Fall arresters tested for mechanical and ergonomics criteria – CSA Z259.2.1-1998 standard

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Abstract: When working at heights, fall protection is required; protection is either provided by a fall prevention system or a fall arrest system. The individual fall arrest system is made of a full body harness, an energy absorber, a lanyard, a connecting subsystem and an anchor. The connecting subsystem is often a fall arrester on a vertical flexible lifeline. A fall arrester is a device that slides along the vertical lifeline (rope) but locks on the rope if a fall occurs; the locking mechanism is done by a cam lever to which a lanyard is connected. Because the fall arrester is moving up and down and its stopping is done by the cam lever squeezing of the rope, the compatibility of the fall arrester and the vertical rope is a key element. A poorly designed fall arrester or an incompatible fall arrester/rope makes the fall arrester not moving easily on rope. In this situation, the user maintains the cam lever in an upward position in order to move it up and down when climbing. If a fall occurs during this operation, the natural reflex is to grasp what is in the hand, here the cam lever of the fall arrester; this action maintains the cam in an up position and makes it not functioning. The fall arrester is overridden and the fall is not arrested. Two well documented fatal accidents and several incidents had demonstrated this scenario. The CSA Z259.2.1-1998 standard includes mechanical strength and ergonomics criteria and the related test methods, the mobility test the panic grab test. Since then fall arresters do not interfere with the task and are fail-safe.

Keywords: Personal protective equipment (PPE), fall protection, fall arrester, ergonomics criteria, human interaction.

1. Introduction

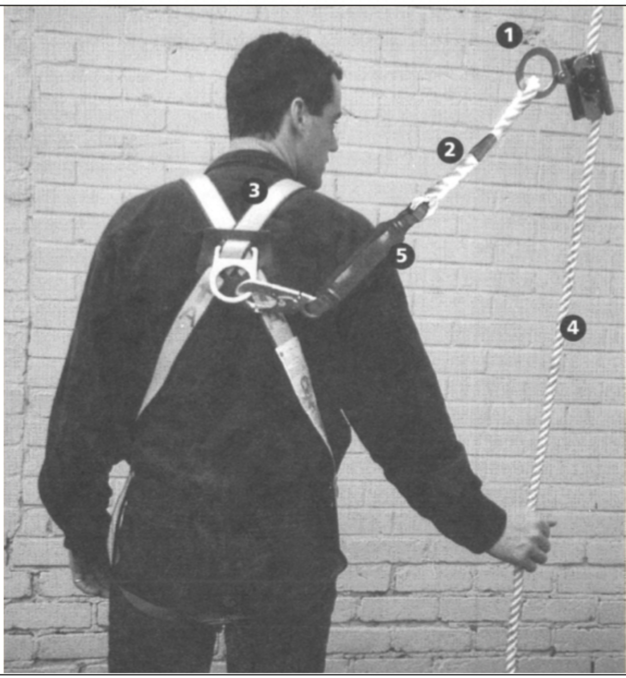
This paper relates the evolution of the fall arrester and its related Canadian standards since 1979 (see Table 1). The consequences of a defective design of fall arrester are identified and demonstrated by fatal accidents and incidents. The defects were conflicting with the workers' tasks. Therefore workers were acting to ease their work despite these actions were making ineffective the protection functions of the fall arrester. New requirements and test procedures in the CSA-Z259.2.1-1998 were the driving forces behind improvements of fall arrester (CSA: Canadian Standards Association). The Z259.2.1-1998 standard is a good example of the integration of ergonomics and engineering principles such conflict between task and safety, userfriendliness and fail-safe design.

Table 1: *Main events*

1979	CSA Z259.2-1979 standard is published
1979-1988	Several observations of misuse without reported accidents
1988	Westmount Square accident: panic grab by the falling worker
1988-1998	Development of new requirements and tests by CSA committee
1998	CSA Z259.2.1-1998 including mobility and panic grab tests is published
After 1998	New fall arresters with mobility and panic grab features
2004	15 May 2004 Toulnustouc accident: incompatible rope-fall arrester → lack of mobility
2006	Device retired from use
2007	Reinforcement of the certification process and posting of compatible rope(s) with each certified fall arrester on the CSA C&T web site
2012	New CSA Z259.2.5 with a more specific compatibility requirement

2. Fall arrester in individual fall arrest system

When working at heights, an individual fall arrest system is used when elimination of the fall hazard by design or when prevention by the use of guardrail are not feasible. The individual fall arrest system (Figure 1) is made of a full body harness, an energy absorber, a lanyard, a connecting subsystem and an anchor. The connecting subsystem could be an anchoring connector or a self retracting lanyard or a fall arrester on a vertical flexible lifeline (Arteau 2000). In the later case, the vertical lifeline is anchored on the roof and suspended along the façade of a building. The worker is then protected along a vertical line. A fall arrester is a device that slides along the vertical lifeline (rope) but locks on the rope if a fall occurs; the locking mechanism is done by a cam lever to which a lanyard is connected (Figure 2). The cam lever mechanism is the most frequent.



1 fall arrester

2 lanyard

3 full body harness

4 vertical lifeline (16mm rope)

5 energy absorber

Ref.: CSST dc-100-1240-11

Figure 1: *Individual fall arrest system*

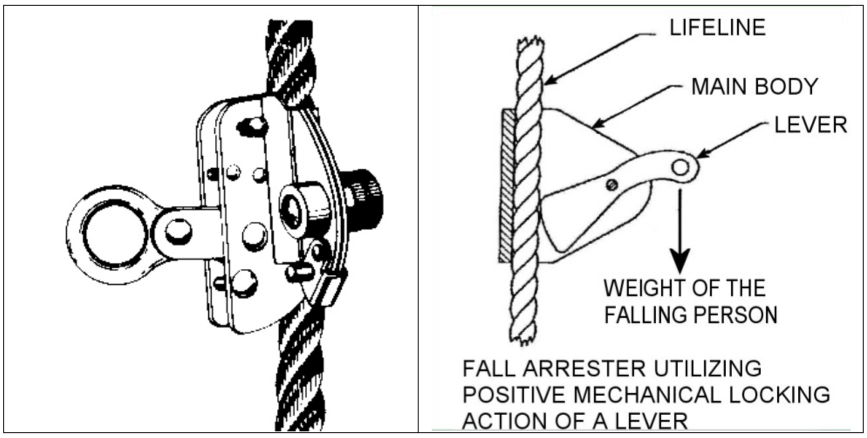


Figure 2: *Fall arrester and its cam lever mechanism*

The workers' tasks require vertical movements along the vertical lifeline for either working or climbing; so the fall arrester must slide freely not to cause conflict with the main tasks. The mobility of the fall arrester along the lifeline is a key function.

3. Z259.2-1979 standard

The CSA Z259.2-M1979 Fall-Arresting Devices, Personnel Lowering Devices, and Life Lines was requiring the mobility of the fall arrester on the vertical lifeline with the use of one hand on the fall arrester itself (Clauses 4.1.2 and 4.1.3). Despite Clauses 4.1.2 "the device shall be of such design that the arresting characteristic is not inhibited should a fall occur while the device is being moved" and 4.1.5 "if the user grasps the device with a hand while falling, it shall not be possible to prevent it from grasping the vertical lifeline", it was very frequently observed that workers were grasping the lever to move the fall arrester along the vertical lifeline (Figure 3).

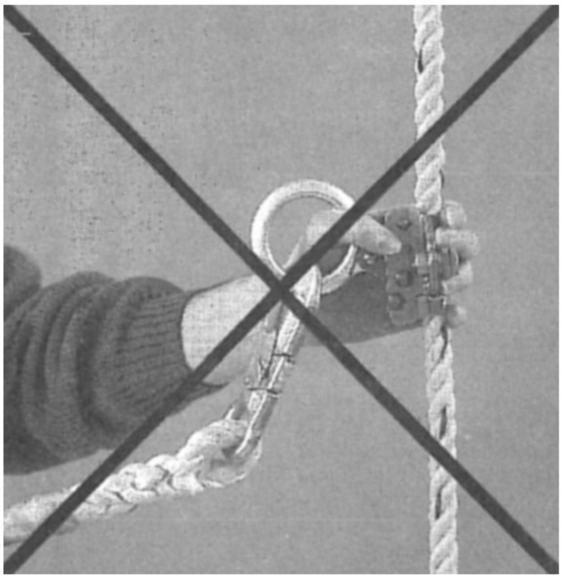


Figure 3: *Grasping the lever of the fall arrester*

Grasping the lever was allowed by 4.1.3 "With Type 1 fall-arresting devices, it shall be possible for the user to move the device up and down on the carrier with the use of one hand". The 1979 standard was including a panic grab concept (4.1.2 and 4.1.5) and a partial mobility concept (4.1.3) without the test procedures to assess the functions. Therefore no real verification was made before certification.

4. Observations 1979-1988

Because the fall arrester is moving up and down and its stopping is done by the cam lever squeezing of the rope, the compatibility of the fall arrester and of the vertical rope is a key element. A poorly designed fall arrester or an incompatible fall arrester/rope makes the fall arrester not moving easily on rope. This situation obliges the user to maintain the cam lever in an upward position in order to move it up and down when climbing. As example, when climbing on a vertical ladder, the worker climbs 2 or 3 steps, manually moves the fall arrester by squeezing its lever, then climbs again 2 or 3 steps and repeats until he reaches the top of the ladder; a long frustrating climbing. These actions were very frequently observed. The most foreseeable consequences are as described. If a fall occurs during this operation, a natural reflex is to grasp what is in the hand, here the cam lever of the fall arrester; this action maintains the cam in an up position and makes it not functioning. The fall arrester is overridden and the fall is not arrested. Despite their potentially fatal consequences, it was nearly impossible to convince for a corrective action because no accidents were reported. The absence of reported accidents does not mean that no accidents had occurred. The workers' actions were natural. As point out by Desjardins and Arteau, the worker prioritizes his main task which is his constant and first duty even if he could jeopardizes a safety device that is rarely in use.

5. October 1988: the Westmount Square accident in Montreal

This accident has demonstrated that the section 4 analysis was not a simple theoretical view. The facts as observed by the occupational safety and health OSH inspectors are:

- the left suspension cable of a 2 cable suspended scaffold broke during the descent of the scaffold;
- the outrigger beams were located on the 22nd floor; the scaffold was at the 12th floor level when the cable broke;
- the fall arrester was of the cam lever type;
- the worker was found injured and suspended in his safety belt above the roof of the 1st floor (in 1988, the harness was not mandatory for all situations);
- the glove from the hand that was holding the fall arrester lever, was burned with a trace similar to a rope;
- his fall arrester was locked on the vertical lifeline (rope);
- the autopsy as presented in the coroner's inquest report was analysed by two independent physicians ignorant of any details from the accident; their conclusions were similar. The two causes of the death are the subarachnoid haemorrhage resulting from the whip-lashing of the head and the laceration of internal organs the internal haemorrhage resulting of the compression of the abdomen soft organs by the belt both during the fall arrest. Other injuries were such as fractures of the legs resulting from the impact on the roof at the maximum extension of the rope; the later were not the cause of the death.

The only possible explanation was: the worker was holding the lever of his fall arrester in an upright position in order to allow the downward movement of the fall arrester while the scaffold was descending. At the instant of the fall, he probably grasped what he had in one hand, the fall arrester, and maintained the lever in the upright opened position impeding the arrest function. He was descending during 11 floors. Looking at the ground, he released the lever allowing the fall arrester to operate, so to lock on the rope and arrest the fall. The arrest force has caused a dynamic extension of the vertical lifeline, enough to produce an impact on the roof. After the rebound, the worker was found hanging on the rope. He deceased few days after. (Arteau 1988, CSST 1988). These findings were published in 1990 (Arteau 1990).

6. The Z259.2.1-1998 standard

After several years of discussions, the standard CSA-Z259.2.1-1998(R2008) "Fall Arresters, Vertical Lifelines, and Rails" was published.

The main test is a dynamic performance test in which the fall arrester must arrest the fall of a 100-kg mass from a height of 1.2 m or with a fall factor H/L of 2, by not sliding more than 150 mm or 1 m along the vertical line.

Two new tests have been developed: the mobility test and the panic grab test. The mobility test consists of checking that the fall arrester slides freely along the rope or rail during ascent and descent, without the worker having to touch the fall arrester (Figure 4).

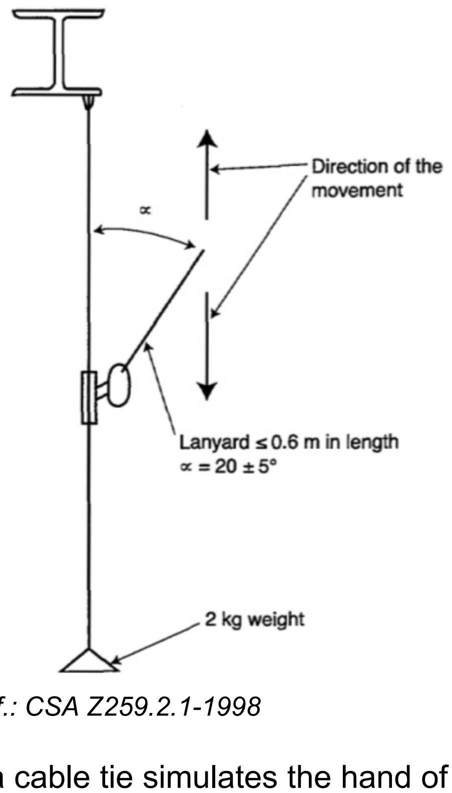


Figure 4: *The mobility test, Ref.: CSA Z259.2.1-1998*

In the panic grab test, a cable tie simulates the hand of a worker, which would hold the lever in the up position (Figure 5). Held in this manner, the fall arrester must nevertheless arrest a fall. The technical solution is to add a protuberance on the upper part of the lever cam which would pinch the rope if the lever is held in the up position.

Therefore a fall arrester is a device that travels freely with the movement of a worker on a lifeline in the vertical or near vertical plane and that will automatically engage on the lifeline in the event of a fall. This device will remain engaged on the lifeline if released or held beyond its non engaged position, and in the event of a fall will lock so as to arrest the fall.

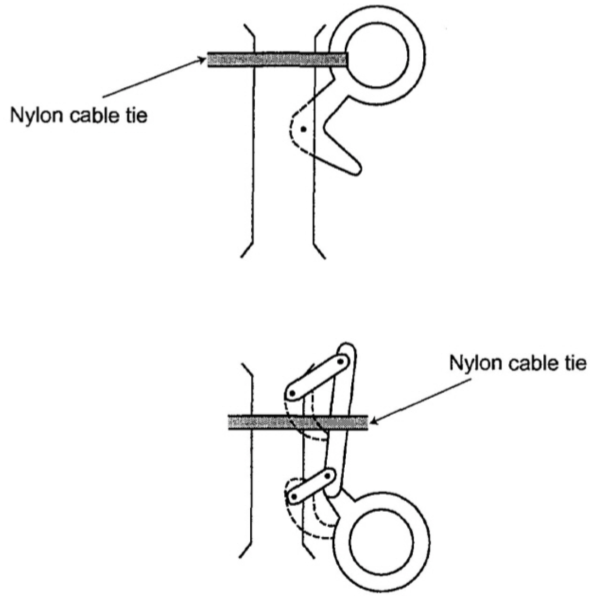


Figure 5: *The panic grab test, Ref.: CSA Z259.2.1-1998*

After the publication of the 1998 standard, a new generation of fall arresters was designed; they do not interfere with the task and are fail-safe. The same example of section 4 of climbing on a vertical ladder is now described; the worker installs his fall arrester on the vertical lifeline and climbs the full height of the ladder without stopping as if he has no fall arrester; instead of a long frustrating climbing this is a normal climbing. Until 2011, the CSA Z259.2.1-1998 standard is the only one covering all these mechanical and ergonomics criteria. Desjardins and Arteau had analysed the strong and complex relation between humans and equipment causes issues during their evaluation and selection process. By keeping in mind that PPE protects a worker efficiently only if he wears it properly, it is necessary to analyze many different aspects to ensure proper selection. The fundamental aspect of this choice is to ensure the PPE was designed to protect workers from the particular risk in their work environment. Desjardins and Arteau also underline that workers will preferably select the task in the conflict between the task and the activation of the personal protective equipment and will act as with their own logic in a panic situation. The Z259.2.1-1998 has introduced a userfriendliness criterion (lack of interference) with the mobility test and a fail-safe criterion with the panic grab test. Even if the worker is not acting as trained, the fall arrester will arrest his fall.

7. 2004 Toulnustouc accident

On 15 May 2004, a fatal accident occurred at a dam construction site on the Toulnustouc River. An incompatible rope-fall arrester combination had caused a lack of mobility of the fall arrester. The worker decided to place his poorly mobile fall arrester at the bottom of the vertical lifeline giving it a large slack in order to avoid any conflict between his task and the fall arrester. The length of the vertical lifeline was longer than the distance between him and the ground at one location. Then the scaffold had collapsed and the worker was found dead on the ground. The analysis of the equipment had demonstrated a failure of the mobility test for a similar fall arrester on the vertical lifeline used at the site as well on a different rope type. Again the lack of mobility of the fall arrester was the cause of a fatal accident. The CSST inspectorate ordered the fall arrester retirement from the market. An administrative inquiry has lead to the reinforcement of the certification process and the posting of compatible rope(s) with each certified fall arrester on the CSA C&T web site (Arteau 2005 and CSST 2006). In 2012, CSA Standards (the standard writing division of CSA) will publish a new version of the fall arrester standard; it will be renumbered to Z259.2.5 covering only flexible lifeline with a more specific compatibility requirement.

8. PPE criteria

As a summary (Table 2), the methodology and the criteria proposed by Desjardins and Arteau are used to compare the evolution of fall arresters and their standards. The efficiency was demonstrated at the beginning. The improvement was on the reliability, the lack of interference and the conviviality.

Table 2: *Desjardins-Arteau methodology - criteria*

	Z259.2-1979	**Z259.2.1-1998**	**After 2006**
Efficiency (Fall arrest)	Yes	Yes	Yes
Reliability	Not tested	Panic grab test	Panic grab test
Accessibility to information on compatibility			Web posting of compatible rope-fall arrester
Freedom of movement	Not tested	Mobility	Mobility
Interferences	Not tested	Mobility	Mobility
Userfriendliness (Conviviality)	Little	Yes great	Yes great

9. Conclusion

The two main concerns regarding the fall arrester were the lack of mobility on the rope and the overriding of the cam mechanism. The lack of mobility causes a conflict between the need to move up and down (the task) and the protection (do not override the fall arrester cam); the worker chooses the task because an accident is very uncommon and the task is always present to his mind.

The mobility of the fall arrester on the rope and thus its compatibility with the rope are verified by a mobility test. Even if the fall arrester passes the mobility test, it is still possible that the worker grasps the cam lever and overrides the arrest function of the fall arrester. Therefore the overriding of the cam mechanism is verified by a panic grab test; to pass the panic grab test, a fall arrester shall arrest a fall even if the cam lever is in an up position.

The Z259.2.1-1998 standard is a good example of the integration of ergonomics and engineering principles; it has conciliated task and safety, userfriendliness and fail-safe design. The mobility test covers the userfriendliness and the absence of interference with the climbing task. Consequently there is no need to grasp the lever up to create mobility for the fall arrester. Even if the user reacts in an unprescribed way and grasps the lever, the device will arrest the fall because it passes the panic grab test; the fall arrester is a fail safe feature. Until 2011, the CSA Z259.2.1-1998 standard is the only one covering all these mechanical and ergonomics criteria.

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