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Field testing of Barry B-Net Systems used in Alpine Ski Race Course Protection – 60 km/hr

Document # 030428

Confidential

Date: April 2003

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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 Bruce McNeney, Race Quality Coordinator, Alpine Canada Alpin
Mr Bruce Hamstead, Race Quality Coordinator, Alpine Canada Alpin
Mr Doug Savage, Safety Equipment Manager, Alpine Canada Alpin

Date : April 28, 2003

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Table of contents

Barry

Table of contents

1. Summary

- Barry B-Net systems (new) with polycarbonate poles were tested using various angles of impact relative to the line of fall of a test dummy.
- A minimum 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 60 km/hr.
- Various clip designs and installation scenarios were tested and results indicate that feeding the poles through the meshes and using a bungee style clip was a good alternative to the bulkier and more expensive clips.
- B-Net systems which are hung too tightly fail to “catch” the skier and tend to either flip out, ramp up or let the skier slide under the net.
- The deceleration difference with systems using poles with or without screw tip is not significant.
- S pattern layering of a single 20 m. unit with 2 meter spacings between the layers was observed to safely decelerate a falling 80 kg skier travelling at 60 km/hr within a 4.2 m.distance with a 90^{o} angle of impact.
- The use of snow anchors with elastic shock cord proved to be beneficial in reducing the risk of the skier sliding under the nets

2. Study specifications

Customer name and address:	**Alpine Canada Alpin** 200, 505-8th avenue SW Calgary, Alberta, Canada. T2P 1G2
Customer representative:	**Mr Bill Mc Neney**
Order number:	N/A
Witness for customer:	Mr Bill Mc Neney, Mr Bruce Hamstead
Test purpose:	Simulation of skier falling in B-Nets and observation of energy dissipation
Test nature:	In situ experimentation using snow as anchoring material
Test site:	Mont Chantecler Ski Area, Mtn # 4, Laurentians, Quebec
Test date:	April 15, 16, 2003
Test personel:	J. Peter Barry, Director J.-F. Robitaille, Installation/timing N. Lachaîne, Installation/timing Valérie Noël, Camera 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.

The present study was initiated as a result of discussions with representatives of Alpine Canada Alpin, whereby it was requested that suppliers of safety equipment be able to demonstrate their system's performance as well as be able to supply installation guidelines and instructions and, if possible, make recommendations and issue warnings for various field conditions not specifically tested.

4. Test certification

The undersigned certify that the tests described herein were carried out in accordance with the procedure listed in theses 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

Witness for Alpine Canada Alpin: ____________________

Mr Bill McNeny and Mr Bruce Hamstead
Race Quality Coordinators

Witness for Barry Cordage Ltd.: ____________________

Mr Normand Lachaîne
Director – Sport Events Division

Prepared by: ____________________

Mr Jean-François Robitaille
Special Project Manager

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, the difference between head first falls versus side/shoulder impact was observed, 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 or 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.

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 sample were:

- Prepared in March, 2003;
- Mounted to validate testing apparatus on April 2, 2003
- Witness tested on April 15, 16, 2003

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

- Various configurations of systems were tested such as: poles with or without screw tips, angle of drilling, attachment clip type and quantity, angle of incidence of net to falling line of test dummy, hanging style (loose vs tight), new anchor design, and S configuration.

8.2 Instrumentation

Timing system:
Microgate Model: Racetime 2 (# 03050938) using 2 Polifemo FTC3 Photocells (# 02420208) (# 02420209) speed trap with 5 meter spacing.

Apparatus:
Articulated manikin Simulaids Rescue Randy test dummy
+ ski boots (5 kg) + misc. hooks/straps (3 kg)
Total weight: 80 kg
Model: 781344 Height: 1.83 m

Trolley cable system:
Special effects cable car pulley assembly, ball bearing sheaves, mounted on 5 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

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 sideways impact

8.2 Instrumentation (cont'd)

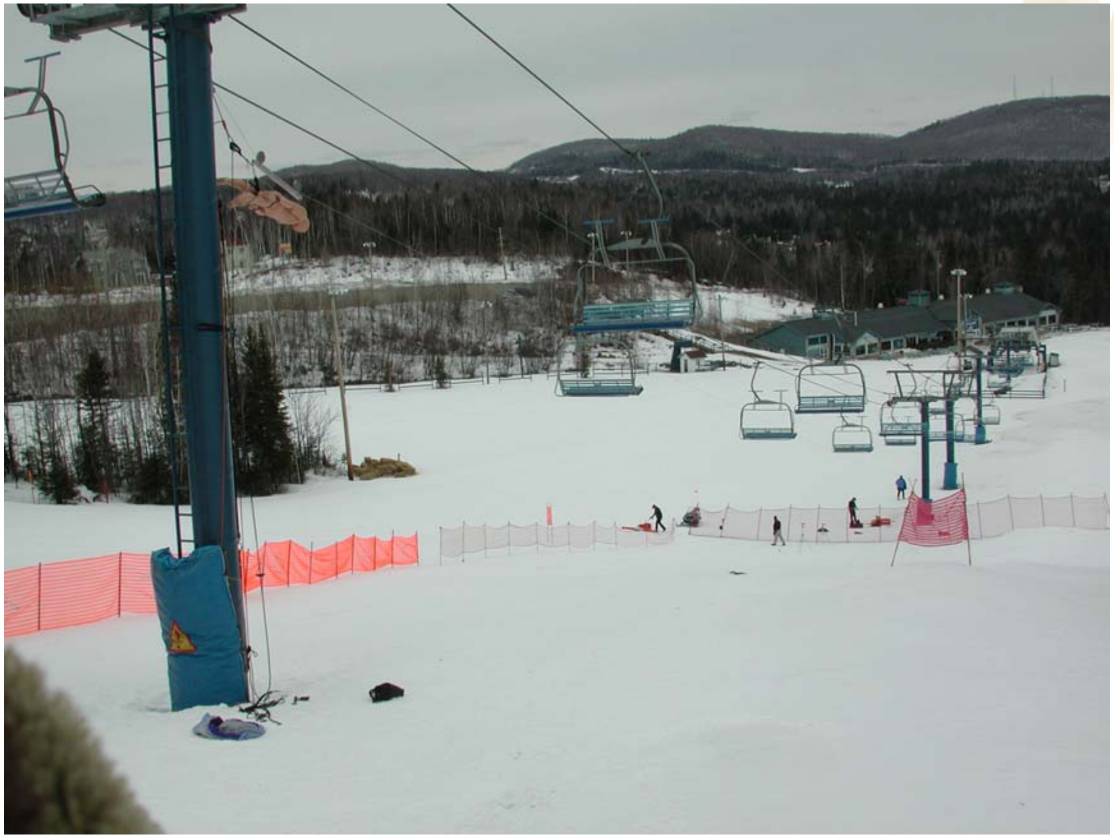

Fig. 3 Photograph illustrating a general view of the test site.

8.3 Methodology

General Description:
Various assembly configurations were installed and tested:

Set-up	**Angle of contact**	**Position**	**Impact zone**
1 row of 1 net (20 linear m.)	90º	Head first	Bottom 1/3 of net/top 1/3 of net
1 row of 1 net (20 linear m.)	45º	Head first	Top 1/3 of net
2 rows of 1 net (total linear 20m.) 2 m. spacings between rows	45º	Head first	" "
1 row of 2 nets (total 40 linear m.)	60º	Head first	Bottom 1/3 of net/mid section of net/3 m. slide before impact
1 row of 3 nets (total 60 linear m.)	60º	Head first before impact	Bottom 1/3 of net/3 m. slide
1 row of 3 nets (total 60 linear m.)	60º	Sideways	3 m. slide before impact
1 S layout (total 20 linear m.) with 2 m.spacing between layers	90º	Sideways	4.8 m. slide before impact

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 various clip designs: coil, strap, plastic, elastic shock cord..
- Snow density is obtained by melting snow and measuring residual water. The average snow density during testing was 600 kg/m^3.
  (glacier ice has d = 900 kg/m^3)
- 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 60 km/hr (17 m/sec)
- Stopping distance is noted in meters, and is recorded on slow motion camera and on site by tape measure. Measurement is estimated ± 10 cm.
- Anchor holes were drilled using conventional ice/snow drill bits (32 mm Ø)
- Drill hole depth ~ .3 m.

8.3 Methodology (cont'd)

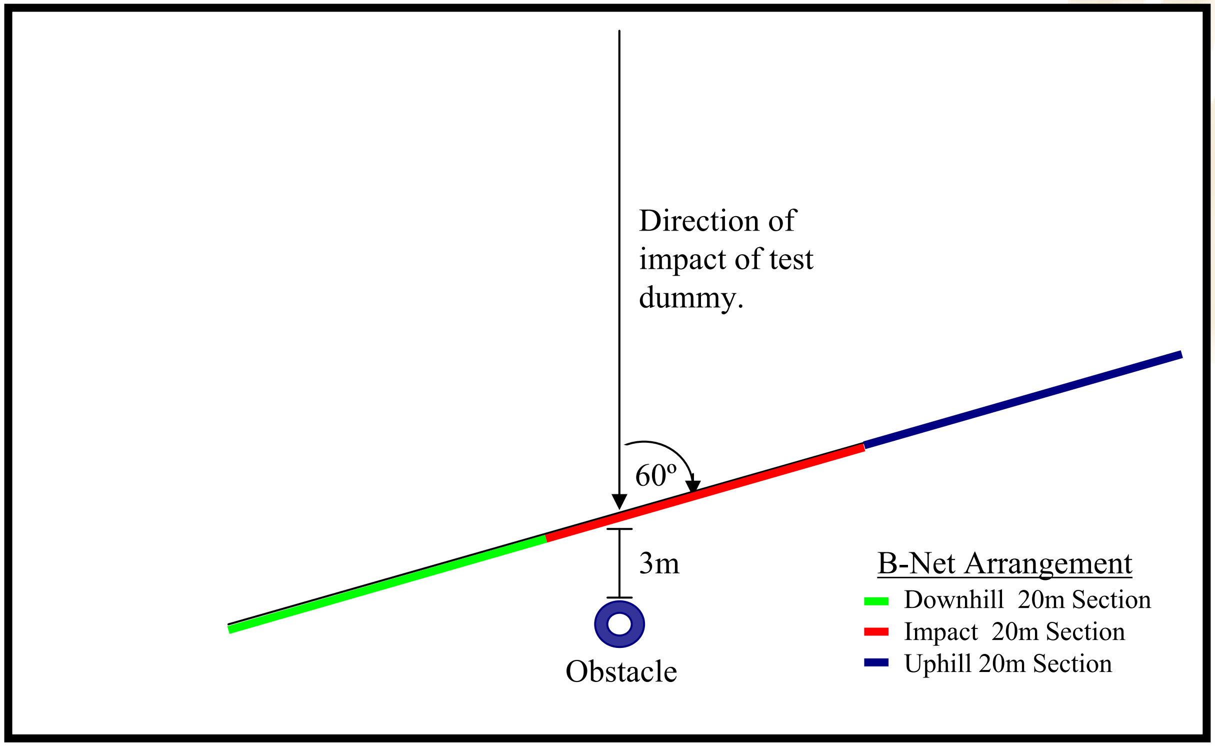

Fig. 3 Drawing illustrating the angle of impact of test dummy to nets

9. Result summary

- Comparison of test results indicate that at least 3 net units totalling 60 linear meters (33 poles) are required to safely decelerate the falling skier, when using only a single row of nets.
- The deceleration mode observed indicate that an 80 kg mass travelling at 60 km/hr may be safely arrested within 4 meters.
- One unit of net (20 meters) layed out in a S manner with 2 m. row spacing is sufficient to decelerate the 12 kJ energy component with a 90^{o} angle of impact within 4.2 m. of space.
- Results indicate that most of the energy is dissipated on the uphill portion of the net system from the point of impact.
- In hard snow and ice conditions, intermediate snow anchors could be used to anchor the net bottom in impact zones, using the same diameter holes as for the support poles.
- 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 3 rd mesh of net.
- The anticipated angle of impact between skier and nets should not exceed 60 degrees (see fig. 3).

Table I: Results from preliminary testing (April 2nd, 2003)

TEST # / VIDEO REF.	IMPACT ANGLE	# OF NETS CONNECTED	HANGING MODE	SPEED (Km/Hr)	# POLES PULLED OUT	IMPACT POSITION	IMPACT ZONE	STOPPING DISTANCE (m)	PROBABLE RESULT	COMMENT
1	90°	1 x 20 m	T	≈ 58	14	H	Bottom 1/3 of net	6+	Major injury or death	All poles ripped out / Dummy slid under *Not on video*
2 10 s to 18 s	90°	1 x 20 m	T	57	14	H	Base of net	6+	Major injury or death	Slid under and crashed with force
3 9:29:00 to 10:19:00	90°	1 x 20 m	T	59	8	H	Top 1/3	6+	Major injury or death	Ramped up and slid out and crashed with force
4 10:20:00 to 10:40:00	45°	1 x 20 m	T	56.3	4	H	Top 1/3	6+	Minor injury	Caught in net - Appears as safer decelaretion
5 11:03:10 to 11:20:00	45°	2 rows x 20 m 2 m spacing	T	≈ 58	4	H	Top 1/3	6+	Minor injury	Ramped up and slid out of second row Second row stood up

Legend: Hanging mode: T – Tight
L – Loose
Impact position: H – Head first
S – Sideways

Table II: Results from witness testing (April 15th and 16th, 2003)

TEST # / VIDEO REF.	IMPACT ANGLE	# OF NETS CONNECTED	SETTING	HANGING MODE	SPEED (Km/Hr)	# POLES PULLED OUT	IMPACT POSITION	IMPACT ZONE	STOPPING DISTANCE (m)	PROBABLE RESULT	COMMENT
1 12:00:00 to 12:40:00	60°	2 x 20 m		T	57	12	H	Mid section	6+	Major injury	Dummy ramped up and ejected from net
2 13:40:00 to 14:05:00	60°	2 x 20 m	Poles inclined 10° uphill 2 screw tips in impact zone	T	55	12	H	Bottom 1/3	6+	Major injury	Dummy caught in net - 1 pole broke at point of impact - 1 pole with screw tip got all clips slipped off but stayed in snow (did not break)
3 15:10:00 to 15:17:00	60°	3 x 20 m	Angled poles 2 screw tips in impact zone	L	57	7	H	Bottom 1/3	6+	Major injury	Ramped up and slid out
4 15:45:00 to 16:00:00	60°	3 x 20 m	Same set up as # 3 except earlier point of dummy release	L	57	4	H	3 m slide before impact	6+	Major injury	Dummy slid under between two screw poles
5 19:35:00 to 20:00:00	60°	3 x 20 m	Same set up as # 4	L	58	7	S	3 m slide before impact	5+	Minor injury	Caught dummy in net Strain on all 9 uphill poles
6 23:45:00 to 00:05:00	60°	3 x 20 m	Same set up as # 4	L	58	6	S	3 m slide before impact	4	Minor injury	Caught in net - All uphill poles sollicited
7 25:50:00 to 02:25:00	60°	3 x 20 m	Same set up as # 4 Shock cord anchor tied to botom	L	57	5	S	3 m slide before impact	4	Minor injury	Caught dummy - Good decelaration 1 broken pole
8 27:15:00 to 28:00:00	60°	3 x 20 m	Same set up as # 4 9 screw poles / fixed tips	L	≈ 58	12	S	3 m slide before impact	6	Minor injury	All screw poles pulled out
9 30:00:00 to 30:19:00	60°	3 x 20 m	Using elastic pole clip (3/pole) Shock cord anchor at 15 meshes from bottom in contact area	T	≈ 58	5	S	3 m slide before impact	6	Major or minor injury	Net too tight - Dummy flipped out and very little load distribution up or downhill
10 30:58:00 to 31:15:00	60°	3 x 20 m	Same set up as # 9 Shock cord anchor at base of net	T	≈ 58	6	S	3 m slide before impact	4	Minor injury	Shock cord anchor at base of net appear to help - Ramped up and slid out
11 32:30:00 to 32:50:00	60°	3 x 20 m	Same set up as # 10 Difference is loose net to shock cord anchors	L	≈ 58	6	S	3 m slide before impact	4	Minor injury	Caught dummy successfully
12 32:55:00 to 33:25:00	90°	1 x 20 m in S pattern	2 m spacing between layers	L	≈ 58	11	S	4.8 m slide before impact	4.2	Minor injury	Caught dummy successfully
13 35:35:00 to 35:50:00	90°	1 x 20 m in S pattern	2 m spacing between layers	L	≈ 58	11	S	4.8 m slide before impact	4.2	Minor injury	Caught dummy successfully

Legend: Hanging mode: T – Tight
L – Loose

Impact position: H – Head first
S – Sideways

10. Interpretation of test results

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

These conditions and limitations are numerous and varied. They may be resumed as follows:

- No head first impact was safely stopped.
- The stopping distance of 3 meters for a single row has not been attained. At best, it appears that a 4 meter distance is required.
- Direct impacts (whether head first or sideways) into the net system, without prior sliding of the skier on the snow surface, would either ramp up, flip or eject the body.
- Screw tip poles offer no significant advantage as anchorage quality.
- When « experts » were asked to set up the safety nets as they historically would on race courses, the tests resulted in failure to absorb the energy of impact.
- There are enormous, yet subtle differences between an effective system that will absorb enerby 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 demonstrated that Barry B-Nets may be able to safely decelerate a following skier when used as a single row, if and only if, some specific conditions are met. More importantly vigilence 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 appears that ACA and FIS should review the safety criteria, as testing has demonstrated that in several instances the safety criteria may not be realistically achieved.