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Test Method for Retractable Type Fall Arresters Designed for Horizontal Use

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Retractable type fall arresters are designed to protect against falls from a height of people who need freedom of vertical movement. The practice of fall protection shows that the devices are also used to protect people who work on flat roofs. This application creates quite different operating conditions for the devices. In some situations those conditions can be dangerous for users. The article presents a theoretical analysis of phenomena occurring during a fall arrest with retractable type fall arresters arranged horizontally. The analysis was verified with laboratory tests. The article presents a proposal for the construction of a test stand and a test method for estimating retractable type fall arresters intended for horizontal use.

personal protective equipment against falls from a height
retractable type fall arresters test methods dynamic performance test

1. INTRODUCTION

Retractable type fall arresters are a common group of personal protective equipment against falls from a height. They are designed to protect against falls from a height of people who need freedom of vertical movement. Their construction and principle of operation (Standard No. EN 360:1992, European Committee for Standardization [CEN], 1992a; Standard No. EN 363:1992,

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CEN, 1992b; Standard No. ISO/FDIS 10333-3:2000, International Organization for Standardization [ISO], 2000; Sulowski, 1991) allow two operating modes:

- free pulling out and retracting of the retractable lanyard (when the velocity of the user is under 2.5 m/s), and
- blocking of the retractable lanyard and absorption of the kinetic energy of the falling user (when there is a free fall of the user).

The requirements and test methods for retractable type fall arresters designed for vertical use have been prepared well and described in European and international standards (Standard No. EN 360:1992, CEN, 1992a; Standard No. EN 364:1992, CEN, 1992c; Standard No. ISO/FDIS 10333-3:2000, ISO, 2000; Standard No. ISO/FDIS 10333-6:2002, ISO, 2002).

The practice of fall protection shows that retractable type fall arresters are also used to protect people who work on flat roofs. Figure 1 shows how they can be used on a flat roof.

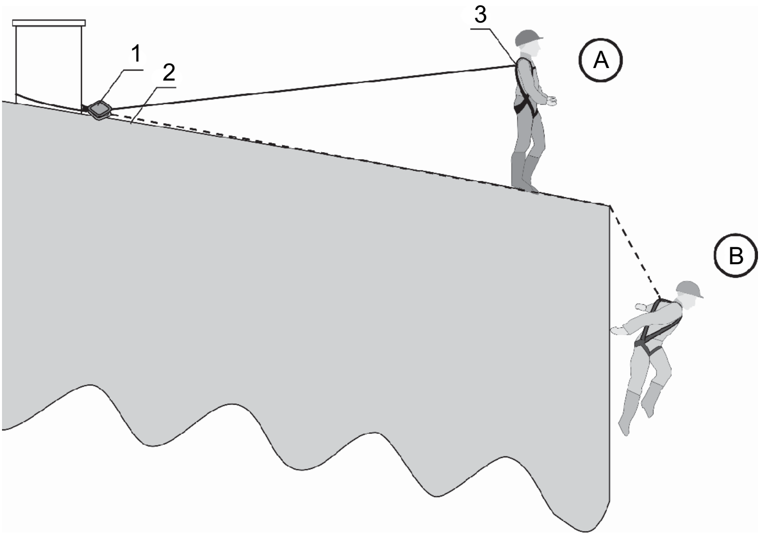

Figure 1. A retractable type fall arrester arranged horizontally—an example. *Notes*. A—position before fall, B—position after fall arrest, 1—retractable type fall arrester, 2—surface of roof, 3—person equipped with full body harness.

This application, in comparison with a vertical arrangement, creates quite different operating conditions for the devices (Kloß, 1985). The phenomena occurring during fall arrest with retractable type fall arresters arranged horizontally can be dangerous for the equipment and, what follows, for the users, too. The need to conduct special tests of retractable type fall arresters intended for horizontal arrangement is a consequence of this problem. Tests should be carried out in order to verify the performance of the devices during fall arrest and their dynamic strength. European and international standards on personal protective equipment against falls from a height do not contain any requirements or test methods that could be useful in this respect. This problem has been noticed by European laboratories involved in tests of personal protective equipment against falls from a height. Vertical Group 11 “Protection against falls from a height,” appointed to co-ordinate notified bodies, prepared the first proposal of requirements and test methods for retractable type fall arresters intended for horizontal arrangement, which can be found in a report of the group’s 11th meeting (Vertical Group, 2001). The proposal is still imperfect and should be improved in the future.

Therefore in 2001–2002 a research project on retractable type fall arresters arranged horizontally was undertaken by the Department of Personal Protective Equipment of the Central Institute for Labour Protection in Poland. This paper is based on information generated in the course of the project and concerns a new test method for retractable type fall arresters designed for horizontal use.

2. THE INFLUENCE OF THE ARRANGEMENT OF RETRACTABLE TYPE FALL ARRESTERS ON THEIR PERFORMANCE DURING FALL ARREST

Performance of a retractable type fall arrester arranged vertically during a fall of a test mass attached to the end of the retractable lanyard can be divided into two phases:

- free fall of the test mass. The phase stops when the velocity of the test mass is sufficient to block the device. Assuming that the mass m of the test mass is m = 100 kg and the maximum value of its velocity V_m, according to the European Standard No. EN 364:1992 (CEN, 1992c), is V_m = 2.5 m/s then the kinetic energy E_{kV} of the test mass is E_{kV} = 312.5 J;
- fall arrest of the test mass. During this phase the device absorbs the kinetic energy of the test mass. The phase ends when the velocity of the test mass equals zero.

The horizontal arrangement of retractable type fall arresters creates completely different operating conditions during fall arrest. Figure 2 shows a diagram of this kind of arrangement.

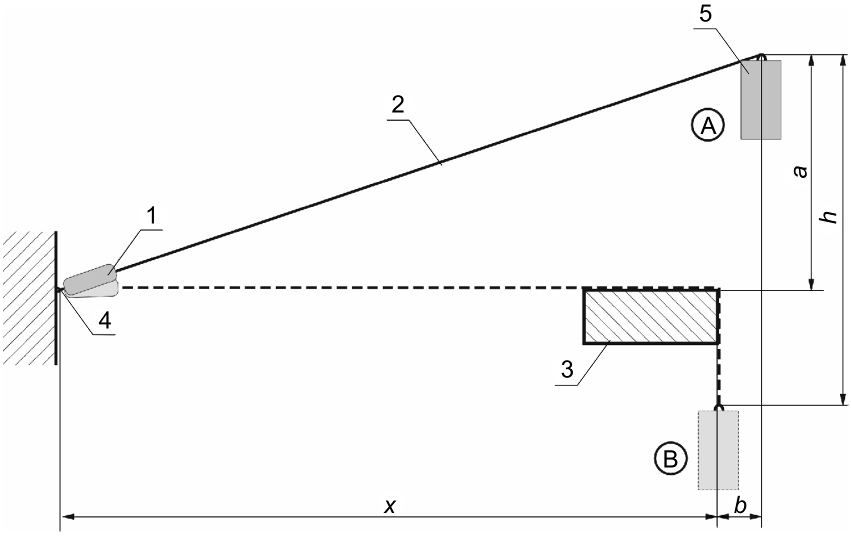

Figure 2. A retractable type fall arrester arranged horizontally—a diagram. *Notes.* A—beginning of free fall, B—end of free fall, 1—retractable type fall arrester, 2—retractable lanyard, 3—test beam, 4—anchor point, 5—test mass, *x*—horizontal distance between anchor point and edge of test beam, *a*—vertical distance between test beam and attachment point of test mass, *b*—horizontal distance between attachment point of test mass (at the beginning of the free fall) and edge of test beam, *h*—distance of free fall.

These conditions can be characterised by

- the kinetic energy of the test mass at the end of its free fall,
- the friction between the retractable lanyard and the edge of the test beam,
- the pendulum motion of the test mass in vertical planes perpendicular and parallel to the test beam.

Determination of the kinetic energy of the test mass, at the end of its free fall, was the first step of the analysis. The following assumptions were made in order to determine the kinetic energy:

- the test mass is totally rigid and its dimensions do not have to be taken into account;
- the mass of the test mass is $m = 100$ kg;
- the horizontal distance b between the attachment point of the test mass at the beginning of the free fall and the edge of the beam is $b << x$ and $b << a$ where x—horizontal distance between an anchor point of the retractable type fall arrester and the edge of the test beam, a—vertical distance between the attachment point of the test mass and the edge of the test beam;

- the device blocks immediately the retractable lanyard when the velocity V of its pull-out is $V > 0$;
- the vertical distance a (representing the medium distance between the back attachment element of a full body harness and the user's feet) equals $a = 1.5$ m.

Taking these assumptions into consideration the kinetic energy can be described by the following equations:

- case I, where the device does not retract its retractable lanyard,

$$E_{kI} = m\,g\left(a - x + \sqrt{x^2 + a^2}\right), \tag{1}$$

where m—mass of the test mass, g—acceleration of gravity;

- case II, where the device ideally retracts its retractable lanyard,

$$E_{kII} = m\,g\,a. \tag{2}$$

Figure 3 shows the results of calculations executed according to Equations 1 and 2.

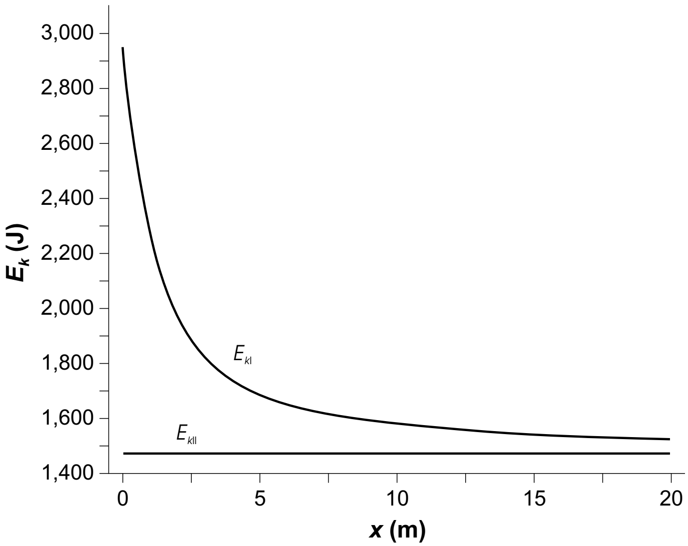

Figure 3. Dependence between the kinetic energy of the test mass (at the end of a free fall) and the distance *x*. *Notes.* E_{kI}—case in which the device does not retract its retractable lanyard, E_{kII}—case in which the device ideally retracts its retractable lanyard.

The results make it possible to draw the following conclusions:

- the kinetic energy of the test mass at the end of its free fall depends on the retracting of the retractable lanyard,
- the kinetic energy $E_{k\mathrm{I}}$ depends on the distance x. The maximum value of $E_{k\mathrm{I}}$ occurs for $x = 0$,
- the kinetic energies $E_{k\mathrm{I}}$ and $E_{k\mathrm{II}}$ are significantly greater than E_{kV}.

These conclusions proved that the retractable type fall arrester arranged horizontally, during a fall arrest, is much more loaded than when arranged vertically.

Friction between the retractable lanyard and the edge of the test beam is another very important phenomenon during fall arrest. This friction can cause partial or total destruction of the retractable lanyard and it can increase the force acting on the attachment point of the test mass (in comparison with the force acting on the anchor point of the retractable type fall arrester).

These effects depend on the following main factors:

- the material of the test beam and the shape of its edge,
- the material and the shape of the retractable lanyard,
- the kinetic energy of the test mass at the end of its free fall,
- the characteristic of the dissipating energy element of the retractable type fall arrester,
- the initial position of the test mass in relation to the test beam.

Some initial positions of the test mass in relation to the test beam can generate its pendulum motion. The distance b causes the pendulum motion in the vertical plane perpendicular to the test beam. A situation in which the angle between the retractable lanyard and the test beam (in the horizontal plane) is other than 90° generates a movement of the retractable lanyard along the beam and the pendulum motion of the test mass in the vertical plane parallel to the beam. The described pendulum phenomena can lead to dangerous collisions of persons with obstacles (Noel, 1991) in real conditions of use of the retractable type fall arresters.

3. LABORATORY TESTS OF RETRACTABLE TYPE FALL ARRESTERS ARRANGED HORIZONTALLY

In order to verify the presented phenomena several series of laboratory tests were carried out. Four types of retractable type fall arresters were tested. Table 1 summarises the construction of those devices.

TABLE 1. Construction of Retractable Type Fall Arresters Used in Tests

Type	Kind of Retractable Lanyard	Total Length of Retractable Lanyard (m)	Termination of Device	Termination of Retractable Lanyard
RW1	25-mm width polyester webbing	5.0	movable shackle connected to housing	
RW2	25-mm width polyester webbing	4.5	U-shaped element connected to housing	
RS1	5-mm diameter steel wire rope	4.5	movable shackle connected to housing	karabiner
RTR1	16-mm diameter, 2-m length three-strand polyamide rope, connected to internal 5-mm diameter steel wire rope	7.0	movable shackle connected to housing	

Figure 4 is a diagram of the test stand used in the tests. The mechanical part of the test stand consisted of a rigid construction with the anchor point (1) for the retractable type fall arrester, the basic part (2) of the test beam (anchored in walls), the upper part (3) of the test beam simulating an edge of a roof, a supporting element (4) for the retractable type fall arrester, the test mass (7, 100 kg), a power winch (5) for lifting and lowering the test mass, a quick release device (6), and its controlling device (8).

The basic part of the test beam (2) was designed (Niezgodziński & Niezgodziński, 1984; Osiński, Bajon, & Szucki, 1978) and constructed in such a way that the application of a force of 20 kN in the vertical axis at the point of contact with the retractable lanyard did not cause a deflection greater than 1.0 mm. The test beam was anchored in walls in a such a manner that the distance, in the horizontal plane, between its edge and

- the anchor point (1) was 2.2 m,
- the quick release device (6) was 0.5 m.

TABLE 2. Upper Parts of the Test Beam Simulating the Edge of a Roof

Type	Material	Dimensions Height (mm)	Dimensions Width (mm)	Dimensions Length (mm)	Additional Information
B1	pinewood	30	125	2,200	—
B2	steel ST3S	30	80	2,000	corner radius of 10.0 mm
B3	steel ST3S	30	80	2,000	corner radius of 1.0 mm
B4	steel ST3S	3	200	2,000	sharp edges
B5	concrete	60	200	1,800	—

The basic part of the test beam was equipped with replaceable upper parts (3) simulating an edge of a roof. Table 2 describes these parts.

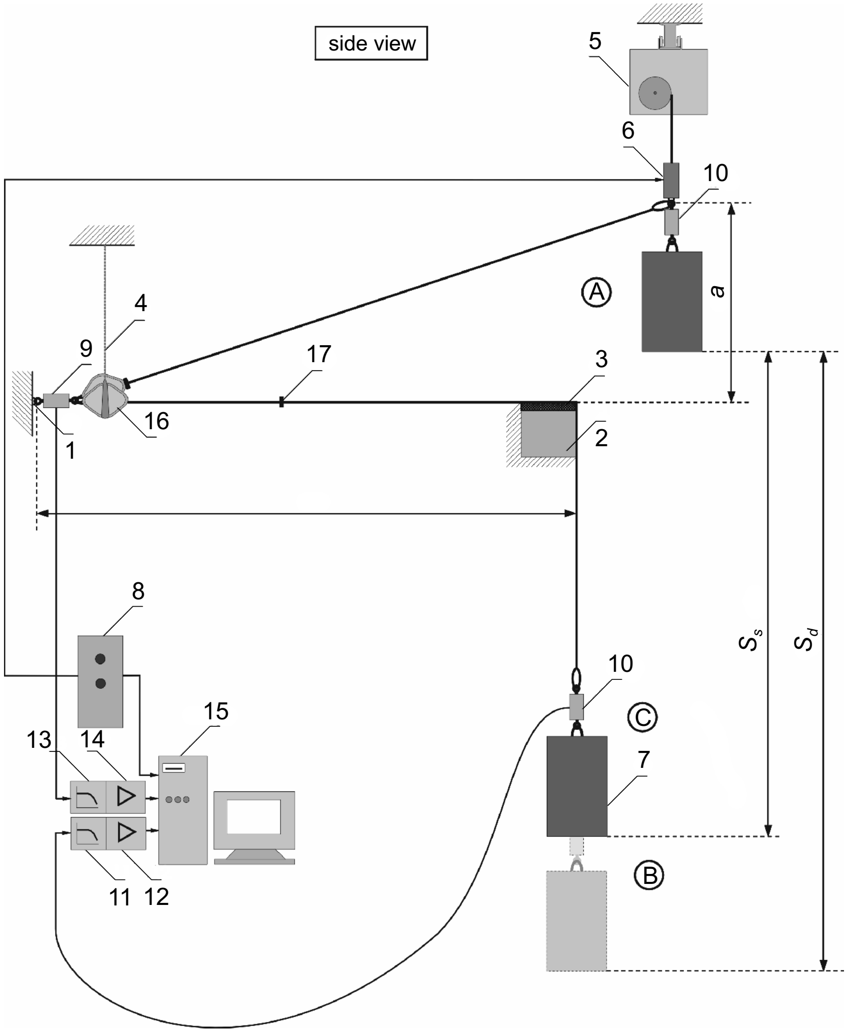

Figure 4. Retractable type fall arrester—test equipment and test method. *Notes*: A—state before fall, B—lowest position of test mass during fall arrest, C—state after fall arrest, 1—rigid construction with anchor point, 2—test beam (basic part), 3—upper part of test beam simulated edge of roof, 4—supporting element for retractable type fall arrester, 5—power winch for lifting and lowering test mass, 6—quick release device, 7—test mass (100 kg), 8—controlling device for quick release device, 9—force transducer FT1 type U9B-20kN (Hottinger, Germany), 10—force transducer FT2 type U9B-20kN (Hottinger, Germany), 11, 12, 13, 14—low-pass filters with amplifiers type AE-101 (Hottinger, Germany), 15—personal computer with measuring card type DAP-1200e (Datalog, Germany), 16—retractable type fall arrester, 17—clip.

In order to measure the forces acting on the anchor point (1) and the test mass (7), the test stand was equipped with a measuring system consisting of force transducers FT1 (9) and FT2 (10) type U9B-20kN (Hottinger, Germany), low-pass filters (11, 13) with amplifiers (12, 14) type AE-101 (Hottinger, Germany) and a personal computer with a measuring card type DAP-1200e (Datalog, Germany).

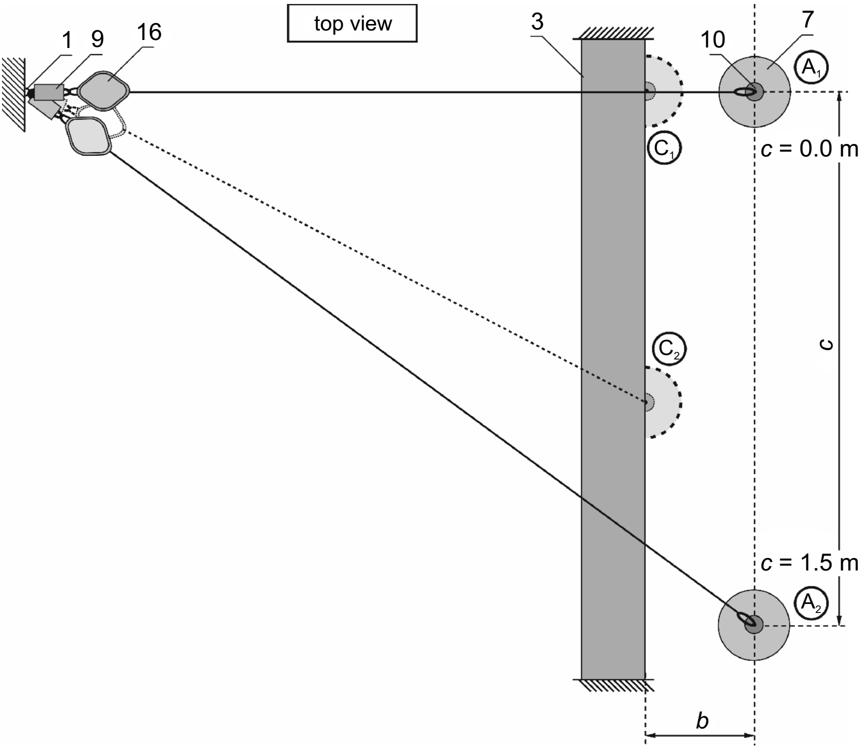

Figure 5. Retractable type fall arrester—test method. *Notes*: A_1—state before fall (c = 0.0 m), C_1—state after fall arrest (c = 0.0 m), A_2—state before fall (c = 1.5 m), C_2—state after fall arrest (c = 1.5 m), 1—rigid construction with anchor point, 3—upper part of the test beam simulated edge of a roof, 7—test mass (100 kg), 9—force transducer FT1 type U9B-20kN (Hottinger, Germany), 10—force transducer FT2 type U9B-20kN (Hottinger, Germany), 16—retractable type fall arrester.

A special computer program was prepared in order to process the data files representing the signals of the forces. The program was prepared using two programs: PIAS version 3.1 (Mess Top Engineering Gesellschaft für Meßtechnologie mbH, 1994) and FIR_BWLP V02.03 (Kayser-Threde GmbH, 1996). The program makes it possible to realise the following main tasks:

- digital filtration of force signals,

- searching of maximum values of force signals,
- calculation of differences between signals from FT1 (9) and FT2 (10) force transducers,
- calculation of the maximum value of the dynamic displacement of the test mass,
- printing diagrams of forces and the displacement.

The tests of retractable type fall arresters listed in Table 1 were carried out according to the method shown in Figures 4 and 5. The test mass (7) was placed before the test in such a position that a = 1.5 m, b = 0.5 m, c = 0.0 m (case I) and c = 1.5 m (case II). The retractable lanyard of the device (16) was blocked with the clip (17) in order to make its retracting impossible. Every kind of replaceable upper parts (3) of the test beam, listed in Table 2, was used in the tests. Signals from transducers FT1 (9) and FT2 (10) were recorded with a personal computer (15) during the falls of the test mass. A device equipped with a new retractable lanyard was used in each test. The tests were repeated three times unless the retractable lanyard was totally cut. The following quantities were obtained as a result of the test:

- the maximum value of the force F_{mT1} acting on the anchor point,
- the maximum value of the force F_{mT2} acting on the attachment point of the test mass,
- the maximum value of the dynamic displacement S_d of the test mass (calculated),
- the displacement S_s of the test mass (measured after fall arrest).

Tables 3–6 present the most important tests results. The tables additionally contain the uncertainty of measurements u_B of the forces F_{mT1} and F_{mT2}. The uncertainty of measurements was assessed with method B (Główny Urząd Miar, 1999).

The presented test results permit to draw the following conclusions:

- Typical retractable lanyards made from steel wire ropes or textile materials (webbing or fibre ropes) are not able to co-operate with the sharp edge of a steel beam. The friction between the sharp edge and the retractable lanyard causes its total cut or considerable damage. The use of retractable type fall arresters on flat roofs with sharp steel edges is very dangerous for the devices and their users and is not discussed further in this paper;
- Some retractable type fall arresters when arranged horizontally are not able to absorb huge kinetic energy of the falling mass without damage to their internal mechanisms;

TABLE 3. Test Results of the RW1 Retractable Type Fall Arrester

Type of Test Beam	c (m)	S_d (m)	S_s (m)	F_{mT2} (kN) / u_B (kN)	F_{mT1} (kN) / u_B (kN)	Additional Information
B1	0.0	3.53	3.49	4.12 0.044	3.30 0.036	Absence of damage to the retractable lanyard Slight damage to the test beam
	1.5	—	3.65	4.34 0.046	3.55 0.038	Absence of damage to the retractable lanyard Slight damage to the test beam
B2	0.0	3.42	3.36	4.59 0.048	4.06 0.043	Absence of damage to the retractable lanyard Absence of damage to the test beam
	1.5	—	3.50	5.14 0.054	3.70 0.040	Absence of damage to the retractable lanyard Absence of damage to the test beam
B3	0.0	3.24	3.19	5.14 0.054	4.14 0.044	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
	1.5	—	3.35	5.17 0.054	3.80 0.040	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
B5	0.0	3.16	3.05	5.81 0.060	3.83 0.041	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
	1.5	—	3.27	5.15 0.054	4.26 0.045	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
B4	0.0	3.40	3.31	4.86 0.051	3.13 0.034	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
	1.5	—	3.11	6.58 0.068	4.41 0.046	Considerable damage to the surface of the retractable lanyard Absence of damage to the test beam

TABLE 4. Test Results of the RW2 Retractable Type Fall Arrester

Type of Test Beam	*c* (m)	S_d (m)	S_s (m)	F_{mT2} (kN) / u_B (kN)	F_{mT1} (kN) / u_B (kN)	Additional Information
B1	0.0	3.24	3.01	8.23 0.085	7.26 0.075	Absence of damage to the retractable lanyard Damage to the brake of the device Slight damage to the test beam
	1.5	—	3.33	6.85 0.071	5.88 0.061	Absence of damage to the retractable lanyard Slight damage to the test beam
B2	0.0	3.26	3.12	8.10 0.083	6.82 0.071	Absence of damage to the retractable lanyard Absence of damage to the test beam
	1.5	—	3.35	8.24 0.085	7.42 0.077	Absence of damage to the retractable lanyard Damage to the brake of the device Absence of damage to the test beam
B3	0.0	3.38	3.21	6.45 0.067	5.30 0.055	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
	1.5	—	3.52	7.48 0.077	6.06 0.063	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
B5	0.0	3.48	3,31	7,05 0,073	5,63 0,059	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
	1.5	—	3.61	6,64 0,069	5,35 0,056	Slight damage to the surface and the edges of the retractable lanyard Absence of damage to the test beam
B4	0.0	3.21	3.08	9.46 0.097	7.40 0.076	Considerable damage to the surface of the retractable lanyard Absence of damage to the test beam
	1.5	—	—	4.02 0.043	2.73 0.030	Total cut of the retractable lanyard Absence of damage to the test beam

TABLE 5. Test Results of the RS1 Retractable Type Fall Arrester

Type of Test Beam	c (m)	S_d (m)	S_s (m)	F_{mT2} (kN) / u_B (kN)	F_{mT1} (kN) / u_B (kN)	Additional Information
B1	0.0	3.05	3.03	5.69 0.059	4.47 0.047	Absence of damage to the retractable lanyard A 30-mm cut of the test beam
	1.5	—	3.20	5.29 0.055	4.08 0.043	Absence of damage to the retractable lanyard Cut of the test beam in depth of 20 mm
B2	0.0	3.08	3.07	6.57 0.068	4.71 0.049	Cut of several outer wires of the retractable lanyard Cut of the test beam in depth of 1 mm
	1.5	—	3.51	4.99 0.052	3.46 0.037	Total cut of the outer wires of the retractable lanyard Cut of the test beam in depth of 1 mm
B3	0.0	—	—	4.65 0.049	2.35 0.027	Total cut of the retractable lanyard Cut of the test beam in depth of 1 mm
	1.5	—	—	4.84 0.051	2.61 0.029	Total cut of the retractable lanyard Cut of the test beam in depth of 1 mm
B5	0.0	—	—	6.36 0.066	3.64 0.039	Total cut of the retractable lanyard Cut of the test beam in depth of 1 mm
	1.5	—	—	6.05 0.063	2.98 0.033	Total cut of the retractable lanyard Cut of the test beam in depth of 1 mm
B4	0.0	—	—	5.63 0.059	3.29 0.035	Total cut of the retractable lanyard Cut of the test beam in depth of 3 mm
	1.5	—	—	5.21 0.054	3.01 0.033	Total cut of the retractable lanyard Cut of the test beam in depth of 2 mm

TABLE 6. Test Results of the RTR1 Retractable Type Fall Arrester

Type of Test Beam	c (m)	S_d (m)	S_s (m)	F_{mT2} (kN) u_B (kN)	F_{mT1} (kN) u_B (kN)	Additional Information
B1	0.0	3.48	3.22	5.65 0.059	4.72 0.050	Absence of damage to the retractable lanyard Slight damage to the test beam
	1.5	—	3.26	4.98 0.052	4.02 0.043	Absence of damage to the retractable lanyard The slight damage to the test beam
B2	0.0	3.60	3.31	4.15 0.044	3.65 0.039	Absence of damage to the retractable lanyard Absence of damage to the test beam.
	1.5	—	3.43	4.30 0.045	3.44 0.037	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam
B3	0.0	3.32	3.07	5.64 0.059	3.59 0.038	Slight damage to the surface of the retractable lanyard Absence of damage to the test beam.
	1.5	—	3.06	6.11 0.063	3.50 0.038	Considerable damage to the retractable lanyard Absence of damage to the test beam.
B5	0.0	3.27	3.08	7.44 0.077	4.75 0.050	Considerable damage to the surface of the retractable lanyard. Absence of damage to the test beam.
	1.5	—	2.89	7.69 0.079	5.16 0.054	Considerable damage to the surface of the retractable lanyard Absence of damage to the test beam.
B4	0.0	—	—	3.21 0.035	1.99 0.023	Total cut of the retractable lanyard Absence of damage to the test beam
	1.5	—	—	3.40 0.037	2.25 0.026	Total cut of the retractable lanyard. Absence of damage to the test beam.

- The application of a test beam equipped with a concrete upper part creates the worst conditions for the devices with retractable lanyards made from webbing or fibre ropes. The fall arrest in these conditions produces the biggest differences between the forces F_{mT2} and F_{mT1} and the most considerable damage to retractable lanyards;
- The difference between S_d and S_s (i.e., the difference between the lowest position of the test mass during fall arrest and its rest position after the fall) is greater for retractable lanyards made from textile materials than for retractable lanyards made from wire ropes. This situation is caused by greater elastic elongation of webbing and fibre ropes than of wire ropes;
- The application of a test beam equipped with a steel upper part (with the corner radius of 1.0 mm) produces the most considerable damage or total cuts of retractable lanyards made from wire ropes. The tests proved that the force F_{mT2}, which accompanied the total cut of the retractable lanyard, was lower in the case of applying a steel upper part of a test beam than in the case of applying a concrete upper part. These results allow drawing the conclusion that the application of a steel upper part (with the corner radius of 1.0 mm) of a test beam creates the worst conditions for the devices with retractable lanyards made from wire ropes.

4. TEST METHOD FOR RETRACTABLE TYPE FALL ARRESTERS DESIGNED FOR HORIZONTAL USE

The presented test results were used to prepare a test method that could be useful for laboratories engaged in tests and evaluation of personal protective equipment against falls from a height. The test method is based on the following assumptions:

- The method should make it possible to determine the performance and the dynamic strength of retractable type fall arresters during fall arrest,
- The maximum value of the force acting on the test mass during its fall arrest and the total fall arrest distance should be determined as a result of a test,
- The initial positions of the test mass should generate movements of the retractable lanyard in the perpendicular and parallel planes to the test beam,
- The test beam should simulate the most critical edge of a roof (excluding sharp elements),

- Tests should create worse operating conditions for retractable type fall arresters than real use.

The test method requires special test equipment, which meets the following requirements:

- The anchor point and the test beam should be constructed in such a way that their natural frequencies (of vibration) in the horizontal and vertical axes are not lower than 100 Hz and the application of a force of 20 kN does not cause a deflection greater than 1.0 mm, according to the requirements of the EN 364:1992 standard (CEN, 1992c);
- The test beam should consist of a basic part anchored in walls and an upper part simulating the edge of a roof;
- The upper parts should be made from concrete (the dimensions of the cross-section 50 × 200 mm) and steel type ST3S or equivalent (dimensions of the cross-section 50 × 50 mm, corner radius 1 mm);
- The upper part should be at least 2.0 m long;
- The test mass should have the mass of 100 kg and should be constructed according to the requirements of the EN 364:1992 standard (CEN, 1992);
- The anchor point and the upper surface of the test beam should be placed at the same level;
- The distance between the anchor point and the edge of the test beam should be 2.0 m;
- The test mass should be dropped from the height of 1.5 m and at the horizontal distance of 0.5 m from the edge of the test beam;
- The apparatus for measuring the force acting on the test mass should comply with the requirements of the EN 364:1992 standard (CEN, 1992c).

The presented test method requires two pieces of retractable type fall arresters. Their producer should prepare the equipment especially for the test. The total length of the device with the fully withdrawn retractable lanyard should be 2.92 m (the piece marked *PA*) and 3.28 m (the piece marked *PB*).

The test procedure should be executed in accordance with the following steps:

1. Install the steel upper part of the test beam (to test a device equipped with a wire rope) or the concrete upper part (to test a device equipped with webbing or a fibre rope).
2. Secure the *PA* device to the anchor point.
3. Withdraw the retractable lanyard and connect it to the attachment point of the test mass.

4. Place the test mass so that
    - the vertical distance between the upper part of the test beam and the attachment point of the test mass is 1.5 m,
    - the horizontal distance between the edge of the test beam and the attachment point of the test mass is 0.5 m,
    - the retractable lanyard is in the vertical plane perpendicular to the test beam and crossing the anchor point.
5. Install the clip on the retractable lanyard making its retracting impossible.
6. Let the test mass fall.
7. Observe whether the tested device arrests the fall of the test mass.
8. Measure the maximum value of the force acting on the attachment point of the test mass.
9. After the fall and with the test mass at rest, measure the displacement of the attachment point of the test mass.
10. Repeat steps 2–9 for the *PB* device, using another initial position of the test mass. In this position the test mass is in the vertical plane 1.5 m away from the vertical plane perpendicular to the test beam and it crosses the anchor point.

5. CONCLUSION

The application of retractable type fall arresters to protect people who work on flat roofs is an example of an untypical use of this equipment. A theoretical analysis and laboratory tests proved that horizontal arrangement created worse operating conditions for the equipment than vertical arrangement. Tests with a sharp hard edge of the test beam proved that this kind of edge was extremely dangerous for retractable lanyards. Therefore the use of retractable type fall arresters on roofs equipped with sharp hard edges should be forbidden. Tests with the test beam equipped with the upper part made from various kinds of materials but without sharp edges showed that such conditions of fall arresting were less critical. Nevertheless these conditions can also cause incorrect actions or damage to the retractable type fall arresters and, as a consequence, create dangerous situations for their users.

In order to avoid these situations there should be a special selection of retractable type fall arresters. The test method presented in this paper, together with the requirements and test methods from standards No. EN 364:1992 (CEN, 1992c) and EN 360:1992 (CEN, 1992a), seems to be a valuable tool for this purpose.

The test method shows the following main advantages:

- It requires few devices,
- It makes it possible to obtain quantities related to the fall arrest of people and affecting their safety,
- It creates worse conditions for fall arrest than real use,
- It uses the upper parts of the test beam simulating worst cases of edges of real roofs,
- It can be easily modified in order to introduce new specific kinds of test beams.

This test method can be used in preparing the final version of the method, which should be accepted by European notified bodies involved in testing personal protective equipment against falls from a height. Therefore it will be presented to members of Vertical Group 11 “Protection against falls from a height.”

The results of the laboratory tests also demonstrate that most retractable type fall arresters used at present are not suitable for horizontal arrangement. In order to solve this problem the manufacturers of personal protective equipment protecting falls from a height should prepare new more resistant constructions of retractable type fall arresters.

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