Artificial release of avalanches using the remote controlled Wyssen Avalanche Tower.

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Abstract: A new remote controlled system to release avalanches with oversnow detonations using appropriate explosives is presented. The system consists of a simple tower that supports a finger type docking system for a compact magazine that includes 12 charges of up to 5kg, the control electronics and a transceiver system. For recharging, maintenance and storage during summer the complete module is moved by helicopter to a base station of the operation.

Keywords: Artificial avalanche release, explosives, remote control

1. Introduction

The method of artificial avalanche release is used for a long time to secure ski areas, roads, railway lines and other installations from avalanches. To reduce the risk for the avalanche control team, optimize charge position, speed up operation and to enable control work to be done in time and independent of the actual weather conditions, different types of remote controlled systems have been developed and improved during the last decades. Each of these systems has its advantages and disadvantages: shells penetrate into the snow cover before detonation and therefore often have a very small effective range, cable way systems are rime- and wind sensitive, system accessibility often depends on weather and operation of long systems is very time consuming. Gas exploders (as originally proposed and tested by Ed Lachapelle) need large and expensive installations and they have a very heavy local effect on the snow cover development, preventing the formation of continuous weak layers, as the most important condition for large area fracture propagation, necessary to unload large release zones. Short range charge deploying systems often work only with charges too small for significant effective ranges for detonations within the snow cover. Also the effective range depends very much on the actual situation and is hard to estimate with respect to a stability test. Suspended charges have shown to be very effective for dry snow conditions even if successive detonations are initiated at the same position. The goal of the system developed by Wyssen and AlpuG is to overcome some of these limitations by building a remotely controllable compact system that allows explosions of large charges at remote locations above the snow cover.

2. Basic requirements

From the theory of slab avalanche formation in a dry snow cover as well as from practical experience we know that detonation above the snow cover lead to best results with respect to residual risk for unforeseen avalanches. The explosive used should detonate at a medium to high detonation speed and produce a large gas volume at a high working factor. The experimental studies show that these type of charges and charge positions relative to the

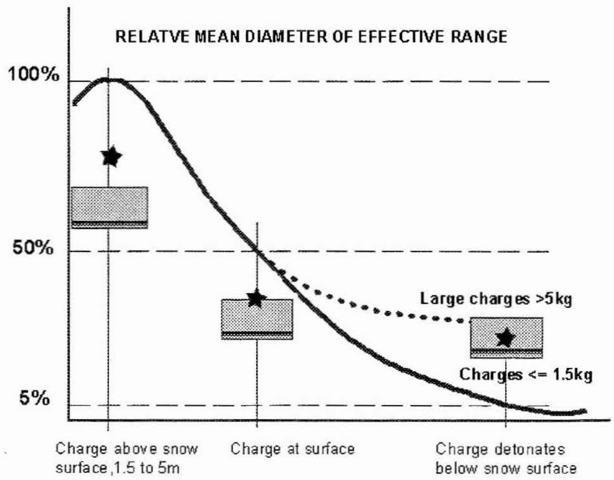

Figure1: Effective range of detonations at different positions relative to the snow surface.

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snow surface produce the largest effective ranges (Gubler, 1977). Figure 1 shows relative effective ranges for charges at different positions to the snow surface. Especially for charges below 2 kg this effect is very significant. To effectively test and secure an avalanche release zone, we know that in case a major avalanche cannot be triggered, the whole potential release zone has to be tested with a minimum additional stress. The reason for this is that at modest mean natural stability, the locations of weak spots, where additional stresses may initialize initial fractures and eventually brittle shear fracture propagation, are not known in advance. We also know that slow loading rates at high amplitudes may produce local cratering and small slides but are inefficient for wide area loading whereas high frequency N-shaped pressure waves produced by explosive charges are significantly more effective at distances of larger than 10m from the charge position. If the charges are suspended by a cord, their height can easily be adjusted. At this point it is important to mention that only those locations of the snow cover within the potential effective range are tested/loaded that can be seen from the position of the charge.

The method of artificial release of avalanches by explosives has manifold purposes:

- To unload potential release zones to a major extent.
- To avoid the formation of very large avalanches that may cause severe damages in the extreme run-out zones.
- To clear potential release zones of spring type glide snow or wet snow avalanches during cold periods respectively immediately after snow accumulation.
- To test stability as a tool to effectively estimate actual danger.

To meet these basic requirements, avalanche control systems have to allow for remotely controlled detonations of highly effective charges. From an operational point of view, these systems should be reliable, compact, easy to reload and maintain as well as easy to install in an alpine environment. For extended alpine snow bowls, the large effective range and the adjustable height above ground of the detonation are important criteria.

3. Wyssen avalanche tower

The Wyssen Avalanche Tower fulfills these requirements almost ideally.

3.1. How the System Works

The release of an explosive charge is initialized by coded radio command, sent from the avalanche control headquarters. The command is received by the remote avalanche control tower which will subsequently drop an explosive charge from a magazine.

The magazine contains twelve explosive charges of up to five kilograms (11 lb.) each, which are activated sequentially. The explosive charge is ignited by pull-action resulting from the free fall of the charge. Two ignition cords are provided. These will ignite the detonator cap that will light the explosive charge.

For reloading the explosives, the entire magazine is

Figure 2: Wyssen Avalanche Tower installed in the big bowl of the Gonda avalanche.

removed by helicopter and transported to an avalanche control building. Thanks to a guiding fork, helicopters can easily put the magazines in place on top of the remote towers. Placement and removal of the magazines by helicopter may be done by the pilot alone without an assistant.

Advantages:

- Explosion takes place above the snow, which is known to produce the most effective explosive action.
- Weather independence: Each remote explosives tower can be deployed by coded radio signal at any time.
- Remote control allows fast interaction by the avalanche control headquarters. Avalanche release can be triggered with powerful charges without mobilization delay.
- Avalanche control staff remains outside danger area.
- Effective avalanche release with minimum number personnel results in cost savings.
- Relatively low investment and installation costs.
- Secure magazine locations: on top of remote towers during winter, removed and stored in a safe place off-season.
- Minimal intervention in the natural environment.
- Absence of duds, shrapnel or other debris.
- Energy supply through solar cells, with no external and susceptible supply lines needed.
- System integration with snow and avalanche measurements, as well as routine information gathering can reduce overall helicopter flight cost.

3.2. Components

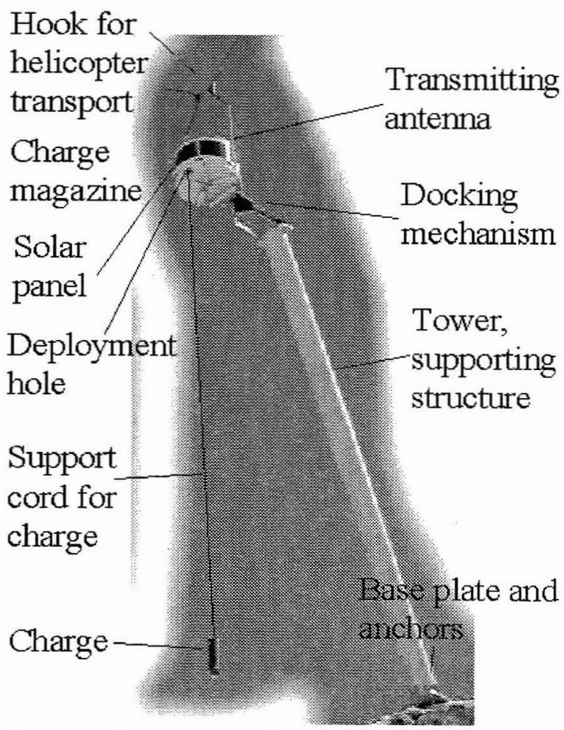

Figure 3: Components of the avalanche tower.

The Wyssen Avalanche Tower consists of two parts, the removable charge magazine and the supporting tower.

3.2.1. Charge Magazine

The magazine includes the charges, the mechanical system to deploy charges, the electronic control system, a battery, solar panels on its enclosure and the radio- or GSM transceiver. It is designed to be removed and placed on the docking system of the tower by a helicopter equipped with a special hook. These operations do not require any onsite assistance.

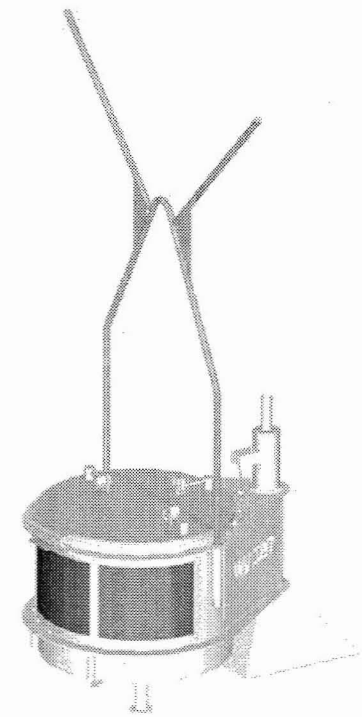

Figure 4: Charge magazine

The weight of a fully charged magazine amounts to appr. 650kg (1'300lbs). Placing the magazine on the docking mechanism also adjusts it's direction automatically. The magazine activates its electronic control only after it is correctly docked in the supporting structure. The charge container is made from 5mm steel or optionally of a bullet proof steel composite and is safely secured by three independent locks. 12 charges of from 2 to 5kg (4.5 – 11lbs) each can be placed in the container. For recharging, maintenance and storage during the summer, the magazine is flown to the operations base station.

After reloading, an extended, manually initiated self- test has to be performed and visually checked by pressing control buttons in the open magazine. The specially prepared explosive charges are placed in vertical tubes in the magazine. The tubes are mounted to a turn table that moves the charges over a hole in the bottom plate of the cylindrical magazine. In the home position of the turntable, the bottom hole is closed by a piston. At initialization, this piston moves at first downward to remove rime in front of the hole and then moves upward to its operating position. If the piston has reached its operating position, the turntable starts to spin until the first loaded tube is detected close to the hole.

Each step of the process is checked twice by independent sensors, and is indicated in the application window of the control computer at the base station. The firing command includes randomly varying codes. At least two independent errors have to occur simultaneously to produce a system failure. If an error is detected, the system returns to its home position. The process can be stopped anytime by a special command. If every detail is correct the turn table continues to move until the charge reaches a position over the hole in the bottom plate. The charge falls through the bottom hole, attached with a cord of appropriate length to the magazine. As the charge falls two pull igniters are activated and fire two slow fuses attached to the detonators within the charge. The detonation is detected by a geophone in the magazine and also is displayed on the control screen. After detonation the remaining cord is detached from the magazine and the system returns to its home position.

Attached to the tower, the system performs continuous self testing, additional extended testing can be activated by sending the appropriate commands from the control computer to the remote system. The results of the automatic self tests are downloaded and displayed by the control computer at regular intervals.

The Wyssen system complies with standard safety requirements and has been approved by the Swiss Federal Police responsible for the handling of explosives and the Austrian TÜV.

The electronics of the control system is based on loggers of Campbell Scientific, the same loggers that are used in the Swiss avalanche warning network and in alarm systems. These products are readily available and well known for their high reliability. This concept allows a simple integration of Wyssen Avalanche Towers in existing avalanche warning systems based on CSI remote stations. Completely integrated systems may be easily designed including remote snow and weather stations, snow drift measurements, snow profilers, geophone sites and alarm systems. Measurements from these systems build the data base for the application of decision support tools (Gubler, 1998,2000).

3.2.2 Tower

The carrier is a simple tower (or a cantilever extending from a rock wall) designed to with-stand snow creep, snow settlement, small rock falls, heavy riming, wind gusts etc. Its design depends on the location. Depending on the ground conditions, the towers are anchored with 4 to 5 rock anchors or micro-piles. The tower supports a special finger-type docking mechanism for the magazine. There is no ladder attached, therefore it is almost impossible to reach the magazine.

3.2.3 Hooking device for Helicopter

This device allows the helicopter pilot to pick up the magazine from the tower without any on-site assistance. For placing the magazine on the tower this device is not needed.

3.2.4 Explosive Charge

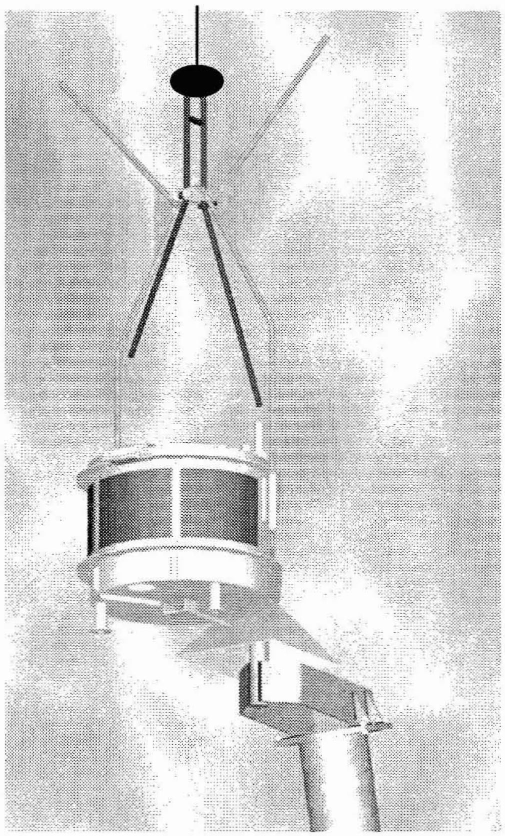

Figure 5: Hooking device for helicopter transport

The explosive charge consists of a cardboard tube surrounding the charge with the double pull-ignitor fuse system, a plastic container for the charge assembly and the string that supports the charge. The size of the explosive can be varied between 2 – 5 kg (4.5 – 11 lbs). The user prepares the charges at the base operation. For highest efficiency, select an explosive that is able to withstand very low temperatures (for example to –30°C/20°F). It should have a medium to high detonation speed and a high work factor.

The charge container and special parts are supplied by Wyssen Seilbahnen AG; the supplier for the explosive can be chosen by user.
After the charge has fallen through the bottom hole of the magazine, two pull igniters are activated and fire two slow fuses attached to the detonators within the explosive. The charge remains hanging on the cord until detonation. After detonation the remaining cord is detached from the magazine and the system returns to its home position.

3.2.5 Control Station and operation software

The control station consists of the control PC with installed operation software, the radio transceiver with antenna and a phone modem for external connecting possibilities. The operation Software runs on Window 98, second edition, W2k, WXP. In the picture below the main menu is shown.

4. Installed systems

After two winters of prototype testing, 10 Wyssen Avalanche Towers are operational in various locations in Switzerland since autumn of 2000. Three towers protect roads, all others installations are at ski resorts for the protection of ski runs, lift installations and buildings.

4.1 Highway and Railroad Protection at Lavin, Eastern Switzerland

The road authorities decided to install three Wyssen Avalanche Towers to protect the main road in the Engadin valley that connects a major tourist area to the rest of Switzerland. The fracture zone is located just below the mountain ridge of Piz Chapisun at almost 3'000 meters above sea level. In February 1999 the Gonda avalanche buried cars on the road. A long period with several storms hindered control teams to shoot the avalanche from the helicopter. Once more the 12cm mortar in use showed the low reliability of even large projectiles because of their small effective range. The upper bowl of the Gonda avalanche extending more than 400m can now be controlled by the three Avalanche Towers installed along the ridge.

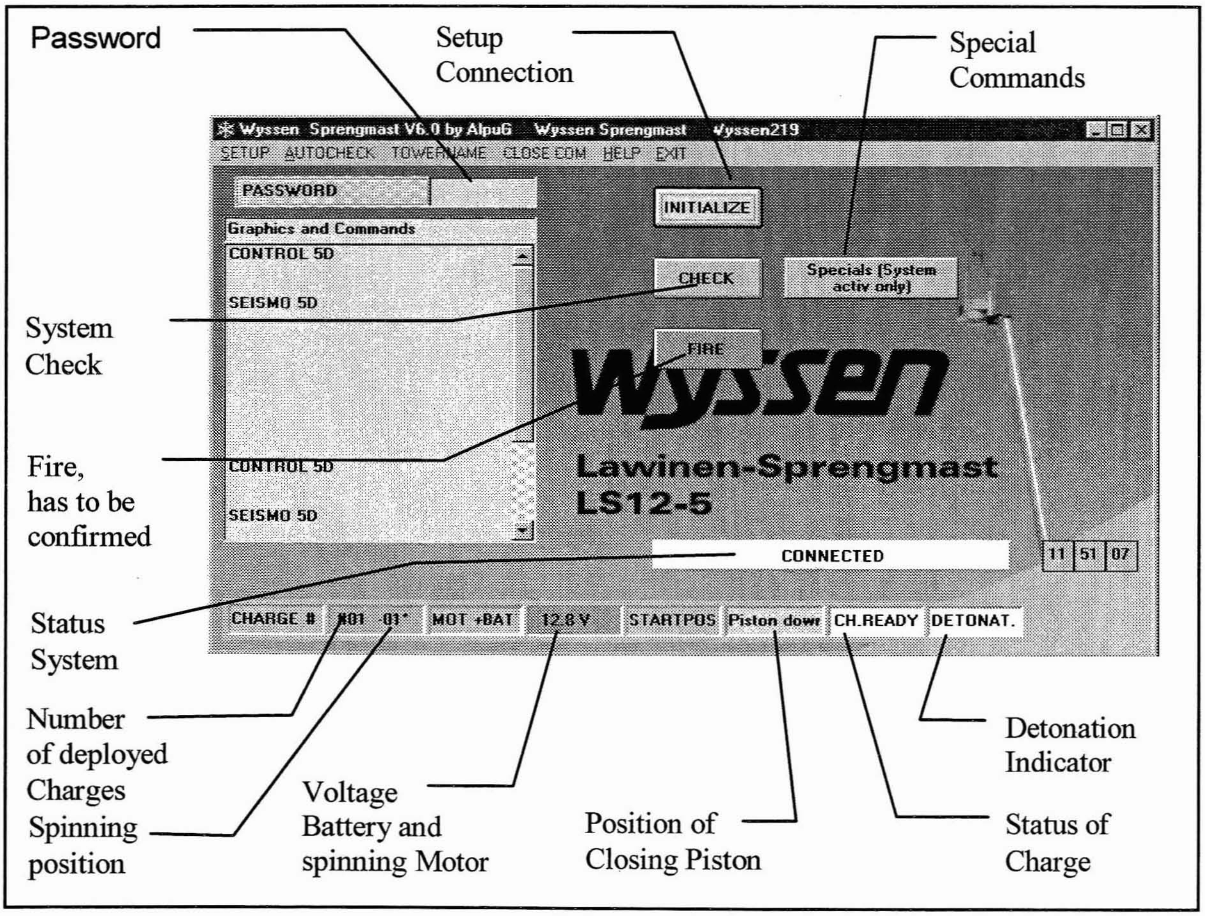

Figure 6: Control window for remote control of the avalanche tower

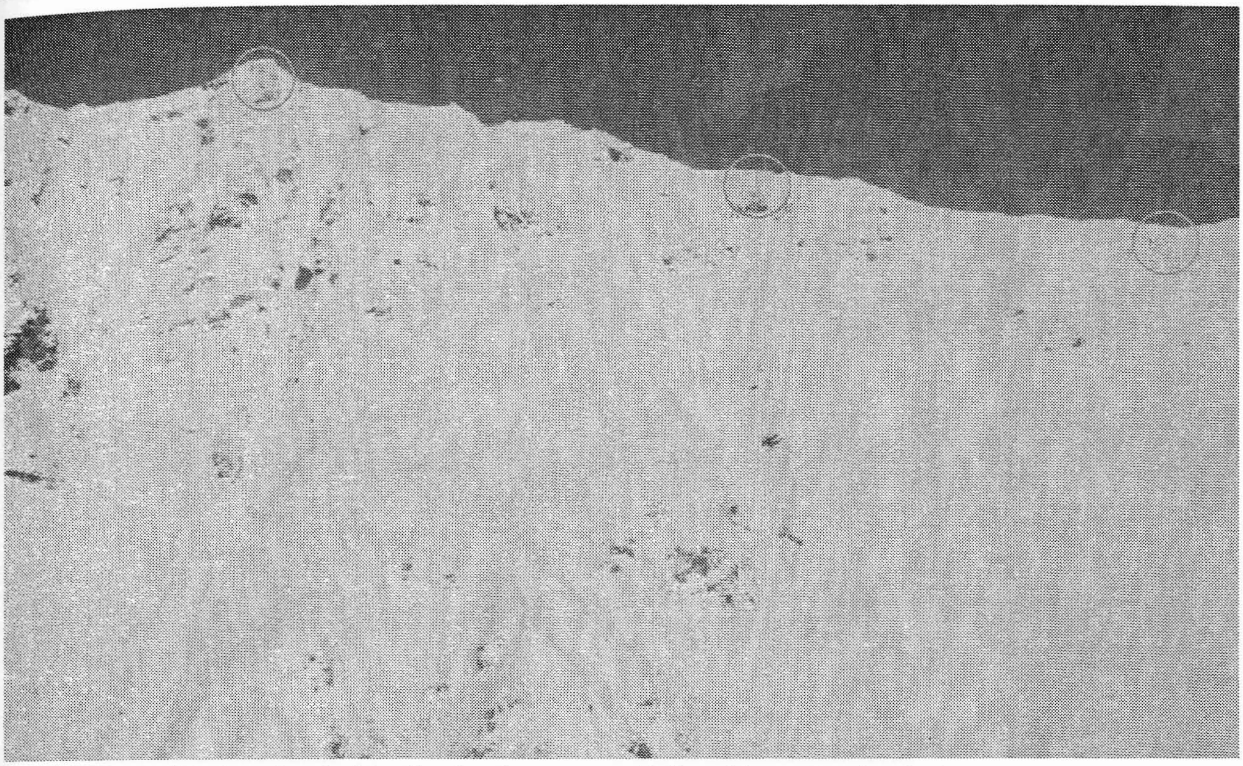

Figure 7: Part of the huge bowl of the Gonda release zone with 3 positions of avalanche towers.

The 3 towers proved to be very efficient to unload the bowl even after minor snowfalls.

4.2. Protection of traverse ski path

The Avalanche Tower installed at the ski resort of Schilthorn/BE fulfils a rather exceptional function: it is used to significantly reduce snow accumulation in a potential avalanche starting zone above an important ski path. The purpose is to avoid problems with wet snow spring avalanches that endanger the ski traverse by reducing the snow cover in the release zone and by avoiding the build up of avalanche deposits above the path by routine blasting during winter.

Hand charges proved to be inefficient. The reason was a slightly convex release zone feeding a narrowing path. The small effective range of hand charges and the impossibility to fire in time often released too small avalanches that stopped above the path. Big deposits resulted during the winter right above the ski path and could suddenly slide off during warm up in the afternoon of sunny spring days. As a consequence the ski path had to be closed for extended periods of time splitting the ski area in two sections. According to Ueli Frei, skipatrol director of Schilthornbahn Corp., the result of the new Wyssen Avalanche Tower installation is just great. Due to the very large effective range of the 5kg air blast and improved timing, it is possible to release avalanches big enough to pass the ski run even after minor snowfalls.

5. Conclusions

Remote controlled systems for artificial avalanche release with a large effective range are well suited to decrease residual risk for avalanche accidents on roads as well as in ski areas. The system described has proven its reliability: no duds, easy to handle, compact design, removable off-season, easy to install and maintain.

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