Avalanche Victim's Air-from-Snow Breathing Device

Thomas J. Crowley, M.D.
13351 East Amherst Court, Aurora, Colorado 80014

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ABSTRACT

This describes a patented emergency breathing device for a person buried in snow. The device extracts air from snow, which contains some 50-90 percent air. It can be incorporated unobtrusively into a parka or vest. The person inhales through a mouthpiece in the garment's collar. The mouthpiece connects via tubing and a one-way valve to a broad, shallow inhalation chamber sewn into the front of the garment. A tough fabric membrane, permeable to air but not to snow, covers the chamber's front surface and contacts the snow. That membrane passes into the chamber (under normal respiratory pressures) enough air from the snow for normal inhalation. The buried person exhales through the same mouthpiece, which separately connects via tubes and another one-way valve to an exhalation chamber sewn into the back of the garment. The exhalation chamber also is covered by a membrane permeable to air but not to snow. The snow-contacting surface of the exhalation membrane passes exhaled air from the rear chamber to the snow. The inhalation and exhalation chambers are sufficiently far apart on the garment to minimize mixing of previously exhaled air with air that will be inhaled. In a field test of the device a person breathed easily for about 40 minutes while fully buried at a depth of about 0.8-0.9 m. The convenience, light weight, and mechanical simplicity of the device make it easy for a skier to carry, wear, and use.


Survival data are discouraging [Armstrong, Williams 1992]. Of persons totally buried in snow with no tell-tale sign to the surface such as a protruding ski, three out of four die. About two-thirds of victims die of suffocation, one-third from trauma. Suffocation is quick. Reporting that only 30 percent survive 35 minutes' burial and 3 percent survive 130 minutes, Falk et al. (1994) called for the development of “...self-help techniques to facilitate creation of a life-saving air pocket, which would give the skier a relatively safe haven...”

Suffocation Mechanisms and Possible Solutions

At least five factors contribute to suffocation among avalanche victims [Armstrong, Williams 1992]. First, as the victim slides along with the snow, gasping for breath may fill the nose and mouth with snow, partially blocking air flow. Second, when the snow stops moving it instantly solidifies, immobilizing the victim so that he cannot clear an air space. A possible solution to the first and second problems would be to have the mouthpiece of an instantly-activated breathing device located near the mouth whenever the traveller is in risky terrain. Breathing through the mouthpiece would avoid filling the mouth with snow, and its convenient location would allow instant access.

Third, avalanches compact snow, reducing its air content, compressing the lattice of snow crystals, and increasing the snow's air-flow resistance. With an average of about 12 breaths per minute divided about equally into inhalation and exhalation, inhalation duration usually is approximately 2.5 seconds. Volume is approximately 500 ml per inhalation (Guyton 1991). A buried person's open mouth and nostrils present an area of approximately 15 cm² to the adjacent snow. Thus, a buried person must move approximately 13 ml of air/cm²/sec with each inhalation and exhalation. However, respiration is carried out at low pressures. Pressures in lung alveoli normally range from -1 g/cm² in inhalation to +1 g/cm² in exhalation (Guyton 1991), which is quite adequate to move air in standard atmosphere. However, moving air through a resisting lattice of snow crystals at a rate of 13 ml/cm²/sec requires pressures well beyond the physiologic capacity of chest wall and respiratory musculature. A possible solution would be to present a larger surface for air exchange with the snow.

Fourth, even if the victim can breath a little, each exhalation deposits oxygen-depleted air into the snow in front of the nose and mouth, only to be drawn back in with the next inhalation. A possible solution would be to inhale air from one area and exhale it into another. Fifth, water vapor in exhaled air may freeze, forming an ice mask in front of the face and further increasing flow resistance. Possible solutions would be to cool exhaled air somewhat before it enters the snow, thereby decreasing its water content, and also to spread water deposition widely by passing exhaled air into snow across a large surface.

Emergency Breathing Devices

Various emergency breathing devices for other applications filter pollutants from incoming air, supply fresh oxygen from chemical or compressed-gas sources, or permit rebreathing of expired air, sometimes after removal of carbon dioxide. Some use small motorized blowers to move polluted air through filters. But such heavy, mechanized devices are impractical for wilderness enthusiasts, who carry all of their equipment on their backs. Large compressed-gas cylinders are too heavy to be carried by skiers, and small ones may be emptied before rescue occurs. Moreover, some 50-95 percent of snow's volume is air, pollutant-free and needing no filtering. Devices with self-contained oxygen sources obviously do not utilize that air in the snow. The weight and mechanical complexity of these breathing devices, which may be excellent for firefighters or miners, make them impractical for wilderness skiers. Neither are problems of weight, size, and mechanical complexity solved by chemically-generated oxygen supplies. The self-contained chemical oxygen supply is
heavy, and the considerable heat produced in these exothermic reactions might burn the buried, immobile avalanche victim.

Most emergency breathing devices were designed for firefighters, miners, aviators, and other non-skiers. However, United States Patent 4,365,628 (issued to Hodel, 1982), described a Scuba-like breathing device for avalanche victims. Skiers would wear this device, with its compressed-gas supply, carbon-dioxide scrubber, and spring-loaded valves, on a vest. Not utilizing air contained in snow, it was too heavy and complex to find wide use.

A useful breathing device for backcountry mountainers must, first, be very light. Second, it must be easy to don and activate. Avalanche breathing devices must be instantly usable. Skiers frequently are swept away without warning. Because most victims are immobilized by packed snow once sliding ends, the victim must be using the device before the snow stops moving, often in a very few seconds. Even seemingly simple procedures for activating previous devices may be too complex for the panicked avalanche victim suddenly being swept along under moving snow. The victim, perhaps still attached to backpack, skis, and ski-poles, could follow only the very simplest of activating procedures.

Third, previous emergency breathing devices depended on air supplied from the device itself, or on filtered atmospheric air. Virtually limitless quantities of clean air can slowly flow through snow itself, and using that air could reduce complexity, risk of mechanical failure, and weight in a breathing device.

Additional useful characteristics would be easy assembly from widely-available and inexpensive materials, sufficient simplicity to allow sales in sporting-goods and outdoor-gear shops, and a modest price acceptable to outdoor sportspersons, ski patrol groups, and other probable users.

This paper describes a device with those characteristics, and a field test of it.

METHOD

Summary of the Device

This emergency breathing device is continuously worn in the jacket of the backcountry traveller. The device consists of (a) an inhalation membrane which permits passage of air from surrounding snow into an inhalation chamber; (b) an exhalation membrane which permits passage of air from an exhalation chamber into surrounding snow; (c) a mouthpiece for breathing; and (d) a system of tubes and one-way valves which convey exhaled air from the mouthpiece to the exhalation chamber, and inhaled air from the inhalation chamber to the mouthpiece, while keeping inhaled and exhaled air substantially separated.

If a snow slide occurs the traveller activates the device simply by breathing through the mouthpiece.

Description of the Device

Figure 1 is a schematic drawing of the breathing device, built into a vest or parka (7). The user can move to his mouth a mouthpiece (10), normally located near the mouth in the garment's collar. A mouthpiece connecting-tube (12) joins the mouthpiece (10) to "Y" tubing-connector (14). One arm of "Y" tubing-connector (14) joins to the inhalation one-way valve (16), which permits flow only toward mouthpiece (10). An inhalation connecting-tube (18) joins...
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inhalation one-way valve (16) to inhalation chamber (20). Exhalation one-way valve (22), which permits air flow only away from mouthpiece (10), mates to the remaining arm of “Y” tubing-connector (14). An exhalation connecting-tube (24) connects exhalation one-way valve (22) to exhalation chamber (26), which mostly is located on the user’s back. The mouthpiece, “Y” tubing-connector, one-way valves, and tubes are like those commonly used in respiratory care equipment, made of, for example, ethyl vinyl acetate, or EVA, and have internal diameters of 22 mm. The parts and joints are reinforced with adhesive fabric tape, which also secures all joints in the system.

Several layers of fine nylon mesh, easily permeable to air but not to snow, comprise the membranes covering the inhalation and exhalation chambers. The membranes present large air-exchanging surfaces to the surrounding snow. The flat, shallow inhalation chamber is 1.5 - 2.0 cm in depth; its snow-facing surface is approximately 665 cm². The exhalation chamber on the back of the garment is of similar construction; its outer surface is approximately 220 cm². A tough protective mesh covers the finer membranes, defending them from tears.

Operation of the Device
The backcountry traveller wears an outer garment incorporating the breathing device. At the first sign of an approaching avalanche, or even while being swept along in one, the traveller turns his head, bites onto the mouthpiece, and breathes through it. This prevents the mouth from filling with snow. During inspiration, inhalation one-way valve (16) opens and exhalation one-way valve (22) closes. Thus, the victim draws inspired air from the snow in front of the garment into the inhalation chamber, through the tubing, and into the mouth. During expiration, inhalation one-way valve (16) closes and exhalation one-way valve (22) opens. Then, the victim blows expired air from the mouthpiece, through the tubing, into the exhalation chamber, and out into the snow behind the victim. This substantially prevents mixing of exhaled and inhaled air.

To avoid rebreathing of expired air, the device separates the course of incoming and outgoing air between the two one-way valves and the two chambers. The “dead space” between the valves and the mouthpiece does permit some mixing of inspired and expired air, but a small dead-space volume minimizes that mixing.

Field Test
I field-tested a prototype of this device at an altitude of about 11,000 feet at Loveland Pass, Colorado. A surface crew fully buried me beneath 0.8 - 0.9 m of compacted spring snow. I had an intercom for communication with the crew. Wearing the device, I easily breathed for about 40 minutes, and could have continued breathing longer. However, I asked to be dug out at that time because of the considerable physical and psychological discomfort of chilling and immobilization beneath the snow. No ice mask formed at the exhalation membrane, although moisture droplets condensed (but did not freeze) along the exhalation tubing; they probably resulted from cooling as the exhaled air traversed the tubing.

DISCUSSION
The described device, called the AvaLung-Avalanche Breather, is very light and incorporates conveniently into backcountry vests or parkas. Its activation is extremely simple and rapid, needing only a shift of the head to bite onto the mouthpiece. Therefore, the device can be used by a severely panicked person, even while being swept along in an avalanche. It needs no pressure-reduction valves, compressed air tanks, chemical oxygen supplies, or other material which backcountry skiers would find difficult to carry or contrary to wilderness esthetics. Driven by normal respiration, the device extracts air from snow, assuring a virtually endless air supply. It minimizes mixing of inhaled and exhaled air. Its simplicity, and the ready availability of its parts, makes it easy and inexpensive to manufacture, distribute, and operate, increasing the likelihood of its use.

The field-test closely simulated an actual avalanche burial at a depth in which about half of buried victims die. Considering only time, about 70 percent of avalanche victims reportedly are dead at just 35 minutes; I was fully awake and breathing easily at 40 minutes.

The device is protected by US Patent No. 5490501 issued February 13, 1996 to T.J. Crowley, who intends to license the device to a commercial manufacturer.

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REFERENCES