**7.3.4 Appearance inspection at ultimate vertical working load**

The test shall be performed according to the following procedure:

- Air spring is in static inflated state and installed vertically;

- Installation height is $H_t$ = ($H_T$±2) mm;

- The internal pressure $P$>1.3 $P_M$;

- MAINTAIN it for 1min ~ 3min after pressure reaches the above-mentioned target values.

Then inspect the outer surface of air spring and this test is performed at normal temperature.

**7.3.5 Gas tightness**

Gas tightness tests include gas tightness at normal temperature and at low temperature. Unless otherwise specified, gas tightness tests shall be performed according to the following methods:

a) Normal temperature gas tightness test

KEEP air spring be in static state at normal temperature and ensure that top plate is parallel with bottom surface and installation height is $H$t = ($H_T$±2) mm. INFLATE air spring to make pressure P>1.3 PM and maintain it for at least 30 s. Then decrease internal pressure of air spring to make P>0.9PM. SWITCH off charging valve and discharging valve and maintain the state for 10min. MEASURE the

a) Test equipment

- It can simulate air spring installation conditions on actual vehicle, especially the upper and lower interfaces;

- FIX top plate and bottom plate which enables relative movement of bottom plate or top plate so as to simulate working conditions of air spring on actual vehicle;

- For torsion fatigue test, horizontal displacement between top plate and bottom plate can be adjusted so as to simulate horizontal displacement between vehicle body and bogie when vehicle passes curved rail;

- INFLATE spring can be performed at any time.

b) Before each fatigue test, air spring shall meet the following basic requirements:

- Air spring is in static inflated state and installed vertically;

- Installation height is $H$t = ($H_T$±2) mm;

- For vertical fatigue test, the volume of auxiliary chamber is determined according to technical specification.

c) Test conditions

Fatigue tests are performed at normal temperature and the applied wave is sine. APPLY vertical, horizontal and torsion test amplitude respectively according to test types.

For the number of load, displacement and fatigue test, unless otherwise required in technical specification, perform according to technical specification.

**7.3.6.2 Vertical fatigue**

The test shall be performed as follows:

a) Before test:

- VIBRATE for 5 cycles at maximum vibration amplitude $d_M$ and at maximum vertical working load;

- LAY it aside for (15±2) min at maximum vertical working load and at installation height $H_t$.

b)Test procedure

- MAKE the air spring have the maximum vertical load. MAKE vibration amplitude equal to air spring gap when air spring has no load. VIBRATE vertically for $1\times10^6$ cycles at frequency 0.5 Hz ~ 3.0 Hz.

- Inspection after fatigue test: CARRY out normal temperature gas tightness test according to 7.3.5. Then disassemble air spring and inspect inner and outer surface of air spring as well as auxiliary spring with visual observation.

- Tests after fatigue test: CARRY out tests in 7.5.2, 7.5.1.2.2 ~ 7.5.1.2.3, 7.4.2, 7.3.7, 7.2.3, 7.2.5, 7.3.3 in sequence.

#### 7.3.6.3 Horizontal fatigue

The test shall be carried out as follows:

a) Before test

- VIBRATE for 20 cycles at maximum horizontal vibration amplitude $d_M$ and at maximum vertical working load;

- LAY it aside for (60±3) min under minimum vertical working load $F_0$(1±0.02) and at installation height $H_t$.

b) Test procedure

- MAKE air spring have maximum vertical load and be at installation height. USE ±30 mm as vibration amplitude. VIBRATE horizontally for $2\times10^5$ cycles at frequency 0.5 Hz ~ 3.0 Hz.

- Inspection after fatigue test: CARRY out normal temperature gas tightness test according to 7.3.5. Then disassemble air spring and inspect inner and outer surface of air spring as well as auxiliary spring with visual observation.

- Tests after fatigue test: CARRY out tests in 7.5.2, 7.5.1.2.2 ~ 7.5.1.2.3, 7.4.2, 7.3.7, 7.2.3, 7.2.5, 7.3.3 in sequence.

#### 7.3.6.4 Torsion fatigue

The test shall be carried out as follows:

a) Before test:

LAY it aside for (15±2) min at minimum vertical working load $F_0$(1±0.02) and at installation height.

b) Test procedure

This test applies horizontal load on air spring to make it generate reciprocating movement, which simulates the relative movement of air spring between vehicle body and bogie when the vehicle is traveling on curved rail. The test principle is shown in Figure 19.

while the installation height is $H_t = (H_T \pm 2)$ mm. FILL water into diaphragm slowly and continuously at speed less than 0.5MPa/min. MAINTAIN the pressure when pressure is increasing until the diaphragm bursts or the pressure exceeds the lower limit specified in 6.2.7. RECORD the burst pressure or the final pressure achieved.

Rather than new air spring, the air spring used in burst test is the product which has undergone fatigue test in 7.3.6 and has not undergone test in 7.3.7.

**Table 2 Test procedures of torsion fatigue test**

| No. of test procedures | Cycles | Vibration amplitude mm | Pressure MPa | Horizontal displacement mm |
|---|---|---|---|---|
| 1 | $1.5\times10^5$ | $\pm a$ | $P_0$ | 0 |
| 2 | $1.5\times10^5$ | $\pm a$ | $P_M$ | 0 |
| 3 | $1.5\times10^5$ | $\pm a$ | $P_0$ | 30 |
| 4 | $1.5\times10^5$ | $\pm a$ | $P_M$ | 30 |

### 7.4 Physical dimension measurement

#### 7.4.1 Physical dimension of new product

At normal temperature, apply the maximum vertical working load on air spring. After the pressure is stable, measure the maximum diameter $D$ and gap $H$ of the air spring according to Figure 4.

#### 7.4.2 Physical dimension after fatigue test

At normal temperature, apply the maximum vertical working load to air spring. After the pressure is stable, apply horizontal displacement 10 mm, 20 mm ... $d_M$; the increment after 20 mm is 15 mm with tolerance of $^{0}_{-2}$ mm. PROCEED as the displacement increase in sequence; MAINTAIN it after each displacement is achieved. MEASURE $R_1$, $R_2$, $H_1$ and $H_2$ according to Figure 6.

If dimensions at different vertical load $F_J$ need to be measured, the applying sequence shall be performed in the manner of load increasing.

When the air spring is installed on test platform before test, if the designed radius rigidity is symmetric, installation can be carried out randomly and installation in actual vehicle direction is not necessary. If the designed radius rigidity is asymmetric, test shall be performed in multiple directions which shall be specified in technical specification

### 7.5 Function property test methods for rigidity, load capacity and damping coefficient

#### 7.5.1 Rigidity test

*X* - Load;

*Y* - Preparation stage of test;

*Z* - Test stage;

▽ - Standing time at the minimum vertical working load;

# - The suspending duration between two loads;

* - Time interval between tests at different vibration amplitude 2 min ~ 3 min.

**Figure 21 Procedure of horizontal static rigidity test**

#### 7.5.1.2.4 Torsion static rigidity

The test shall be carried out as follows:

a) Test preparation

Before test:

- VIBRATE for 5 cycles at the maximum torsion amplitude $\theta_M$ and with the maximum vertical working load;

- LAY it aside for (15±2) min under minimum vertical working load $F_0$(1±0.02) and at installation height.

b) Test and measurement

The test speed is (5±0.5)×$10^{-3}$ rad/s. For any vertical load, the loading tolerance is ±1%. If measurements of torsion rigidity at different torsion amplitudes are carried out, different amplitudes shall be applied in ascending order and the time interval between two measurements shall be 2 min ~ 3 min.

The torsion amplitudes include:

- When $\theta_M \leq 60\times10^{-3}$ rad, the torsion amplitude is a=30×$10^{-3}$ rad;

- When $\theta_M > 60\times10^{-3}$ rad, the torsion amplitude is a=60×$10^{-3}$ rad.

If measurements of torsion static rigidity at different vertical load $F_J$ are carried out, vertical load shall be applied in ascending order. There shall not have time interval between measurements of two loads as far as possible; if the suspending duration exceeds 5 min, pre-cycling shall be carried out again. The test procedure is shown in Figure 22.

### 7.5.1.3 Dynamic rigidity

#### 7.5.1.3.1 Summary

Before each test is carried out, air spring shall meet the following requirements:

- Air spring is in static inflated state and installed vertically;

# - Standing time 15 min ± 2 min;

* - Time interval between tests at different amplitudes 2 min ~ 3 min.

**Figure 25 Procedure of torsion dynamic rigidity test**

For the test at the same vertical load but has different frequency, the test frequency shall be applied in ascending order.

### 7.5.2 Pressure load property

INSTALL the air spring on test platform at installation height $H_t$ = ($H_T$±2) mm and make the top and bottom surface be parallel with each other while keep the air spring in static inflated state.

If the pressure load property in technical specification is expressed in pressure value corresponding to different loads, carry out the test according to the following method:

INFLATE the air spring to make the vertical load be $F_J$(1±0.01). RECORD the corresponding internal pressure of air spring after the pressure is stable. The load shall be applied in descending order and there shall not have time interval between measurements of two loads as far as possible.

If the pressure load property in technical specification is expressed as curve, carry out the test according to the following method:

MEASURE the pressure $P_M$ corresponding to the maximum vertical working load $F_M$ firstly. CARRY out it in descending order of pressure and the pressure nearest to $P_M$ shall be rounded as integer. The pressure step size is 100kPa. DECREASE the pressure from $P_M$ to 100kPa. RECORD the vertical load corresponding to each pressure value. There shall not have time interval between measurements of two pressures as far as possible.

### 7.5.3 Pressure load stability

a) Test preparation

INSTALL the air spring on test platform at installation height $H_t$ = ($H_T$±2) mm and make the top and bottom surface be parallel with each other while keep it in static inflated state. The internal pressure of air spring is $P_M$(1±0.05) and the corresponding vertical load is $F_M$. PERFORM as follows under the maximum pressure $P_M$:

- CARRY out 5 vertical vibration cycles from -$d_M$ to +$d_M$;

- LAY it aside at installation height for (15±2) min.

b) Test and measurement

**Figure 26 Illustration for height of auxiliary spring at specified load**

For any vertical load, measure the vertical damping coefficients corresponding to different excitation amplitudes. The different excitation amplitudes shall be applied in ascending order. The time interval between two measurements shall be 2 min ~ 3 min.

If the technical specification does not specify test frequency range, the recommended frequency is 0.01 Hz ~ 5.0 Hz. The test is carried out by scanning at varied frequency. The excitation amplitudes are a=2.5 mm, 5.0 mm and 7.5 mm. CARRY out scanning at varied frequency for each amplitude. RECORD displacement variation curve for planar response of air spring. The frequency corresponding to the maximum response amplitude for each excitation amplitude is the resonance frequency. When resonance occurs, the ratio between response amplitude and excitation amplitude is the resonance ratio, and damping coefficient can be deduced from resonance ratio, see Formula (6):

$$C_d = 2\pi \times f \times m_d / \sqrt{\xi^2 - 1_\xi} \qquad \cdots\cdots\cdots\cdots\cdots\cdots (6)$$

The measurement shall be carried out for all the 3 excitation amplitudes. The average value got from different excitation amplitudes is the damping coefficient corresponding to this load.

If measurements of vertical damping coefficient corresponding to different loads are carried out, the load shall be applied in descending order and the loading tolerance is ±5%.

### 7.6 Function property test method of auxiliary spring

#### 7.6.1 The height at specified load $F_J$

The test shall be carried out at (23±2)°C.

CARRY out loading test for 4 cycles. The load increases from 0 to 1.25$F_M$. The period of the first 3 cycles is 30 s ~ 60 s while the period of the 4th cycle is 60 s ~ 120 s.

RECORD data starting from the 4th cycle. On the unloading stage of the 4th cycle, stop and maintain it for (10±2) s if the load reaches expected $F_J$ and then record the height $h_{AF}$ corresponding to load $F_J$. Figure 26 illustrates the displacement corresponding to specified load.

The height $h_{AF}$ corresponding to specified load shall meet requirements of technical specification and the recommended tolerance is in Annex C. Before the maximum load 1.25$F_M$ is reached, the load displacement curve shall have no steep rise.

#### 7.6.2 Load displacement characteristic

specification has not specific requirements, load used for creep test is recommended to be calculates as Formula (8).

$$F_C = 0.5F_0 + 0.5(F_1/3 + 2F_2/3) \quad \cdots\cdots\cdots\cdots\cdots\cdots (8)$$

The time interval between vulcanization and test shall not be less than 24h. Before the test is carried out, 24h environment adjustment shall be performed and the adjusted environment temperature is (23±2)°C. The test shall be carried out at (23±2)°C and the rigidity at load $F_C$ shall be measured firstly according to 7.6.2 before test.

MEASURE the height at load $F_C$ according to the test procedure in 7.6.1. USE this time point as zero time. MAINTAIN the load $F_C$ as constant. RECORD the auxiliary spring height variation with time and continuous recording is recommended. If there is no condition for continuous recording, intermittent recording can be used and time interval between recording is 2 h while recording shall be carried out for height at time 1 min, 10 min, 1 h, 1 h 40 min and 24 h. The recorded data includes creep time and height.

The duration of creep depends on stability time of creep. If the creep within the last 24 hours is less than 10% of the creep from 1st hour to 24th hour, the creep test can be stopped. RECORD the time and height of the ending time and unload $F_C$.

The following definitions are used when data is processed.

- $t_0$ = 1 min

- $t_2$ = 100 min

DRAW auxiliary spring height - time logarithm curve shown in Figure 29 by using denary logarithm for time point of $t_0$ and $t_2$ together with the corresponding creep value $d_{cr0}$ and $d_{cr2}$.

In the figure :

- $L_0$ is the height corresponding to time point $t_0$;

- $L_2$ is the height corresponding to time point $t_2$;

- $t_0$=1 min;

- $t_1$=10 min;

- $t_2$=1 h 40 min;

- $t_3$=16 h 40 min;

- $t_4$=6 d 22 h 40 min;

- $t_5$=69 d 10 h 40 min;

### 7.7 Friction pair property test method

#### 7.7.1 Friction factor

APPLY vertical load $F_L$ at normal temperature and vibrate horizontally at speed of 5mm/s and at amplitude of *a*. CARRY out pre-cycling for 10 cycles and record the load displacement data for the 11$^{th}$ cycle. GET the absolute values of the horizontal force in the two directions and then average these values. The ratio between average value and vertical load is friction factor.

Vertical load and horizontal vibration amplitude are determined according to technical specification. If there no specific requirements in technical specification, the recommended vertical loads are $F_0$, $F_M$ and the recommended horizontal amplitudes are ±10 mm, ±30 mm, ±50 mm as well as the maximum horizontal displacement $\pm d_M$.

#### 7.7.2 Friction fatigue property

CONNECT the top plate of air spring with auxiliary spring at normal temperature. APPLY the maximum vertical working load $F_M$. CARRY out friction wearing fatigue test for $7.2\times10^4$ cycles at frequency within range of 0.1 Hz ~ 0.5 Hz and at amplitude of ±10 mm. Then carry out friction wearing fatigue test for $1.8\times10^4$ cycles at amplitude of ±30 mm. MEASURE the friction factor after fatigue test is finished. INSPECT the upper and lower friction pair and the result shall meet requirements of 6.6.2.

During the fatigue test, when the surface temperature of wearing plate exceeds +40°C, air cooling can be used or test frequency can be lowered.

## 8 Inspection rules

### 8.1 Raw material inspection

Raw material and machined parts of air spring shall be checked and accepted before they are received by factory. The inspection contents shall meet requirements of Table 3 and there shall have accompanied material certifications.

**Table 3 Inspection requirements for raw material of air spring**

| Items | Inspection contents | Inspection period | Requirements |
|---|---|---|---|
| Rubber | Physical and mechanical properties | Each lot of rubber shall undergo tensile strength test, test of elongation at break. Brittleness temperature, hot air aging, rubber yield property, permanent compression deformation, adhesion strength between rubber and metal as well as other tests required by technical specification shall be carried out semi-annually. | See Table 4 |

| | | | |
|---|---|---|---|
| Metal | Material as well as physical and mechanical properties | Each lot of machined parts | Technical requirements of products |

**Table 4 Physical and mechanical property requirements for rubber material of air spring**

| Items | | Indexes | | | | Test methods |
|---|---|---|---|---|---|---|
| Tensile strength MPa | | ≥15 | ≥15 | ≥15 | ≥18 | GB/T 528-2009 |
| Elongation at break % | | ≥450 | ≥450 | ≥250 | ≥450 | |
| Hot air aging (70°C, 96h) % | Tensile strength variation | ≥-10 | ≥-10 | ≥-20 | ≥-10 | GB/T 3512-2001 |
| | Elongation variation at break | ≥-20 | ≥-20 | ≥-20 | ≥-20 | |
| Rubber yield property (rectangular sample is recommended) | | $2\times10^5$ times No cracks | $5\times10^5$ times No cracks | / | / | GB/T 13934-2006 |
| Adhesion strength between rubber and metal MPa | | / | / | ≥5 | ≥5 | GB/T 11211-2009 |
| Permanent compression deformation (A type, 70°C, 24h)% | | / | / | ≤30 | ≤20 | GB/T 7759-1996 |

### 8.2 Exit-factory inspection

**8.2.1** Contents and methods of air spring delivery inspection are listed in Table 5. Delivery is permitted only after air spring is qualified; there shall have accompanied product quality certification.

**Table 5 Exit-factory inspection of air spring**

| Inspection items | Technical requirements | Test methods | Inspection Plan |
|---|---|---|---|
| Appearance in free state | 6.2.1 | 7.3.1 | 100% |
| Appearance at ultimate vertical load | 6.2.4 | 7.3.4 | 100% |
| Gas tightness of air spring | 6.2.5 | 7.3.5 | 100% |
| Height of auxiliary | 6.5.1 | 7.6.1 | 100% |

| | | | |
|---|---|---|---|
| spring without load | | | |
| Vertical rigidity of auxiliary spring without load | 6.5.2 | 7.6.2 | 100% for cone-shaped and sandglass-shaped rubber metal spring. This item is not applicable to plate type rubber metal spring |
| Adhesion strength of auxiliary spring | 6.5.5 | 7.6.5 | 100% for cone-shaped rubber metal spring. This item is not applicable to plate type and sandglass-shaped rubber metal spring |

**8.2.2** If there is one unqualified item when exit-factory inspection of air spring is carried out, then double quantity products shall be sampled randomly from the lot for re-inspection. If all items are qualified, the product lot is judged as qualified. If there is one unqualified item, this product lot is judged as unqualified.

**8.3 Type test**

**8.3.1** Type test shall be carried out for air spring in the following cases:

a) When type identification of new product is carried out;

b) When production lasts continuously for more than 2 years;

c) When production is resumed after it is shut-downed for more than 1 year;

d) When there are significant changes related to product design, raw material and technology;

e) When production is carried out in other places.

**8.3.2** The whole type test shall be carried out on diaphragm, top plate, support rim and clamping ring with unique production sequence number; whole type test consisted of test items on above-mentioned multiple parts (with different production sequence number) is not permitted. Different products can be used for auxiliary spring test and friction test according to test items.

**8.3.3** Test items and test sequence of air spring shall be carried out according to Table 6.

**Table 6 Type test of air spring**

| No. | Test items | Judgment criteria | Test methods |
|---|---|---|---|
| 1 | Appearance in free state | 6.2.1 | 7.3.1 |
| 2 | Appearance at ultimate vertical working load | 6.2.4 | 7.3.4 |
| 3 | Pressure load property | 6.4.2 | 7.5.2 |
| 4 | Gas tightness | 6.2.5 | 7.3.5 |
| 5 | Physical dimensions of new product | 6.3.1 | 7.4.1 |

There shall have clear and endurable mark for each air spring and the contents of mark are as follows:

- Trademark of supplier;
- Manufacturing factory code if supplier has many factories;
- Product model;
- Date of manufacture (including year, moth or year, week);
- Unique production sequence number.

The above-mentioned mark shall be on noticeable place of outer surface and shall not be in contact with other parts, such as auxiliary spring.

Customer can propose places on which mark is prohibited and supplier can indicate the mark position explicitly.

**9.2 Packaging**

Package shall be firm and reliable to prevent product from being squeezed and deformed. Product name, quantity, specification and protective measures shall be indicated on outer surface of product.

**9.3 Storage**

**9.3.1** Air spring shall be stored in dry, well ventilated place which is kept away from light. The temperature range for storage is -15°C ~ +40°C. The products shall be stacked in neat manner and be kept away from acid, alkali, oil, organic solvent and so on. They shall be kept more than 1m away from heat source and shall be better to have no direct contact with ground.

**9.3.2** Air spring shall not be stored for more than 2 years.

**9.4 Transportation**

During transportation, air spring shall be kept away from direct exposure to strong sunshine, rain, snow and be kept clean. It shall not be in direct contact with material which may affect rubber quality.

# Annex C

**(Normative)**
**Properties tolerance of air spring**

## C.1 Purpose

This Annex specifies tolerance range for all function properties of air spring.

Normal tolerance in Table C.1 shall be used as properties tolerance. Strict tolerance standard will increased manufacture cost.

## C.2 Tolerance grade

The technical specification shall specify tolerance requirements. Tolerance range of products is listed in Table C.1. The function properties of products shall not exceed the requirements of this table. If customer has tolerance requirements different from the annex table, then customer shall negotiate with manufacture; the tolerance requirements of customer can be used if agreement is reached by both parties.

**Table C.1 Tolerance limits for air spring**

| Property items classifications | Property description | Strict tolerance | Normal tolerance |
|---|---|---|---|
| Properties of inflated air spring | Vertical static rigidity | ±15% | ±20% |
| | Horizontal static rigidity | ±15% | ±20% |
| | Torsion static rigidity | ±15% | ±20% |
| | Pressure load property | ±3% | ±5% |
| | Vertical pressure load stability | ±5% | ±8% |
| | Vertical dynamic rigidity | ±15% | ±20% |
| | Horizontal dynamic rigidity | ±15% | ±20% |
| | Torsion dynamic rigidity | ±15% | ±20% |
| | Vertical damping coefficient | ±10% | ±15% |
| Properties of auxiliary spring | Height at specified load mm | ±2 | ±2.5 |
| | Load displacement property rigidity | ±15% | ±20% |
| | Vertical dynamic rigidity | ±15% | ±20% |
| | Rigidity variation before and after creep | ±10% | ±15% |
| | Rigidity variation before and after high temperature aging | ±15% | ±20% |
| | Rigidity variation before and after low temperature freezing | +60% | +70% |

# Bibliography

[1] BS EN13913:2003 Railway applications. Rubber suspension components. Elastomer-based mechanical parts.

[2] JIS E 4206:1989 Spring rigging for railway rolling stock

**_____ END _____**

**This is an excerpt of the PDF (Some pages are marked off intentionally)**



**------ The End ------**