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**Field testing of Barry B-Net Systems used in
Alpine Ski Race Course Protection – 100 km/hr**

Phase II

Document # 040123

Confidential

Date: January 2004



Field testing of Barry B-Net Systems used in Alpine Ski Race Course protection

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Field testing of Barry B-Net Systems used in Alpine ski Race Course protection

- Project :** An *in situ* experiment involving a moving test dummy striking into knotless nylon netting and polycarbonate support poles.
- Objective :** Simulate a racing skier falling into a B-Net system and observe the energy dissipation mode.
- Validate supplier guideline and installation instructions.
- Presented to :** Mr Bill McNeney, Race Quality Coordinator, Alpine Canada Alpin
Mr Bruce Hamstead, Race Quality Coordinator, Alpine Canada Alpin
- Date :** January 23, 2004
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1. Summary

- Barry B-Net systems (new) with polycarbonate poles were tested using various installation scenarios.
- Although a minimum of two rows of three (3) units of 20 meters (total 60 linear meters) is required to safely decelerate and stop a falling 80 kg skier travelling at 100 km/hr.
- It is recommended to install three rows whenever and wherever it is feasible in order to greatly enhance the safety.
- B-Net systems which are installed according to the “Barry Technical Specification and Installation Guidelines” have proven their ability to safely decelerate the falling skier in the specified test scenarios.
- Double S pattern layering of two 20 m. unit with 0.5 meter spacings between the layers was observed to safely decelerate a falling 80 kg skier travelling at 100 km/hr within a 0.5 m. distance from the obstacle with a 90° angle of impact
- The deceleration difference with systems using Barry PC poles versus bamboo poles is radical. Using bamboo poles as a replacement for PC poles is dangerous as the bamboo shows none of the required deceleration flex and tends to splinter in the crash zone.



1. Summary (cont'd)

- Functionality patterns for the Barry B-Net Systems were observed as follows:
 - Net layering density seems to play a vital and more important role in safe deceleration than the distance of slide on the snow surface by the falling skiers, either before impact of the first row, or between the rows of nets.
 - The greater the density of layered rows of nets, the greater the energy value which can be safely dissipated.
 - An increase in the number of rows of netting and not necessarily distance between the rows appears to be more effective for energy dissipation.
 - Video images of some of the tests are visible on the Barry Website, www.barry.ca (Sport Events Div.)



2. Study specifications

Customer name and address:	Alpine Canada Alpin 200, 505-8 th avenue SW Calgary, Alberta, Canada. T2P 1G2
Customer representative:	Mr Bill Mc Neney
Order number:	N/A
Test purpose:	Simulation of skier falling in B-Nets and observation of energy dissipation
Test nature:	<i>In situ</i> experimentation using snow as anchoring material
Test site:	Mont Chantecler Ski Area, Mtn # 4, Laurentians, Quebec
Test date:	January 19-22, 2004
Test personnel:	J. Peter Barry, Director N. Lachaîne, Installation/timing Frédéric Caron, Installation/photography Jean-Patrick Masson, Installation/observation André Laperrière, Rigging Mario Lachaîne, Rigging



3. Introduction

The use of B-Net as a safety measure to decelerate and protect ski racers is widespread and has been adopted for several decades by the FIS and the ski industry at large.

Recently, there has been an increase of interest concerning safety materials used on race courses, particularly since there have been cases of racers going through safety nets (either A or B), resulting in serious injury. While the exact causes of these accidents are nebulous, they are currently under investigation.

Barry Cordage undertook field testing of B-Net systems in April 2003, and published “Field Testing of Barry B-Net Systems” used in Alpine Ski Race Course Protection (document 030428), essentially defining the operational range for its Barry B-Net systems used as a single row in GS races in the 60 km/hr speed range.

The present study was initiated as a result of discussions with representatives of Alpine Canada Alpin, whereby it was deemed important and useful for Barry to test its B-Net systems in the 100 km/hr speed range. This would enhance the knowhow of safety equipment made by Barry and would demonstrate their system’s performance. Furthermore, the analysis of the test results will enable the Barry team to supply additional installation guidelines and instructions for the oft attained speed range of 100 km/hr during GS and Super G races.



4. Test certification

The undersigned certify that the tests described herein were carried out in accordance with the procedure listed in these pages, where applicable with the National Testing Standards, and that all equipment used was in calibration.

B-Net impact tests conducted by:

Mr André Laperrière
Special Effects Rigger, Prod. de l'Intrigue

Third Party Witness:

Mr Jean-Patrick Masson
CSIA Instructor, CSCF Coach

Witness for Barry Cordage Ltd.:

Mr Normand Lachaine
Director – Sport Events Division

Prepared by:

Mrs Joëlle Morrissette (Msc)
Scientific Advisor

Approved by:

Mr Peter Barry
President

* The original copy is signed and kept in on file at Barry Cordage Ltd Head Office Montreal, Canada



5. Safety criteria

The following is the energy absorption performance criteria required by FIS and ACA.

- Type B Systems must be able to absorb the impact of a ski racer with an energy value of 12 kJ.
- The force applied during deceleration shall be of not more than 7.5 G.
- The deflection for the impact zone must not exceed three (3) meters of space.



6. Discussion

Various suppliers of safety systems have claimed to perform laboratory and field testing of B-Net system's ability to safely decelerate a falling skier.

The result of these tests are not available for evaluation and comparison, although, the literature often discusses energy dissipated by the body/snow surface contact and friction as a contributing factor. Also, photographs of testing on B-Nets often illustrated a toboggan or sleigh riding on the ground surface and impacting the bottom (strongest) part of the nets. It appears that this may not be representative of all types of falls, as indeed, was witnessed by Herman Maier's famous flight over B-Nets during the Nagano Olympics.

In the present study, we are not relying on the body/snow surface friction to act as an energy dissipation mechanism. The reason being that in certain cases a skier may be landing in the mid to upper section of nets and will not ever be in contact with the snow surface either before or between the net sections.

The present study has made the test conditions very severe. For example, a hard snow surface, snow density of 600 kg/m^3 , and un-attached test dummy contacting the nets. Further, all falls were performed using head-first impacts, as well as various height of impact on the nets were simulated.



7. Interpretation of data

The performance results determined by these tests do not necessarily give a precise or accurate indication of the performance at which the safety nets will perform in other situations of circumstances.

For example, the quality of snows, in terms of anchorage of the support poles may vary greatly. Ambient temperature, humidity, water or ice presence on the nets etc., all these factors may affect the elastic properties of the nets systems and affect results, which may vary from the data hereby submitted.

As with previous observations, it was noted that a system configuration which did not work effectively one day and was left installed overnight did work the next day when the effect of overnight re-freezing and settling could occur.



8. Materials and Methodology

- 8.1 Test samples
- 8.2 Instrumentation
- 8.3 Methodology





8.1 Test samples

Test samples : Barry B-Net Systems

- Prepared in January 2004;
- Mounted to validate testing apparatus on January 19-20, 2004
- Witness tested on January 21-22, 2004

- Test samples measuring 2 m x 20 m were tested; nets were installed with polycarbonate poles every 2 meters.

- Various configurations of system layout (double rows, triple rows and double S layering), as well as a scenario involving bamboo poles as a substitute for PC support poles were tested.



8.2 Instrumentation

Timing system:

Microwave Radar Gun - Model Munigrip K-Gp (487-51-41)

Apparatus:

Articulated manikin Simulaid's Rescue Randy test dummy

Total weight: 80 kg

Model: 781344 Height: 1.83 m

Trolley cable system:

Special effects cable car pulley assembly, ball bearing sheaves, mounted on 6 mm Ø galv. Aircraft cable (7 x 19).

Cable tension: approx. 450 kg

Cable length : 70 m.

Quick release mechanism: Wichard SS snap hooks using Barry spectra trigger line

Acceleration mechanism:

Counter-Weight 100 kg mass

Block and tackle system 5:1

SUV Assisted traction

Spectra static rope (10 mm)





8.2 Instrumentation (cont'd)



Fig. 1 Photograph illustrating the test apparatus set-up for head first impact



8.2 Instrumentation (cont'd)

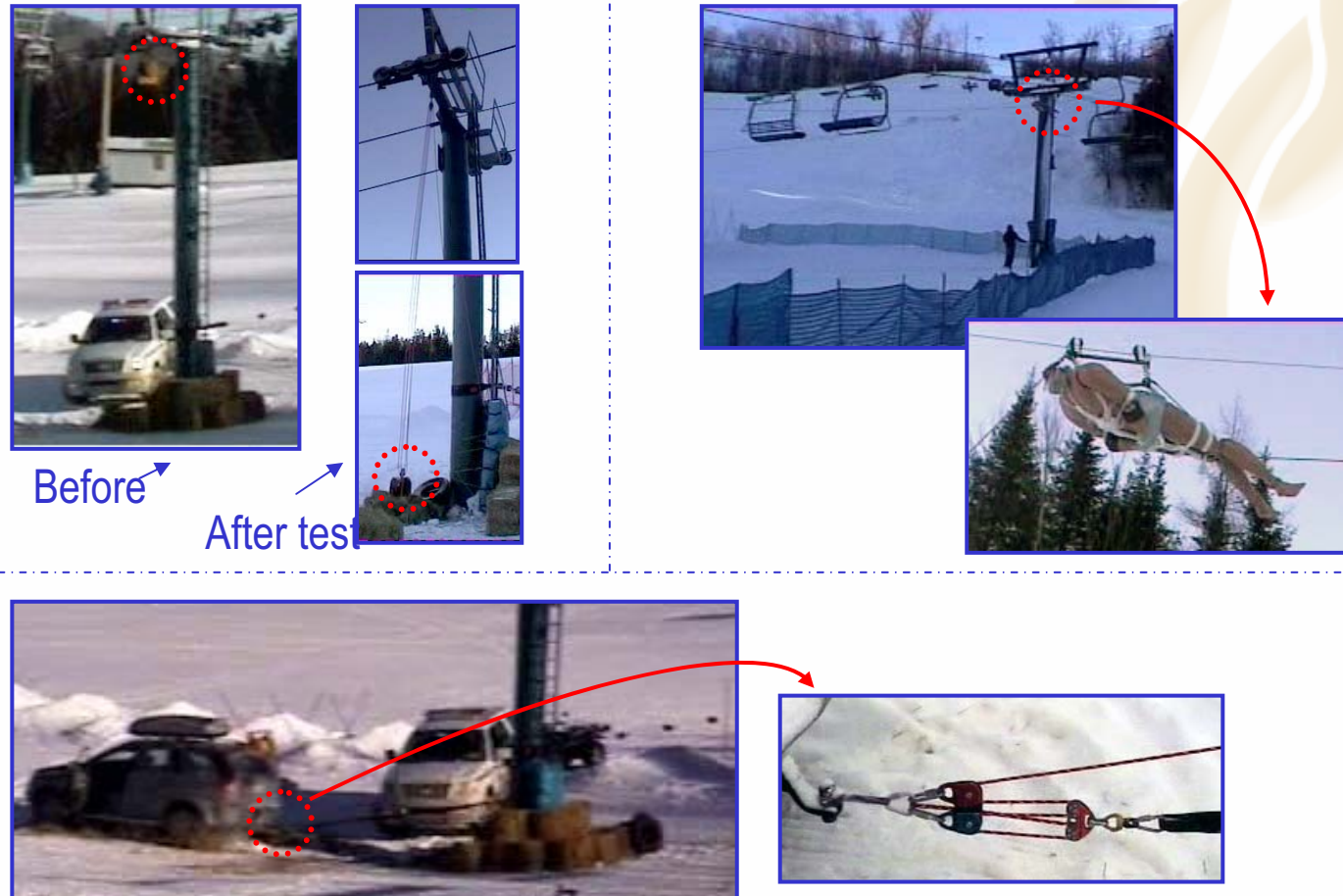


Fig. 2 Photograph illustrating the test apparatus set-up for increased traction and acceleration



8.2 Instrumentation (cont'd)

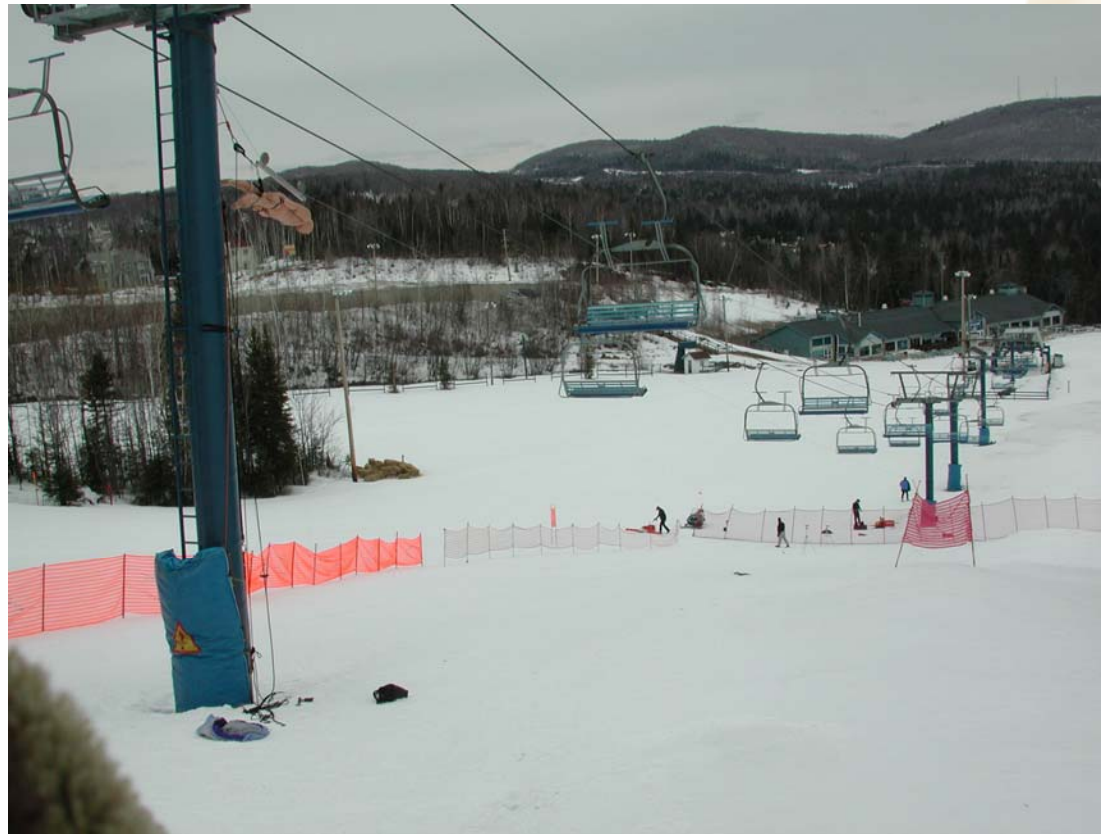


Fig. 3 Photograph illustrating a general view of the test site.



8.3 Methodology

General Description:

Various assembly configurations were installed and tested:

<u>Set-up</u>	<u>Angle of contact</u>	<u>Position</u>	<u>Impact zone</u>	<u>Row spacing</u>
2 rows of 3 nets (60 linear m.)	60°	Head first	Bottom 1/3 of net	2 m.
3 rows of 3 nets (60 linear m.)	60°	Head first	Bottom 1/3 of net	2 m.
Double S layout using 2 sections of 20 m/ea.	90°	Head first	Bottom 1/3 of net	0.5 m.
1 row of 3 nets (60 linear m. bamboo poles) 1 row of 3 nets (60 linear m.) of Barry B-Net Systems	60°	Head first	Bottom 1/3 of net/ 3 m. slide	2 m.



8.3 Methodology (cont'd)

- Samples are new at beginning of test and have been subjected to all test series. ie. Nets and poles were not replaced during testing (unless broken).
- Broken or damaged clips/poles were replaced after each test.
- Samples are mounted using new Barry clip design (elastic shock cord) and the tie-wrap at top of pole to secure net position.
- Snow density is obtained by melting snow and measuring residual water. The average snow density during testing was 600-650 kg/m³. (glacier ice has $d = 900 \text{ kg/m}^3$)
- Air temperature was in the -10 to -12°C
- Net dimensions are 2 m x 20 m with support pole spacing at 2 m.
- Nets were joined by overlaying a 2 m. section and interchanging poles/clips. The up-hill net overlays on the race course side.
- The travel speed of test dummy is approximately 100 km/hr (28 m/sec)
- Stopping distance is noted in meters, and is recorded on slow motion camera and on site by tape measure. Measurement is estimated $\pm 10 \text{ cm}$.
- Anchor holes were drilled using conventional ice/snow drill bits (32 mm \emptyset)
- Drill hole depth $\sim .3 \text{ m}$.



8.3 Methodology (cont'd)

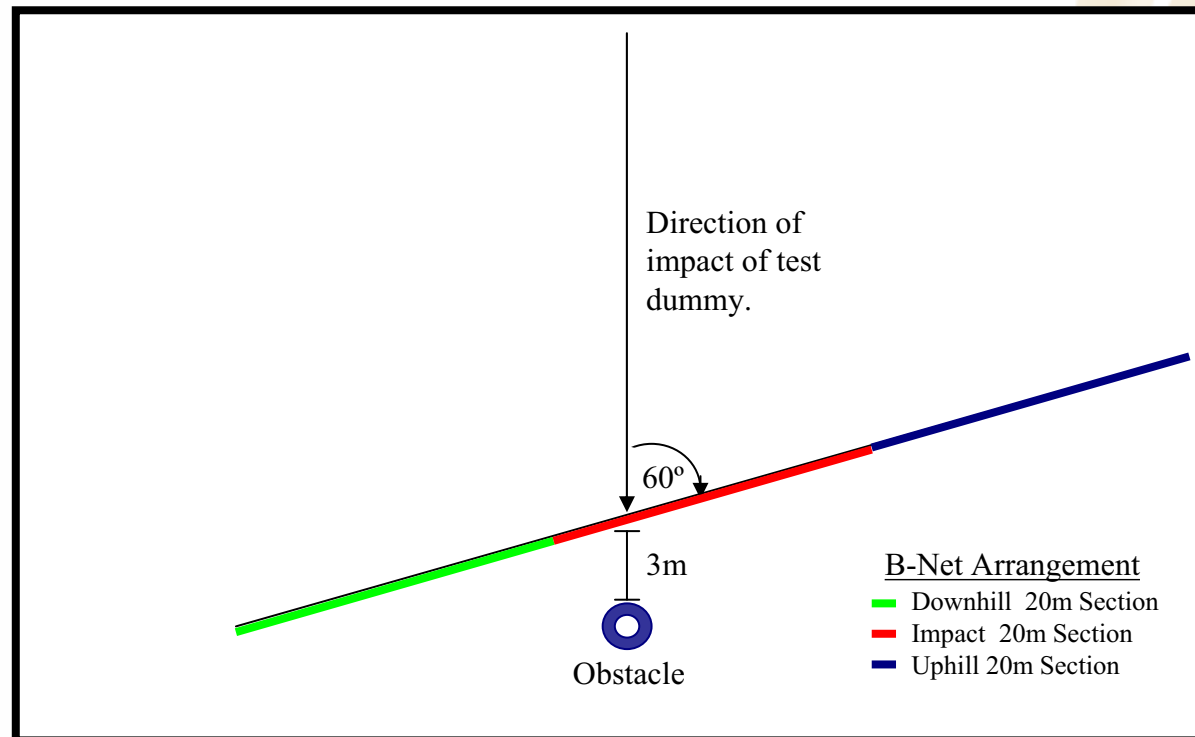


Fig. 3 Drawing illustrating the angle of impact of test dummy to nets



8.3 Methodology (cont'd)

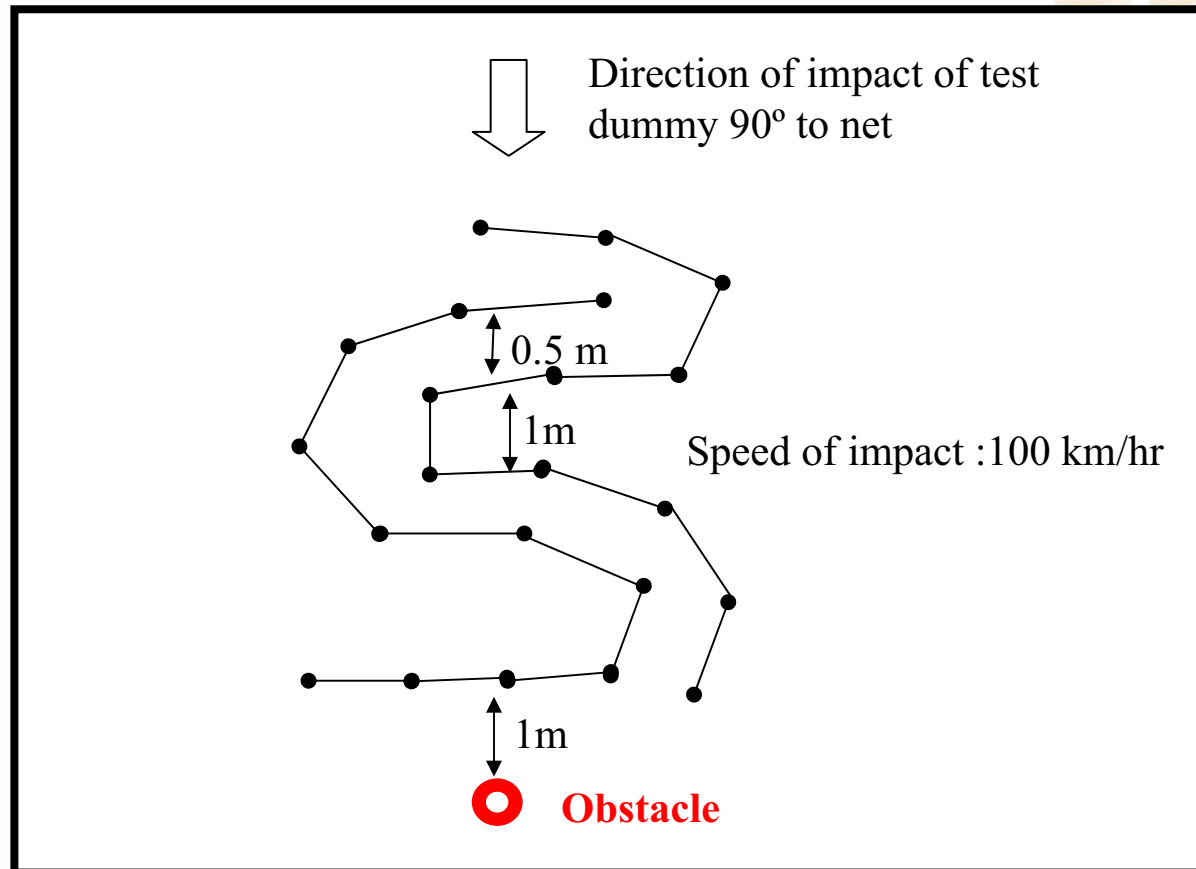


Fig. 4. Double "S" layering - Plan view



9. Result summary

- The deceleration mode observed indicate that an 80 kg mass travelling at 100 km/hr may be safely arrested within 1 meter from the obstacle.
- Comparison of test results indicate that at least 2 rows of 3 net units totalling 60 linear meters (66 poles) are required to safely decelerate the falling skier, when using a double row of nets
- Two units of net (20 meters) layed out in a S manner with 0.5 m. row spacing is sufficient to decelerate the energy component with a 90° angle of impact within 1 m. of space from the obstacle.
- Results indicate that most of the energy is dissipated on the uphill portion of the net system from the point of impact.
- Net tension should be “loose” between poles. ie 2 m of net hung between 1.95 m. pole spacings.
Note: netting which is too tight will not “catch” the skier who may ramp up, flip out or slide under the nets.
- Angling the poles approximately (10 degrees) to the up-hill direction and equally towards the race course appears to be beneficial in dissipating some impact energy.
- 40 of the 60 m. linear length of 20 m. connected units should be up-hill of an obvious/potential obstacle.
- A middle clip (3rd) appears beneficial, as is feeding the net through each 3rd mesh of net.
- The anticipated angle of impact between skier and nets should not exceed 60 degrees (see fig. 3 and fig. 4), except for the double S Layering pattern which could be set at 90 degrees.



9. Result summary (cont'd)

Double S Layering (100 km/hr 90° angle of impact)

- i) At a 90° angle of impact, the test dummy was caught in the last row of netting, indicating that no distance between the last row and the obstacle is required. However, it is recommended to allow at least 1 meter of space from the obstacle.
- ii) The total distance between an obstacle and the first row of net was 4.5 meters using 6 rows of netting, indicating that with some additional distance between the last row of nets and the obstacle (ie. 2 m.) at a 60° angle of impact, the 130 km/hr impact from skiers may possibly be safely decelerated. The hypothetical model was not demonstrated during this testing session as the maximum speed which was reached was 100 km/hr.
- iii) All tests conducted presented the crash dummy in a head-first position.
- iv) It appears that net layering density plays a vital and more important role in safe deceleration than the distance of slide on the snow surface by the falling skier, either before impact of the first rows or between the rows of nets.
- v) The greater the density of layered rows of nets, the greater the energy value which can be safely dissipated.

In other words: an increase in the number of rows of netting, and not necessarily distance between the rows appears more “efficient” in bringing the test dummy to a slow/safe stop, and furthermore, enhances the ability of the net to trap the dummy, thereby preventing ejection, ramping up, etc.



9. Result summary (cont'd)

Bamboo poles used as B-Net support poles

Configuration

8' bamboo poles (new and un-used) attached to the nets at 1.5 meter spacings, using conventional tie-wrap (40 lb cap).

A 60 meter row of nets/bamboo poles was set @ 60° to the angle of fall of the crash test dummy, and a secondary row of Barry B-Nets was set behind with a 2 m. spacing between the rows.

Results

The row of netting using bamboo poles did not effectively decelerate the dummy. The dummy pulled out 5 poles, 4 of which were shattered at the base and one which landed in the secondary row.

Only 10 of the 60 linear meters of netting appear to have come into contribution during testing. The probable cause is the the bamboo poles' lack of flex which causes the poles to splinter and/or pull out locally and let the test dummy slide out under.

The secondary row of Barry B-Nets caught the test dummy as predicted.



9. Result summary (cont'd)

Bamboo poles used as B-Net support poles

It should be noted that a splintered bamboo pole was found near the dummy in the secondary row of nets. This indicates that the bamboo poles present a risk of injury to the skier because of the sharp splinters which could puncture the skier in the event of a fall.

We conclude that bamboo poles should never be used as support for B-Net Systems because of their lack of flex and adherence in the snow at the base, and, more importantly, because of the risk of splinters causing further injury to a fallen skier.

It would appear that the opinion held by some that *“having B-Nets supported by bamboo poles is better than nothing”* is erroneous and potentially more dangerous. Indeed, not having any safety netting is probably safer as the informed skier will automatically slow down his speed or adjust in an instinct of self-preservation.

In any case, bamboo poles should absolutely never be used for this application. Additionally, only very flexible and non-splintering materials such as 1st grade polycarbonate should be considered for its resilience, high flexoral modulus and predictable performance over time and at cold temperature.

Table I: Results from field testing (January 19-22, 2004)

TEST #	IMPACT ANGLE	# OF NETS CONNECTED	# OF ROWS	SPEED (Km/Hr)	# POLES PULLED OUT	IMPACT ZONE	STOPPING DIST. (m)	PROBABLE RESULT	COMMENT
1	60°	3 x 20 m 2 m spacing	2	64	3	Bottom 1/3 of net	< 1	Safe	Speed not in target range Caught dummy successfully
2	60°	3 x 20 m 2 m spacing	3	94	5	Bottom 1/3 of net	< 1	Safe	Caught dummy successfully Slip under the 1st net but was caught by the 2nd net. 3rd net was not solicited
3	60°	3 x 20 m 2 m spacing	2	100	4	Bottom 1/3 of net	< 1	Safe	Caught dummy successfully
4	90°	1 x 20 m 0,5 m spacing Double S Layering	2	100	3	Bottom 1/3 of net	< 1	Safe	Caught dummy successfully Effective deceleration
5	90°	3 x 20 m 1st row bamboo pole 2nd row PC pole 2 m spacing	2	100	5	Bottom 1/3 of net	4	minor/major injury from bamboo splinters	Slid out of first row of bamboo poles (Bamboo poles broke under impact) Second row caught dummy successfully

Legend: Hanging mode: L – Loose
Impact position: H – Head first



10. Interpretation of test results

This study has demonstrated that several conditions must be achieved in order for the B-Nets to function adequately.

These conditions and limitations are numerous, varied and shall be published in an updated version of Barry B-Net Systems « Technical Specification and Installation Guidelines ». They may be resumed as follows:

The stopping distance criteria of 3 meters for double rows has been demonstrated.

Direct impacts into the net system, without prior sliding of the skier on the snow surface, were observed during this testing series. Results indicate Barry B-Net Systems effectiveness in safe deceleration.

There are enormous, yet subtle differences between an effective system that will absorb energy and others that may look « neater » but won't work.

Netting which is hung too tightly does not work.



10. Interpretation of test results (cont'd)

- . It is possible and easy to put up the system so that it will not work as predicted.
- . Variables such as:
 - Snow density and crystalline structure
 - Excessive hole diameter for support poles
 - Inclination of support poles
 - Carelessness as to setting up the row of nets at less than 60° to the angle of impact, or hanging the nets too tightly
 - And others, may affect a B-Nets' ability to catch and decelerate the falling skier.



11. Conclusion

The present report demonstrates that Barry B-Nets may be able to safely decelerate a falling 80 kg skier travelling at 100 km/hr when used in double rows, if and only if, some specific conditions are met. More importantly vigilance during installation and throughout the duration of a race are a *sine qua non* condition for a B-Net System's ability to perform as expected.

It is recommended to install three rows of netting whenever and wherever it is feasible in order to increase the safety factor.

It appears that ACA and FIS should review the safety criteria, as previous testing has demonstrated that in several instances the safety criteria may not be realistically achieved.

While it was not possible for the test team to obtain higher impact speeds than the 100 km/hr range due to physical constraints, it is hypothesized that having a minimum of 3 rows of 60 linear meters of Barry B-Net Systems, with a row spacing of 1-2 meters and a 2 m distance from an obstacle may be effective in safely decelerating the skier at speeds reaching 120-130 km/hr. More analysis and research is required to validate this scenario in actual field testing conditions.