HIGH EXPLOSIVES AND ARTILLERY IN AVALANCHE CONTROL

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Introduction

Avalanche technology in North America depends heavily on explosives for artificial release and stability testing. Approximately 10^5 explosive charges are detonated annually to protect ski areas, roads, and mines. The explosives are hand-thrown from ridges, trams, or helicopters, or launched by military or civilian artillery systems. For safety and convenience, the vast majority of avalanche explosives have high detonation speeds (5000 to 8000 m/s). Occasionally, low percentage dynamite (3000 to 4000 m/s) is used in cornice blasting. Slower-speed explosives such as black powders and permissibles (2000 m/s or less) could conceivably be more efficient through a pushing action on the snow. However, operational problems in avalanche work (exposure to severe weather) require the explosive to be highly insensitive and waterproof--properties that are more inherent to high-speed compounds such as TNT, pentolite, and gelatin. Thus, even if it were possible to demonstrate the efficiency of slow-speed explosives, it is highly unlikely that they would be used by avalanche workers because of other undesirable properties.[1]

A description of the properties of commercially available explosives is summarized by Dick (1968). The two types of explosives that are presently most popular in avalanche work are "cast primers" and "blasting gelatin". These explosives are of comparable speeds. Blasting gelatin is considerably cheaper, but has a shorter storage life, causes headaches, and is not as conveniently armed as the cast primer which can be manufactured with a cap sensitive core as shown in Fig. 1. Also, blasting gelatin is not normally packaged with enough support to be dropped from trams or helicopters. In terms of shock sensitivity, cast primers may have a small advantage since the bulk charge of the blasting gelatin is usually sensitive to No. 1-sized cap or less, whereas in a properly designed cast primer, a relatively insensitive explosive like TNT can be cast around a core of No. 6 cap

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[1]Recent work by H. Gubler at the Swiss Federal Institute for Snow and Avalanche Research, Davos, indicates that the distance of stress wave propagation in snow increases with the detonation speed of the explosive. Thus, it is unlikely that slow-speed explosives would have higher efficiencies for snow slab blasting.

sensitive material in such a way to protect the more sensitive core. For these reasons, cast primers are the more popular of the two systems, despite higher costs. At the Snowbird Ski Area, over 27,000 cast primers have been used since 1971 (Anderson et al., Table 1, page 13). Snowbird has had very good experience with 50/50 Pentolite cast primers (No. 3 cap sensitivity) that do not require booster inserts in the cap-well.[1]

Because of the possibility of static discharge when working on ridge crests or during blowing snow conditions, electric detonators (electric blasting caps) are not recommended, and it is accepted practice to detonate using the components: pull-wire fuse igniter, safety fuse, and non-electric blasting cap. With a properly designed cap-well, it is possible to reliably detonate a cast primer with a No. 6 blasting cap. Data are not available, but from interviews with the users of the system diagrammed in Fig. 1, it appears that the dud ratio (number of misfires) is below 0.1%. The few misfires that are experienced each season are due mostly to improper assembly of cap and fuse.

The general consensus of opinion is that 1 kg of high explosive is adequate for a hand-charge, and avalanche blasters have maintained excellent public safety using this amount. The 1 kg standard charge is more an outgrowth of practical considerations and tradition, rather than a number derived from scientific studies. For example, a typical load of 10 hand-charges, 1 kg each, is manageable in a ski-patrol pack. Occasionally, ½ kg charges are used for thin, new snow instability. Other times, when deep slab instability is suspected, the charge will be increased to 2 kg or more.

Mammoth Mountain Accidents

Two accidents at the Mammoth Mountain Ski Area, California stimulated a detailed review of avalanche blasting procedures (Austin et al., 1974). The main conclusion of the review and the unpublished communications of avalanche workers throughout North America was that the present version of the pull-wire fuse igniter is unreliable, and that it was quite possible, in light of the procedures used at Mammoth, that

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[1] Units consist of: Trojan Brand Cast 2 pound (1 kg) primers with cap-well ½ inch (1 cm) from centre hole; Orange Sword Brand safety fuse, manufactured by Ensign Bickford; Dupont or Atlast No. 6 non-electric blasting caps; Martin and Shaft pull-wire fuse igniters; and black friction tape. (Information based on personal communications with Kent Hoopingarner, Mountain Manager, Snowbird Corp.)

pull-wire igniters fired prematurely to cause both tragedies. In a series of simple experiments, Austin et al. (1974) demonstrated that insertion of the safety fuse may push the ignition compound of the pull-wire igniter close to the pyrotechnic cup so that the slightest movement will set off ignition. They were quite explicit in their first recommendation:

> "The fuse igniter is a very serious safety hazard. Its safe use requires the wire to be pulled as soon as the fuse is installed into the igniter."

Experience from other control teams will support the recommendation that the blaster must be in position and ready to toss the charge before attaching the pull-wire igniter. Considering documentation of problems with the igniter, control teams may wish to reconsider whether the practice of double-fusing actually contributes to a safer operation. Double fusing was routinely practiced at Mammoth at the time of the casualties.

One should not discard the possibility that the Mammoth accidents were caused by some other faulty blasting supply (fast fuse, sensitive cap). The Mammoth teams were using high-strength caps and a main explosive mixture called Minol (TNT, ammonium nitrate, aluminum). A high-strength cap is considered an unnecessary hazard since the explosive mixture in a cap is an order of magnitude more sensitive than the bulk explosive. The aluminized explosive charge for avalanche work was an innovation of the local explosive manufacturer near Mammoth, and not a mixture commonly used at other areas. Austin et al. (1974) report that quality control of the cap holes in the aluminized primers used at Mammoth was poor, and that it was necessary to jam and twist the caps to force them into holes. In any case, aluminized explosives are not recommended for avalanche work.

The study by Austin et al. (1974) also implied that the accidents could have been caused by discharge of electric charge from the blaster's body and clothing, through the powder train of the safety fuse, through the non-electric detonating cap, and into the aluminized primer. Unfortunately, their experiments were unconvincing since they replaced safety fuse with an equivalent electrical resistor when they could not reproduce detonation with actual safety fuse. They further recommended that safety fuse incorporate a staple to shunt static from powder core to cap shell, but they did not test the effectiveness of available shunt assemblies. It is curious that the shunt safeguard, presently on the market, comes as part of a factory assembly with a metallic seal on

the opposite end of the safety fuse from the cap. It would seem that the metallic seal is an excellent conductor of charge into the powder core and defeats the purpose of the protective shunt. To add confusion, the major manufacturer of safety fuse in Canada strongly recommends the shunt, but the major manufacturer in the United States decided against marketing the assembly and seems less concerned about the static hazard. Of course, blasting should not be conducted in the mountains when there are obvious signs of electrical activity.

Did a short fuse contribute to the Mammoth accidents? This is not known, but it is interesting that, after the Mammoth accidents, fuse lengths increased at many ski areas. Most explosive regulations insist on at least a two-minute or 1 m fuse length. Many avalanche workers insist from their experience that a shorter length is adequate, and argue that overall safety increases if the blaster does not have to wait for detonation, exposed to wind, snow, and cold temperatures. However, avalanche workers are reminded that there are numerous documented cases of accidents due to short fuse (Department of Energy, Mines and Resources, 1971).

Hand-Charge Improvements

Irrespective of the Mammoth accidents, it is clear that the present version of the pull-wire igniter is not foolproof. Working from a design provided by the U.S. Forest Service, Martin and Shaft Co. developed a new pull-wire igniter with a transparent tube and a safety stop. The transparent tube allows the blaster to see if the fuse is seated properly and if ignition has occurred. Unfortunately, the transparent igniter has a design defect--sparks are not completely sealed. Because of the defect, plus its cost and complexity, the new pull-wire igniter has not gained popularity. The transparent model costs about six times as much as the standard cardboard model. Martin and Shaft Co. claims that the combined market of all avalanche blasting could not significantly reduce the cost difference. Although their standard cardboard model is quite inexpensive (approximately $0.10 each), it may be possible to devise a reusable fuse lighter that would be competitive with the dispensible cardboard model, even considering much higher initial costs and maintenance.

Other important problems are suppliability and quality control of present explosives. Only the largest users (over 1000 units/season) are in a position to influence the market standards in order to obtain explosive mixtures and packaging suited to the special conditions of avalanche blasting. In terms of assuring future supplies and quality, it would be advantageous if all avalanche workers could agree

to a set of specifications for a hand-charge assembly. As a start, the system diagrammed in Fig. 1 has much in its favour. It is the simplest, the most tested so far, and is presently the most popular in terms of units per season. The Snowbird Ski Corporation has suggested that one major improvement would be to paint the primers red to facilitate location of misfires.

A standard hand-charge would have the added and important advantage of permitting a detailed set of safety instruction to be drawn up. On this issue, the critique of avalanche blasting by Austin and others (1974) was very clear:

> "Specific detailed written procedures are mandatory if a safe operation is to be achieved. These must be specific, not broad platitudes such as 'the operation shall be conducted in a safe manner'."

It is difficult to prepare specific safety guidelines without referring to a specific hand-charge system.

Military Artillery

Surplus weapons used for artillery control are the 75 mm mountain Howitzer, the 75 mm recoilless rifle, and the 105 mm recoilless rifle. Non-surplus weapons are the 105 mm Howitzer and the 106 mm recoilless rifle. The explosive content of ammunition in these weapons varies from about 0.7 kg to 3.5 kg of high speed explosive. About 1.5×10^5 rounds have been fired in avalanche work in Canada and the USA since 1950. Presently, each year about 10^4 rounds are fired in the USA, and 10^3 rounds in Canada (at Rogers Pass, B.C. and Granduc, B.C.).

Artillery can be fired at remote slopes during storm conditions. With experience, it is possible to time artillery control to release small avalanches which cause minimum damage to the environment. The disadvantages of artillery are: shrapnel is scattered over the mountain; over 1% of the artillery rounds fail to detonate on impact and remain as potential threats to hikers and climbers; the noise factor is objectionable; rounds are occasionally mis-sighted or fall short; and it is a problem (if not impossible) for civilians to acquire parts and ammunition. Moreover, there are increasing reports of ear injury due to artillery concussion, in spite of using ear protectors.[1] Certain fuse

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[1]Protective helmets that could prevent ear injuries have been introduced recently at Snowbird, Utah (Pers. comm., Dean Anderson, Snowbird).

components are not reliably detonated in deep snow. The base-detonating fuse, for example, has a 10% chance of inactivity. The avalanche control team at Granduc Mines report that the 75 mm projectile penetrates too deeply for their snow conditions, and that they do better with their "Avalauncher" projectiles which explode closer to the surface. To compensate, avalanche workers will often fire against rock faces and thus cause additional environmental damage. One fatality occurred due to the backblast of the 75 mm recoilless rifle. A thirty-five year supply of surplus rounds remain in the U.S. (dispatched from Toole, Utah).

Substitutes for Military Artillery

A compressed gas launcher ("Avalauncher") was marketed about 1965 without adequate safety fuse. There were at least seven casualties (including three fatalities) using the early model. The present fuse seems to be greatly improved, although it does not contain the spin-actuated safety mechanism of the military fuse. The range and accuracy of the "Avalauncher" are also inferior to those of military weapons. However, its projectile costs much less than a military round, and does far less environmental damage. Thus, the "Avalauncher" is a practical alternative for many operations.

A large number of avalanche targets are outside the range and accuracy of the "Avalauncher", and require the capability of a military piece or its equivalent. In response to a U.S. Forest Service call for proposals, several corporations in the U.S. submitted designs for an alternative to military artillery. The Bermite Corporation (California) developed a rocket system (originally intended for the U.S. Marine Corps) which appeared to have some promise for avalanche work since the projectile was launched with minimum backblast by a shot-gun capsule. The rocket motor fires after the projectile leaves the launch stand. The initial cost of the launch stand would be much less than the cost of an artillery piece; at least an order of magnitude less. Projectiles would also be less by a significant factor. So far, Bermite has not solved accuracy and fuse problems, and tests at Snowbird were quite discouraging in terms of accuracy and number of duds.

Honeywell Corporation (Minnesota) has a preliminary design of a 57 mm recoilless rifle system, almost identical to the military rifle, but capable of delivering a payload of 1 kg. The increased payload is achieved by substituting explosive for shrapnel. Limiting factors of this system would be the initial cost of the rifle, cost per round, and the obnoxious backblast characteristic of all recoilless systems. Also, it is doubtful that sufficient range could be built into

a 57 mm recoilless system to attract some of the largest users of military artillery. The range of the military 57 mm recoilless is 4508 metres. However, avalanche workers find that recoilless rifles give an unacceptable number of duds when used at much over ½ maximum range. The weight of the military 57 mm round (HE-M306A1) is 1.25 kg with a payload of 0.45 kg of composition B. According to Honeywell, the payload could be increased to about 0.85 kg of composition B, which would be equivalent in energy to about 1 kg of TNT.

If Honeywell is correct in believing it is technologically possible to substitute payload for shrapnel in conventional military ammunition, then another solution would be to manufacture special ammunition for the 75 mm Howitzer which is probably the most versatile piece presently available for avalanche work. The 75 mm Howitzer has enough range (8800 m) to meet the requirements of almost all avalanche targets. It is less obnoxious than a recoilless with respect to the gunner's ears, its shells can be recycled, and its breach assembly outlives the recoilless.

In retrospect, it is possible to devise other combinations of ammunition and artillery based on military design, but manufacture of these designs specifically for avalanche control seems not quite within economic reach. For the immediate future, it appears that avalanche control will continue to be based on a "day-to-day" existence in terms of locating suitable explosives and artillery.

References

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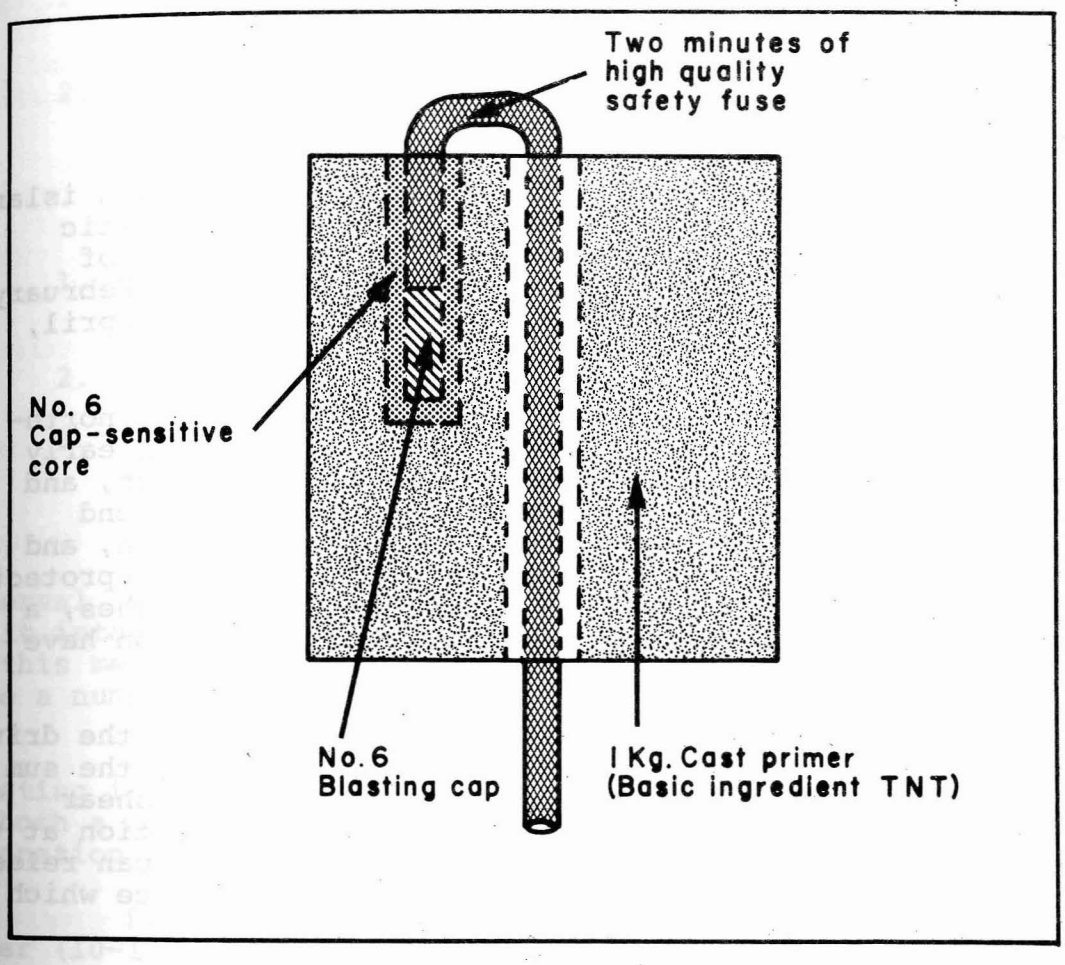

FIGURE 1 HAND-CHARGE ASSEMBLY RECOMMENDED FOR AVALANCHE CONTROL