

AVALANCHE FLOTATION DEVICES

1. ISSUE

In the Coroner's Report into the deaths of Ms. Kimberly Anne Manchip and Mr. Daisuke Matsui, both of whom were caught in an avalanche and died from asphyxiation, the Coroner found that evidence from the incident pointed to the lifesaving potential offered by avalanche flotation devices. The Coroner recommended that WorkSafeBC "evaluate the efficacy of avalanche flotation device use by workers whose workplace involves frequent and extensive exposure to conditions which may result in life-threatening avalanches."

Existing literature on avalanche flotation devices has been reviewed in order to evaluate the performance of these devices.

2. LITERATURE REVIEW

2.1 Avalanche Fatalities

In the majority of avalanche fatalities, the fatality is due primarily to asphyxiation. Data from Canada, the United States, and Europe indicate that asphyxia accounts for up to 70-80% of avalanche deaths.^{1,2} Asphyxia has been found to occur rapidly after burial. Time to recovery, therefore, is a critical factor in regards to survival. In cases of complete burial,³ 92% of victims will be found alive if recovery is accomplished within 15 minutes; however, the survival rate drops to 30% at 35 minutes after burial.⁴

Depth of burial is another critical factor with regards to survival; the probability of a live recovery decreases as depth of burial increases.⁵ The chance of survival in the case of complete burial has been found to be only about 50%, whereas the survival probability of not or partially buried people has been found to be approximately 97%.⁶

2.2 Avalanche Flotation Devices

Avalanche flotation devices aim to prevent asphyxiation by reducing the depth of burial in the event of an avalanche. These devices are designed to increase flotation, keeping the wearer at the surface of the avalanche, and thereby prevent or minimize burial.

¹ Boyd, J. et al (2009) at 509

² Radwin, M.I. & Grissom, C.K. (2002) at 144

³ Complete burial is defined to mean that the victim's head and chest are covered with snow.

⁴ Falk, M., Brugger, H., Addler-Kastner, L. (2001) at 140

⁵ Radwin, M.I. & Grissom, C.K. (2002) at 144

⁶ Tshirky, F., Brabec, B., & Kern, M. (2000) at 2

2.2.1 What is an Avalanche Flotation Device?

Unlike other avalanche rescue devices, the primary purpose of an avalanche flotation device is not to facilitate and accelerate rescue but to prevent burial of the victim under snow altogether. Avalanche flotation devices consist of a self-contained balloon system housed within a backpack. If caught in an avalanche, the wearer can deploy the balloon by pulling the activation handle. This will initiate the release of gas/compressed air from the cartridge housed in the backpack, causing the balloon to inflate. The inflated balloon increases the wearer's volume and size, preventing burial.

2.2.2 How Avalanche Flotation Devices Work

Avalanche flotation devices work through a process known as *inverse grading* or *inverse segregation* (see Figure 1). A moving avalanche can be compared to a flowing granular medium, composed of differently sized particles. Under the influence of gravity, granular flows segregate in such a way that larger particles are more likely to be found near the surface, while smaller particles move to the base of the flow. In an avalanche, larger "particles" will be held on the snow surface.⁷

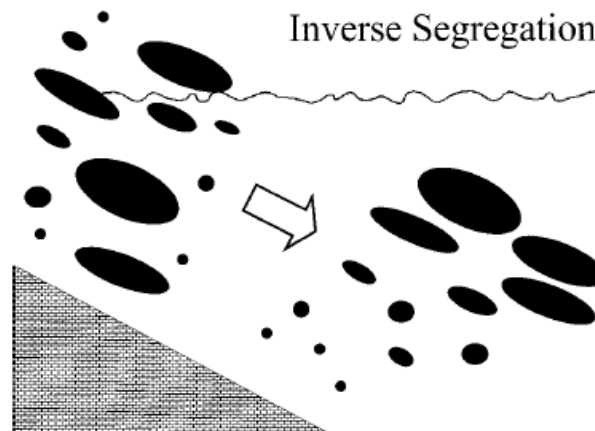


Figure 1. Diagram of Inverse Segregation⁸

An avalanche flotation device works by increasing the volume and size of the wearer. Once inflated, the device will render the wearer an even larger "particle" in the avalanche flow. The wearer will be subjected to the separation effect and move to the surface of the avalanche, thereby preventing or minimizing burial⁹ (see Figure 2).

⁷ Tschirky, F, Brabec, B., & Kern, M. (2000) at 6

⁸ Radwin, M.I. & Grisson, C.K. (2002) at 149

⁹ Radwin, M.I. & Grisson, C.K. (2002) at 149

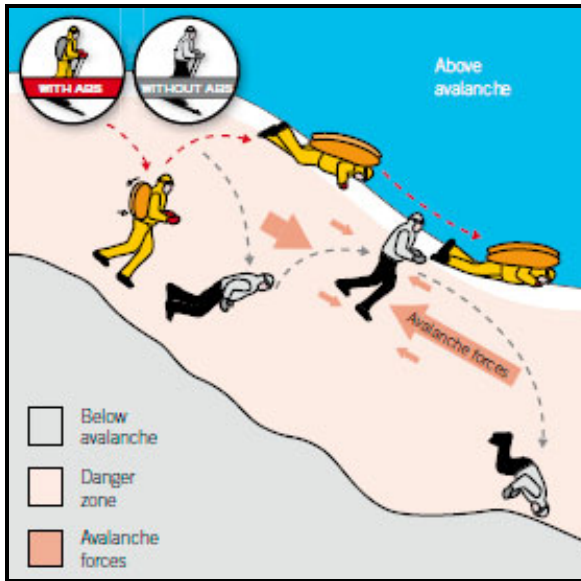


Figure 2. Illustration of Effect of Avalanche Flotation Device¹⁰

2.3 Effectiveness of Avalanche Flotation Devices

Several studies have examined the effectiveness of avalanche flotation devices¹¹ in reducing burial depth and improving chances of survival for persons caught in an avalanche. These studies have reviewed documented cases of persons equipped with an avalanche flotation device being caught in an avalanche and have also reviewed data from field tests of various avalanche flotation devices (i.e., where a dummy is equipped with an avalanche flotation device and then dropped into a triggered avalanche).¹²

Each of these studies found that while avalanche flotation devices cannot in principle prevent burial, they can reduce the frequency and extent of burial in an avalanche. One study found that the use of an avalanche flotation device reduced the likelihood of complete burial from 39% to 16.2%.¹³

In cases where individuals were completely buried despite utilizing an avalanche flotation device, the presence of the avalanche flotation device was found to facilitate rapid rescue by companions, as at least part of the balloon was visible above the snow. This is an important finding given that asphyxiation occurs rapidly after burial and time to rescue is an important factor in determining survival.

¹⁰ Avalanche Airbag System 2008/09 Catalogue

¹¹ Most of these studies involved the ABS Avalanche Airbag.

¹² Most of this information around comes from data collected in Switzerland.

¹³ Brugger, H. & Falk, M. (2002) at 3.

Research has shown that the role of avalanche flotation devices in reducing burial and facilitating rapid rescue greatly reduces the mortality rate for persons caught in an avalanche. The use of an avalanche flotation device has been found to reduce the relative risk of being killed by over 90%.¹⁴

2.3.1 Statistics

Documented Avalanche Incidents

The Swiss Federal Institute for Snow and Avalanche Research (“SLF”) has documented avalanche accidents involving an ABS avalanche backpack since 1990. As of September 2008, the SLF has documented 167 avalanche accidents, involving 200 people who were equipped with an ABS avalanche backpack and 41 people who were not.¹⁵

Out of the 200 people equipped with an ABS avalanche airbag, the airbags were fully inflated in 180 cases.¹⁶ In these 180 cases with inflated airbags:

- 82 people were not buried;
- 64 people were partially buried;
- 17 people were completely buried with the airbag visible on the avalanche surface;
- 3 people were completely buried with the airbag not visible on the avalanche surface; and
- for the remaining 14 people, the degree of burial was unknown.

Out of these 180 cases involving fully inflated airbags, 177 people¹⁷ survived the avalanche (approximately 98%) incident and 3 died (see Figure 3). Two of the three people who died were killed during the downfall, and one was caught in a depositional zone and buried by a secondary avalanche.

¹⁴ Brugger, H. et al. (2007) at 481

¹⁵ ABS Avalanche Airbag System

¹⁶ There were 20 cases in which the ABS avalanche airbag did not fully inflate, either due to human failure or a technical malfunction. Out of these 20 cases, 6 people were killed.

¹⁷ Of these 177 survivors, 160 escaped the avalanche incident uninjured.

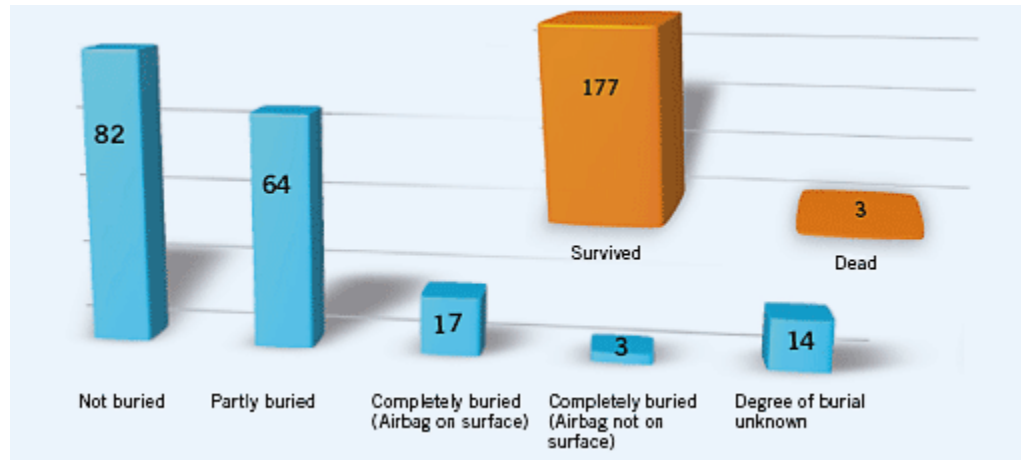


Figure 3. Documented Accidents Involving Fully Inflated ABS Avalanche Airbag¹⁸

Of the 41 people who were caught in an avalanche accident without an ABS avalanche airbag:

- 10 people were not buried;
- 11 people were partially buried; and
- 20 people were completely buried.

Thirteen of the 41 people without ABS were killed during the avalanche incident (approximately 32%).

More detailed information about the documented avalanche accidents involving ABS Avalanche Airbags can be found in Appendix A.

Field Tests

The SLF carried out field tests of the ABS Avalanche Airbag in the winter of 1994-95.^{19,20} Fourteen dummies were placed on an avalanche test slope that was then triggered by explosives. Six dummies were equipped with properly inflated ABS airbags and eight were not. The results were as follows:

¹⁸ ABS Avalanche Airbag System

¹⁹ Tschirky, F & Schweizer, J. (1996) at 257-259.

²⁰ Radwin, M.I & Grisson, C.K. (2002) at 150.

Degree of burial	Dummies with inflated balloon	Dummies without inflated balloon
not buried	1	0
partially buried	1	2
complete with some parts (i.e., balloon) visible	4	2
complete	0	4

Table 1. Results for the 14 dummies involved in the SLF's field test of the ABS Avalanche Airbag²¹

None of the six dummies with an inflated balloon were deeply buried by the avalanche; one dummy even remained completely on the avalanche surface. In contrast, all of the dummies without an inflated balloon were at least partially buried, and four of the eight were deeply buried with no parts visible on the avalanche surface.

WorkSafeBC Record of Incident

On March 20, 2009, a 35-year old heli-ski guide was guiding skiers when he was caught in an avalanche. The guide was equipped with a Snow Pulse avalanche airbag, which he deployed once caught by the avalanche. The airbag prevented the guide from being buried by snow. The guide survived the avalanche accident but did suffer serious injuries, including a fractured skull, fractured left arm, left knee trauma, and laceration to the head.²²

2.3.2 Limits of Effectiveness

Tests of avalanche flotation devices have revealed the following limits to their effectiveness.

(a) Must be moving with avalanche

Avalanche flotation devices only appear to be effective if the victim and the flotation device are flowing along with the avalanche. Once the victim and flotation device come to a stop, particularly in a depositional zone or terrain trap, the victim may be completely buried by further avalanche snow.²³ In this situation, the presence of an avalanche flotation device will not help to prevent or minimize burial, nor will it facilitate rapid location and rescue.

This is evidenced by the data from the SLF on documented cases of avalanche accidents in which an ABS Avalanche Airbag was involved

²¹ Tschirky, F & Schweizer, J. (1996) at 259.

²² Notice of Incident Report 2009155980157

²³ Tschirky, F & Schweizer, J. (1996) at 260.

(see Appendix A). Only three individuals equipped with an inflated airbag were completely buried (airbag not on surface) by an avalanche. Each of these individuals was buried either by a secondary avalanche or by floating snow after the avalanche.²⁴

(b) Prone burial

Tests have shown that during an avalanche and after standstill, conventionally designed avalanche airbags (such as the ABS Avalanche Airbag) are usually located above the victim.²⁵ Victims, therefore, are likely to be buried in a prone position and require companion rescue.²⁶

(c) Travel farther with uncertain consequences

There is a strong possibility that individuals will be carried faster and further along the avalanche slope when equipped with an inflated avalanche flotation device than they would without, since the surface of the avalanche travels more quickly.²⁷ The consequences of this would depend on the avalanche terrain but could include a greater risk of traumatic injury.^{28,29}

(d) Failure to release avalanche flotation device

Information from documented avalanche accidents reveals that a number of people equipped with an avalanche flotation device fail to release the device when caught in an avalanche (see Appendix A). The figures relating to failure to activate the avalanche flotation device demonstrate that manual release of the device by the user represents a weakness. There are situations where an individual may not be capable of releasing the device due to mental or physiological reasons. In order to effectively use an avalanche flotation device in situations of extreme stress, users should practice releasing the device.³⁰

2.4 Concerns Related to Avalanche Flotation Devices

Existing studies make a compelling case for the use of avalanche flotation devices; the devices have been shown to be effective in reducing burial depth

²⁴ ABS Avalanche Airbag System

²⁵ The Snowpulse avalanche airbag has been developed with “head on top” technology, which is designed to keep users on their backs with their heads out of the snow. Prone burial, therefore, may not be an issue with the Snowpulse brand of avalanche flotation devices.

²⁶ Tschirky, F & Schweizer, J. (1996) at 260.

²⁷ Scrivener, L. (2008)

²⁸ Tschirky, F & Schweizer, J. (1996) at 260.

²⁹ Radwin, M.I & Grisson, C.K. (2002) at 150.

³⁰ Kern, M, Tschirky, F. & Schweizer, J. (2002) at 4

and facilitating rapid location and rescue of avalanche victims. Most of the existing research on the efficacy of avalanche flotation devices, however, comes from Switzerland and other areas of Europe. The conclusions reached by the research may not, therefore, be generalizable to Canada.

There are certain risks specific to the Canadian context which could affect the ability of avalanche flotation devices to improve safety for users. As a result, Canadian avalanche professionals have expressed concerns with respect to the use of the devices. These concerns are summarized below.

2.4.1 Trauma

The issue of trauma suffered during an avalanche incident is not fully addressed by research into avalanche flotation devices. These devices are designed to prevent death by asphyxiation, which is the primary cause of death in avalanche incidents. However, trauma is also a relatively common cause of avalanche fatalities in Canada.

Research on snow avalanche deaths in British Columbia and Alberta reveals that, while asphyxia was the dominant cause of avalanche-related deaths, major trauma contributed to a total of 33% of avalanche deaths.³¹ The greater number of fatalities caused by trauma in Canada is attributed to the differences in terrain between Canada and Europe (i.e., greater access to forested ski terrain in Canada). Collision with obstacles during avalanche descent is rare in Europe but is a common mechanism for injury in Canada.³²

Given that research has shown that individuals equipped with an inflated avalanche flotation device travel down the avalanche slope at a greater velocity, there is a concern that individuals could hit trees or other debris harder if they have deployed an avalanche flotation device. This could lead to a greater degree of traumatic injury than if the individual had not deployed an avalanche flotation device.

2.4.2 Helicopter Safety

There are concerns about the use of avalanche flotation devices in the context of heliskiing, specifically with regards to the safety risks associated with accidental inflation near a helicopter. If an avalanche balloon were to contact the blades of a helicopter, the helicopter could become unstable; this would pose a significant risk of injury or death for all of the occupants of the helicopter.

³¹ Boyd, J. et al. (2009) at 510

³² Hohlrieder, M. (2007) at 60

2.4.3 Weight

An avalanche flotation device can weigh from 4 to 7 pounds, depending on the brand and model of device. The weight of these devices could contribute to occupational injuries, such as lower back pain.

Reference List

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Documented avalanche accidents with ABS Avalanche Airbag

Number of documented accidents - 167

Number of caught people with ABS - 200

		total	uninjured	injured	dead	unknown
(1) with inflated airbags	180	82	77	5	0	
	not buried					
	partially buried	64	60	4	0	
	completely buried (airbag on surface)	17	11	4	2	
	completely buried (airbag not on surface)	3	2	0	1	
	degree of burial unknown	14	10	2	0	2
(a) injured	15	0				
	head/cervical spine	0				
	torso	0				
	arms/legs	9				
	unknown	6				
(b) dead	3	1				
	buried by secondary avalanche	2				
	died from downfall					
(c) completely buried	3	2				
	by secondary avalanche	1				
	by floating snow after avalanche					
(2) with partially or not inflated airbags	20	16	6	2	6	2
	human failure	4	3	1	0	
	technical malfunction					
(a) human failure	15	4	2	2	2	
	improper pack maintenance	10	2	2	4	2
	no activation (mental/physiological reason)	2	2			
	intentionally not activated					
Number of people caught without ABS - 41	41	10	8	2	0	
	not buried	11	11	0	0	
	partially buried	20	3	3	13	1
	completely buried					