EFFECT OF PROLONGED EXPOSURE TO ULTRA-VIOLET RAYS ON BARRY B-NETS[MD] – PHASE III

A comparative analysis between natural ageing of nets and accelerated weathering

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Effect of prolonged exposure to ultra-violet rays on B-Nets – Phase III

Project : Measure the residual mechanical properties of nets after certain periods of use and compare to the data obtained after simulating the ageing of the nets in a QUV chamber (2002-2003 Studies #020411-1 and -2).

Objective : Determine the residual tensile strength of nets subjected to prolonged UV ray exposure and other natural outdoor factors in order to demonstrate the correlation to the results for accelerated weathering, thereby allowing the extrapolation of the latter results for other regions of the world such as Europe and North America.

Presented to :

Date : September 2008

By : **Véronique Cossette**, Research Advisor

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1. Summary

- The present testing may serve as a starting point to establish current tensile strength of materials in use. Future testing of the nets could be carried out and results compared with the present data in order to determine further decline in the tensile strength properties.

- Two previous studies on the effect of UV-rays on B-Nets (Ref. Documents #020411-1 and -2) have shown that nylon nets maintain their mechanical properties above the required safety threshold when exposed to 500 hrs of UV rays (equivalent to 6 months of outdoor exposure) and even to 1000 hrs. The equivalence in UV exposure was estimated according to various factors such as latitude and altitude and reproduced for the region of Mount Kobau (BC), allowing to calculate similar data for other skiing regions of the world by using comparison factors. Any given correlation in the results obtained by natural ageing is to corroborate the results obtained from simulated UV exposure and to confirm the extrapolation for different locations.

- Several B-Net samples were removed from existing B-Net systems temporarily stored for annual refurbishing at Barry Cordage Ltd in order to calculate their residual tensile strength after 5 years of service. These nets were used by different ROC in Western Canada (Lake Louise, Nor-Am, Pontiac Cup, Winterstart World Cup) and Eastern Canada (Bromont, Craigleith, Mont Ste-Anne, Mont Tremblant, Orford, St-Sauveur). The position of these nets on the slopes when used is random. Information with regards to the year of manufacture was obtained from the ID label of each net, while the approximate record of usage was documented by the users.

- The nets tested were supplied by Barry in 2003 and put in service at that time by two different organisations, Alpine Canada Alpin (ACA) and Ski Québec Alpin (SQA). All nets are part of travel inventories which call for intensive use, and the samples were taken from the panels with the worst looking appearance, typically at the ends of nets and on the bottom portions as the end sections were more exposed to abrasion when rolled during transport and to UV when stored and left in open air.

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1. Summary

- The nets are made of knotless nylon (polyamide) with different coatings : ACA (red coating) and SQA (blue coating). The samples used by ACA were tested in June 2006 (Ref. Document #060614) and in September 2008, while the samples used by SQA were only tested in September 2008.

- While data on the actual average residual strength is presented in the following pages, comments as to the decline in the strength properties over time are based upon the start hypothesis regarding initial tensile strength. In this matter, the value for the initial tensile strength used for comparison is 359 lbf, as taken from the control samples in the Phase I and II of the current study (Ref. Documents #020411-1 and -2).

- Results indicate that the nets have not lost more than 22% of their strength after 5 years when compared to the initial values, while the acceptable safety threshold tolerates a total loss of 30%. On average, the ACA nets have lost around 14% of their rated strength while it is the least efficient net that showed a loss of 22%. On the other hand, nets used by SQA have lost no more than 11% of their initial tensile strength in the case of the worst sample tested, or an average loss of only 9%. We can thus say that all tests show that the nets remain above the safety limit and can be kept in use.

- On a greater point of view, the nets were expected to lose 13% of their mechanical properties after 3 years of intensive use and 22% after 5 years , according to the predictions made from previous stages of the QUV simulation studies. This corresponds to an annual decrease of around 4,6%. **The nets have proven to fall within these forecasts, which thus far confirms the reliability of the simulated ageing tests on the effect of UV exposure, compared to natural outdoor exposure to UV rays.**

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2. Study specifications

Customer name and address:	Internal Study
Customer representative:	N/A
Order number:	N/A
Witness for customer:	N/A
Test purpose:	Compare residual tensile strength of Barry B-Net systems after different degrees of use
Test nature:	Tensile strength test on horizontal bed
Test site:	Barry Cordage Ltd 6110 des Grandes Prairies Montreal (Qc) H1P 1A2
Test date:	October 2002, June 2006 and September 2008
Test personel:	Pascale Cossette, Research Advisor Véronique Cossette, Research Advisor J.-F. Robitaille, Special Project Manager Peter Barry, President (Program Director)

3. Introduction

In the first two sections of the current study, it was proven that knotless nylon nets used in the Barry B-Net System resisted to 1000 hrs of accelerated UV exposure without significant loss in their tensile strength properties.

However, these first studies were limited to the standardized methodology of QUV chamber ageing, which do not include subjecting the samples to other damaging factors caused by field service, such as abrasion, cuts, sharp bends, water absorption, knots or torsions of the material. However, other environmental factors in real outdoor conditions contribute to increase the UV exposure of nets above the simulated amount such as altitude, latitude, cloud cover, ground cover or ozone layer and these may adversely affect the results given in the first two phases of the study.

Consequently, it is crucial to apply the same protocol to nets whose use corresponds to a mix of various external degradation factors in order to consider situations of different latitudes, altitudes and so on. This way, the “laboratory vs. outdoor UV exposure” comparison data and the tensile strength data can be used to make a general comment on the expected long-term outdoor exposure effects of short wavelength UV (at 320-340 nm) on the strength properties on the ski barrier netting tested.

4. Test certification

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

Tensile strength tests conducted by: ______________________________

Ms Pascale Cossette (B. A. A.)
Research Advisor

____

Ms Véronique Cossette (B. Ing)
Research Advisor

Prepared by: ______________________________

Mr Jean-François Robitaille (B. Ing)
Special Project Manager

Approved by: ______________________________

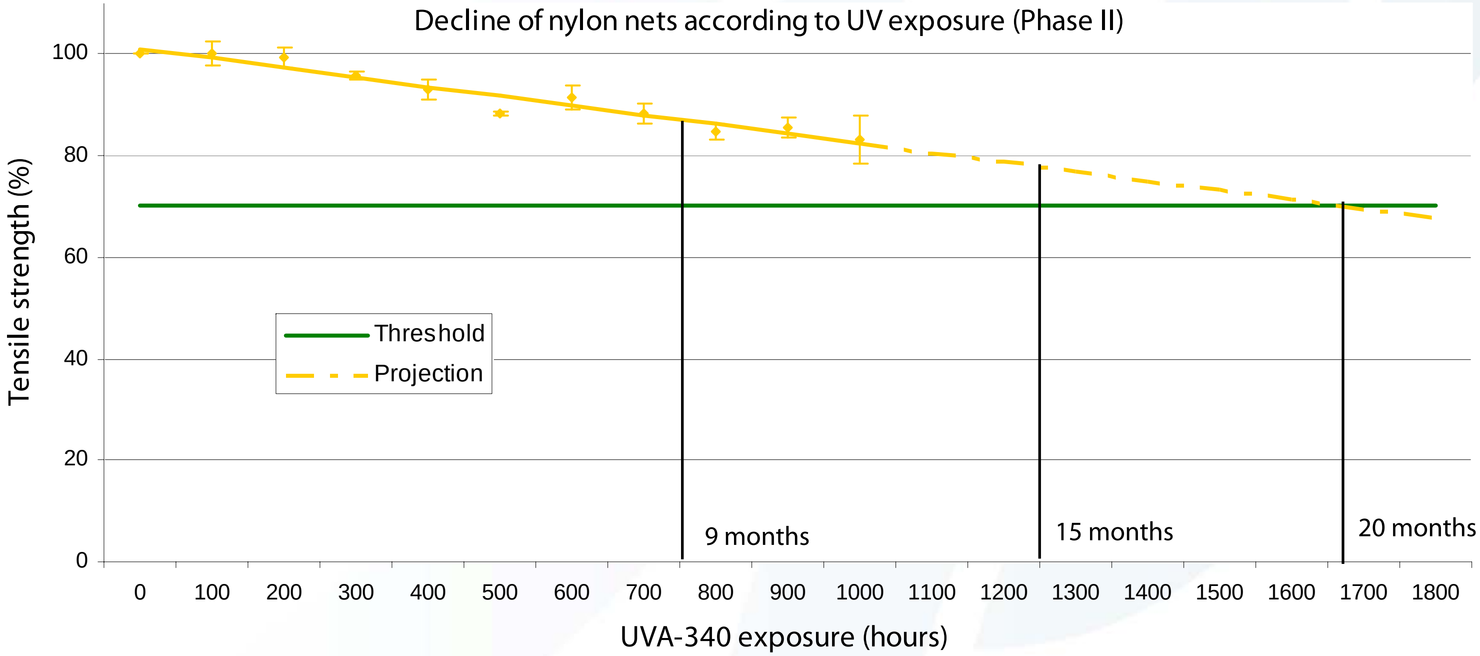
Mr Peter Barry
President, Program Director
Barry Cordage Ltd

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

5. Start hypothesis

In the first place, the nets are expected to show a decrease in residual tensile strength versus their initial resistance of 359 lbf, although this loss in the nets' mechanical properties is not expected to drop below the 30% tolerable safety threshold (equivalent to a residual breaking strength of 251 lbf), according to the initial tensile strength results tested in 2003 on the new material.

As to the global picture of the project, the nets are expected to have lost around 13% of their strength after 3 years of use (equivalent to 750 hours of UV exposure), whereas they are expected to lose 22% after 5 years (1250 hours). The following graph illustrates the anticipated decrease in tensile properties in proportion to the loss measured over accelerated UV testing (Ref. Phase II). The theoretical out of service date is located around 1675 hours of UV exposure.



5. Start hypothesis

Also, the current analysis relies on the fact that a general hypothesis had to be drawn as to the correspondence between the simulated UV trials and real life tests. Since 500 hours in QUV chamber equal to 6 months of outdoor exposure according to Bodycote Material Testing Canada and to experts ANSI, ASTM etc., it was just a matter of deciding how frequent the nets were exposed during a ski season. As a season normally consists of close to 6 months of skiing, and because the nets do not remain indefinitely exposed during the season, it was estimated that the nets were exposed half of the time of the skiing season, therefore 3 months. This hypothesis is very general and represents an arbitrary choice as further exposure sometimes took place since the nets have happened to be in place before the start of the season or after its end. However, this equivalence was established for the purposes of the study, where 5 years of use of the nets would compare to 15 months of QUV chamber weathering.

6. Safety criteria

Industry Norm for safety nets

Nets having lost ***more than 30%*** *of their original strength are considered to have been seriously affected by UV or other environmental factors and should be removed from service. This standard is a generally accepted good practice for equipment used in safety applications, and accounts for mechanical properties of nets.*

7. Interpretation of data

Note 1:

The tensile strength measured in the current tests is used solely as an indicator of the degradation incurred by the nets since this feature is easily quantifiable. For that reason, it needs to be compared to the initial value of the nets (359 lbf) as a reference to better quantify or approximate the amount of UV rays which may have affected it. This approach differs from the one developed when the tensile strength is used to determine whether a certain variable such as abrasion, discoloration, chemical attack or other has enough influence on the nets to render them no longer usable, as was the approach reported in document #060614 "Performance Testing of Safety B-Nets" for the testing of the ACA nets in 2006 whereby the threshold was determined to be 331 lbf.

Nevertheless, the tensile strength values should not be used in any case as the only measure of the energy dissipation capacity of the nets, as these react as a whole system and not only one mesh breaking at a time when subjected to dynamic loading impact situations.

Note 2:

The results for the following tests may be used independently of any previous study as it reports on real life utilization. These results allow on one hand to conclude effect of UV degradation of the B-Nets used in real outdoor situations, regardless of any correlation to previous studies on the subject.

However, as part of a greater project, the initial tensile strengths used as reference for grounds of comparison are those measured during previous experiments (Ref. Study #020411-1), i.e. in 2003 before the nets were put into service.

7. Interpretation of data

Note 3:

The breaking point determined by these tests presently accounts for external factors of use such as abrasion, cuts, sharp bends, or others, as part of a normal use made to the ACA and SQA inventories.

Note 4:

The nets were put in service for a duration of 5 seasons (November 2003 - April 2008), equivalent to around 1250 hours of UV exposure as it is considered that one season accounts in total to around 3 months of outdoor exposure. Since 500 hours in QUV chamber equal to 6 months of outdoor exposure according to Bodycote Material Testing Canada and to experts ANSI, ASTM etc., 15 months should equal to 1250 hours of accelerated weathering. Therefore, the measured residual tensile strengths would be expected to be slightly lower than those obtained in the Phase II of the study where UV exposure equals to 1000 hours.

7. Interpretation of data

Note 5:

The solar region, as well as other environmental factors, which cause maximum degradation of safety nets is largely unknown. Therefore, only general comments on expected outdoor exposure effects can be made on the scope of the laboratory tests conducted at Barry. It is estimated that the usage of the B-Nets provided by both ACA and SQA balances out differences in UV exposure that could occur due to altitude, cloud cover, ground cover or ozone. These factors are balanced out since the nets were used in various places across the country, following various environmental factors. Nevertheless, these results could not be applied to situations were the ground cover AND the latitude AND the altitude AND the cloud cover are always in the worst conditions for UV exposure.

We can then safely assume that small variations in any one of the outdoor variables (such as ground cover, latitude and other) do not individually cause a significant impact on the loss of mechanical properties of the nets, but that would not be the case with larger fluctuations of any one of these variables for a long period (for example, intensive use at high altitude should prove to have a very significant effect on the loss of mechanical properties).

8. Materials and Methodology

8.1 Test samples

8.2 Instrumentation and methodology

8.1 Test samples

- Originally, the new B-Nets were tested as part of the study on the effect of prolonged exposure to Ultra-Violet rays on B-Nets - Phase I on October 31st, 2002. The nets were originally put in service in 2003.

- The ACA B-Nets were first tested from June 12th to June 16th of 2006, as reported in document #060614 in order to better understand the impact of their faded colour and possible water absorption on the residual tensile strength. At the time, six (6) nets were tested with a number of ten (10) tests performed on each net. These nets were then replaced because of the sections that were cut off and could not be re-tested in 2008. However, three (3) different nets of the same lot were again examined on September 24th, 2008 and picked out as per their worst looking appearance with twelve (12) tests being conducted on each net, varying in position along the net.

- The SQA B-net samples were prepared on September 17th, 2008. All three (3) samples were taken from the same net, although ten (10) tests were executed at each of the three different locations on the net, whether at the bottom, the middle or the top section.

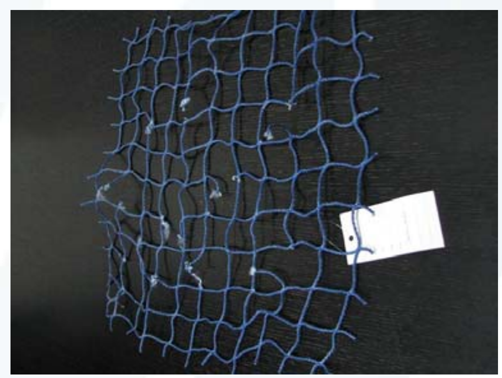
- Altogether, a total of twelve (12) samples were tested in 2008 (three picked from the net used by SQA and 3 picked from each of the three nets used by ACA), each sample being tested from 10 to 12 times.

8.1.1 Test samples

Sample ID:

SAMPLE #	DESCRIPTION	NUMBER OF TESTS	NOTE
1-5	Coated knotless nylon (polyamide) with red urethane coating	n = 10/sample, total 52	Unused material
6-11	Coated knotless nylon (polyamide) with red urethane coating	n = 10/sample, total 60	Used by ACA (3 years)
12-14	Coated knotless nylon (polyamide) with blue urethane coating	n = 10/sample, total 30	Used by SQA (5 years)
15-17	Coated knotless nylon (polyamide) with red urethane coating	n = 12/sample, total 36	Used by ACA (5 years)

Photograph of ACA Nets



Photograph of SQA Nets

8.2 Instrumentation

Natural weathering: Outdoor UV exposure of the nets was done in authentic conditions and can vary from day to day in relation to various factors.

Tensile strength: AMD-1 test bench with a rated capacity of 20 000 lbf, maximum distance of 3m between the bollards, 1 m travel distance of the mobile part, normalized

Last calibrated on November 19th, 2007 (Certificate M-719) and the error tolerance is ± 1% as per ASTM E4-96 Standard Practises for Force Verification of Testing Machine, which is traceable to the Strainsense cell #890508 Hi/Lo of the Standard National Laboratory, Washington, USA.

Graphic plotter: Allen Datagraph Model 720-E30-XY s/n 13864

Last calibrated November 19th, 2007 (Certificate M-720) to ASTM E4-96 Standard Practices for Force Verification of Testing Machine

8.2.1 Methodology

General description

Eighteen (18) samples of used B-Nets were collected as follows:

- Six (6) samples used by ACA, all tested in 2006. Another nine (9) more were taken to be tested in 2008.
- Three (3) samples used by SQA for testing in 2008.

Each sample was tested for tensile strength a number of ten to twelve times and compared to initial values obtained in previous testing of 2003 and to residual values of 2006 in the case of ACA.

Photograph of testing apparatus

Photograph of B-Net Systems

8.2.1 Methodology

Tensile strength

- Samples prepared 30 cm. X 120 cm.;
- Samples are secured at each end to the test bed shackles, ensuring that there are no torsion or twist in the fibers.
- The force applied on the net meshes was in both the netting fabrication direction and opposite direction (across the mesh). This allows to both consider the weakest results in the analysis (usually obtained across the mesh) as well as the normal conditions in which the net will resist (normally in its fabrication direction).
- The shackle pin diameter is 12 mm.
- The length of sample mounted is one mesh, approximately 2" square (50 mm x 50 mm).
- The sample is put under load by increasing the distance between the shackles in the test bed until a break point is attained.
- The travel speed of the mobile part of the test bed is between 75-100 mm/minute as per the CGSB 40-GP-1M standard.
- Results are expressed in pound – force (lbf): (225 lbf = 1kN)
- The displacement distance (inches) and the load (lbf) are recorded on a graph paper which denotes the stress/strain curve.

9. Result summary

Disclosure of results

The results show that after both 3 years and 5 years of service, all nets remain sufficiently resistant to be kept in use.

In the case of the 5 year old nets used by SQA, only one break test has reached failure under the safety threshold of 251 lbf, but this value is not considered risky and can be discarded as it does not reflect the behaviour of all meshes of the nets, with the global average tensile strength being of 327 lbf. Therefore, if a skier were to encounter any accident, this particular mesh of the net would break but all others around would still maintain the skier on safe grounds. The same reflection accounts for the one mesh that broke at 250 lbf for the ACA nets tested after 3 years of service (average tensile strength was then 321 lbf).

In the case of the ACA 5 year old nets tested in 2008, one of the three nets proved to be significantly less resistant, bearing an average of 280 lbf while the other nets could stand on average 328 lbf and 324 lbf. This particular net may have been put to use more frequently in higher altitudes as a lower resistance could be explained by a greater exposure to UV rays. Nevertheless, it can still withstand the required load of 251 lbf with the exception of two meshes that reached failure under that threshold, but those can be discarded as previously explained. Overall, the ACA nets tested in 2008 can take an average of 321 lbf, rendering them more than safe to use.

9. Result summary - Table I

New material – 2003

Sample #	1	2	3	4	5
test 1	346	358	345	346	364
test 2	346	357	363	347	371
test 3	359	344	355	376	372
test 4	349	342	336	364	356
test 5	381	356	346	360	354
test 6	371	362	345	361	344
test 7	366	374	351	356	373
test 8	344	388	360	366	344
test 9	380	346	372	349	367
test 10	356	380	357	374	364
test 11				358	367

	1	2	3	4	5	Total
Average	360	361	353	360	361	359
Standard deviation	14	16	11	10	11	12
Max	381	388	372	376	373	388
Min	344	342	336	346	344	336
Number	10	10	10	11	11	52

9. Result summary - Table II

ACA - 2006

Sample #	6 Net 238	7 Net 236	8 Net 181	9 Net 131	10 Net 213	11 Net 214
test 1	355	258	328	278	349	315
test 2	328	253	286	305	315	298
test 3	315	279	294	250	325	319
test 4	327	297	324	301	360	344
test 5	354	359	357	268	341	351
test 6	349	342	361	294	326	345
test 7	372	368	314	314	330	322
test 8	335	346	321	263	316	344
test 9	321	340	310	329	303	294
test 10	323	335	340	304	314	323

	Net 238	Net 236	Net 181	Net 131	Net 213	Net 214	Total
Average	338	318	324	291	328	326	321
Standard deviation	19	42	24	25	18	20	29
Max	372	368	361	329	360	351	372
Min	315	253	286	250	303	294	250
Number	10	10	10	10	10	10	60
Efficiency	94	88	90	81	91	91	89

9. Result summary - Table III

SQA - 2008

Sample #	12	13	14
test 1	331	348	211
test 2	315	335	333
test 3	354	344	313
test 4	367	330	339
test 5	348	265	360
test 6	349	328	360
test 7	332	331	315
test 8	335	325	311
test 9	303	317	344
test 10	312	337	322

	12	13	14	Total
Average	335	326	321	327
Standard deviation	20	23	43	30
Max	367	348	360	367
Min	303	265	211	211
Number	10	10	10	30
Efficiency	93	91	89	91

9. Result summary - Table IV

ACA - 2008

Sample #	15 Net 107	16 Net 056	17 Net 037
test 1	271	314	291
test 2	283	321	330
test 3	281	317	360
test 4	327	340	329
test 5	299	315	320
test 6	247	309	308
test 7	324	318	315
test 8	293	352	334
test 9	256	352	338
test 10	282	313	303
test 11	244	343	315
test 12	252	336	347

	Net 107	Net 056	Net 037	Total
Average	280	328	324	311
Standard deviation	28	16	19	30
Max	327	352	360	360
Min	244	309	291	244
Number	12	12	12	36
Efficiency	78	91	90	86

9. Result summary - Table V

A comparison of the results from the three different cases of use indicate that all types of nets maintain a residual tensile strength above the required threshold of 70% of the initial strength (equal to 251 lbf).

	New	ACA 2006	SQA 2008	ACA 2008
Average	359	321	327	311
Standard deviation	12	29	30	30
Max	388	372	367	360
Min	336	250	211	244
Number	52	60	30	36
Efficiency	100	89	91	86
Verdict	-	✓	✓	✓

10. Interpretation of test results – Immediate outcome

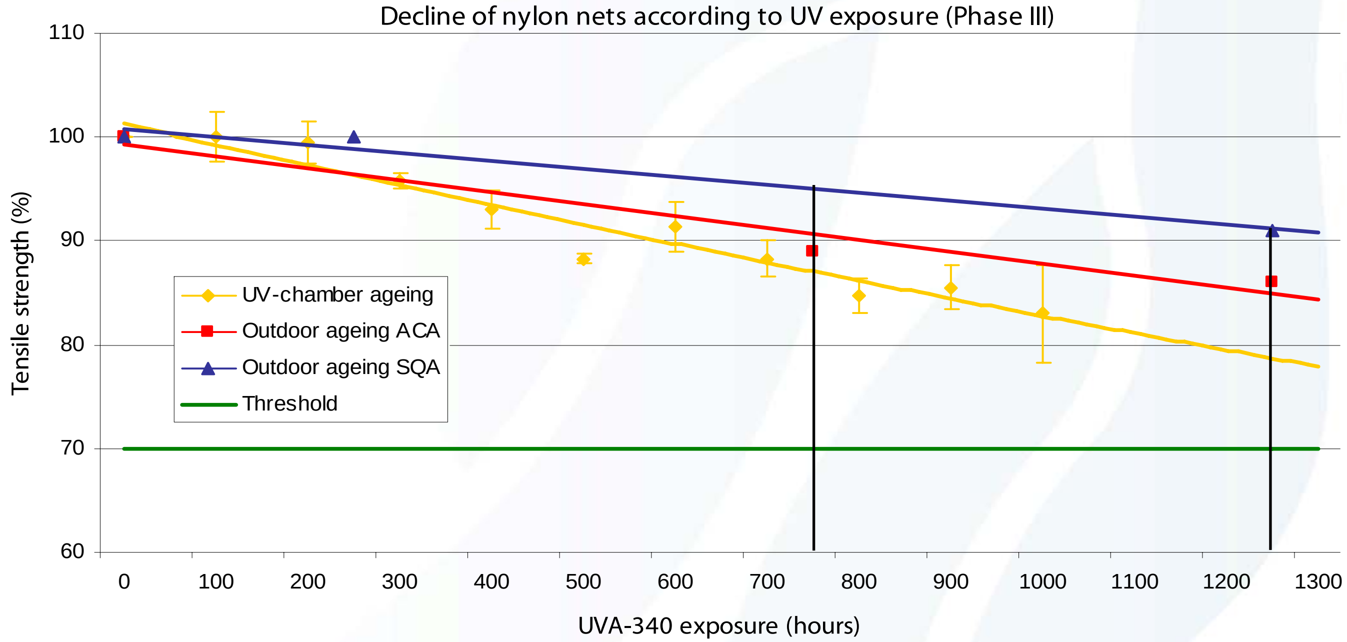
However conclusive the results, we can still see a great difference between those of SQA and ACA. Indeed, the nets used by SQA proved to be more resistant after 5 years of service than those of ACA after a 3-year utilization period. This variation indicates how influential the conditions of use are on the results, accounting for a 5% efficiency divergence between the tests of 2008. The disparity in results could also be imputed to the color variation, supposing that blue coating was to be more UV resistant, although further testing would have to be executed in order to refute or corroborate this hypothesis.

It is therefore considered that the nets may not have been subjected to the same exposure conditions. The SQA nets are brought back to the Olympic Stadium (Montreal) storage facility every year around June, whereas the ACA nets have happened to remain outside at times until July, possibly being stored in exposed conditions. In addition, the ACA lot might not uniformly have been submitted to the same exposure environment with some nets being kept at the top of the pile (therefore more exposed to UV rays) while others were hidden underneath, explaining the disparity in results between Net #107 and Nets #056 and #037. Furthermore, the typical elevation where the ACA West travel inventory is used is higher when compared to the SQA typical elevation of use (5000-8500 ft in Western Canada compared to 1350-3300 ft in Eastern Canada), hence influencing the degree of UV exposure.

Nevertheless, all tests showed that real outdoor exposure to UV has not sufficiently affected the nets' properties to render them vulnerable below the bearable threshold. For that reason, **all nets are said to be safe to remain in service.**

10. Interpretation of test results – Global picture

Since the results given by natural ageing are associated with a longer exposure to UV rays than the estimated time in the accelerated weathering procedure (1250 hours vs. 1000 hours), it is possible to extrapolate from the graph obtained in Phase II of the study and say that a loss of over 20% in the tensile strength was to be expected after 5 years according to the linear relation plotted. However, results show that only 12% was lost on average (9% for SQA and 14% for ACA). The same goes for estimations regarding tests after 3 years of service: a reduction of 13% was expected but results showed that only 11% was lost.



10. Interpretation of test results – Global picture

Although real life decline in mechanical properties was seen to be slower than that expected from accelerated ageing procedures, these contradictions still confirm the observation that artificial weathering gives a more conservative evaluation of the residual tensile strength of nets, hence remaining a fairly reliable indicator of the nets' resistance. Furthermore, all tested results are found down along the trend curve model elaborated in QUV chamber, meaning that the general trend line given by the laboratory data is accurate.

Nevertheless, this interpretation remains only an indicator of further concordance between both relations, which definitely needs to be supported by future testing in order to be confirmed. Correlating only 2 different periods of use (3 years and 5 years in the case of ACA) does not allow to significantly predict the law ruling the decline of the breaking strength of nylon nets when subjected to real outdoor ageing conditions.

11. Conclusion

The present report demonstrates that there exists basic correspondence between the laboratory and the outdoor UV exposure data which tends to prove the veracity of the results for accelerated weathering and to confirm that the laboratory model is useful in predicting the service life of these materials.

It is absolutely necessary to conduct further testing in order to verify the correlation between these two models since what has been proved so far is not necessarily a guarantor for future consistency.

It becomes therefore possible to make only a general comment on the expected long-term outdoor exposure effects of short wavelength UV (at 320-340 nm) on the strength properties of the ski barrier netting tested as to what has been correlated so far.

All in all, Barry B-Net Systems are able to bear and exceed the equivalent of at least 1250 hours of UV exposure in a QUV chamber, which is comparable to 5 years of service in Canada, 6 years in Germany (1539 hours) or 4 years in Colorado (960 hours) [1], accounting for variations due to elevation, latitude and other factors.

Source: 1 Solar Engineering of Thermal Processes, 2nd Ed. By J.A. Duffe & W.A. Bedkman, J. Wiley & Son, inc. (1991)