Ministry of Agriculture, Food & Fisheries
B.C. FISHERIES

NET PEN TESTING PROJECT

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Contract #406

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EXECUTIVE SUMMARY

The salmon farming industry, insurance companies and government all recognize that net strength is an important component of escape prevention. In October 2000, the provincial government amended the Aquaculture Regulation to include among other things, minmum breaking strength standards for net pens. The objective of these standards is to set minimum enforceable benchmarks for the strengths of nets used in BC's aquaculture industry. Currently there is no standard protocol for testing the breaking strength of net pens in British Columbia. As a result, very different testing results can be obtained, depending on the instrument and method used. In addition, more research was deemed to be necessary to validate the minimum breaking strength existing in the Regulation. To meet these needs, M.M. Johnson Ltd. was retained by BC Fisheries to conduct a study in three parts:

1) Identify an existing device for testing the breaking strength of net pens used in B.C. aquaculture. The device was to meet the criteria that it be accurate, durable and suited to the wet environment of fish farms, inexpensive, portable enough to be taken to aquaculture sites by fisheries inspectors, and easy to calibrate.
2) Develop a standard testing protocol to be used by fisheries inspectors, net pen manufacturers (net lofts), and salmon farmers to determine the breaking strength of net pens. The purpose of the protocol is to ensure consistent testing conditions between different testers. To be of greatest use, it must be easily performable in a net loft facility or on a salmon farm.
3) Determine the recommended minimum breaking strength values for the various classes of net pens specified in the Appendix II, Section 13(c) of the *Aquaculture Regulation.*

A number of additional criteria were developed for the testing device, and available equipment was compared and assessed. No existing equipment was found which met all the criteria, and subsequently a simple device was developed incorporating a custom testing stand and an off-the-shelf digital tension dynamometer.

A standard testing procedure was developed, based upon the custom testing device but written to allow testing by any suitable device meeting the procedure's criteria. Potential variables in testing conditions were isolated to determine their significance, and the findings incorporated into the procedure. The procedure is intended to be accurate enough for the purpose, yet practical enough for easy use under variable conditions. The proposed procedure is attached as Appendix C to this report.

A large number of mesh break tests were conducted in order to assess testing devices, develop the standard testing procedure, compare tested breaking strengths to listed strengths for different meshes, and to determine the strength conditions of existing net pens of various ages. Analysis of the results of this testing, along with comparison to the required minimum breaking strength standards for other jurisdictions, led to recommendations for revised values for the Regulation, along with suggestions for some revisions to the text of Section 13 of the Regulation, dealing with net pens. Recommendations are also made to conduct additional research over a period of time, following the life cycle of net pens in use.

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1. INTRODUCTION

1.1 Assignment

This report describes the work performed and conclusions reached by M.M. Johnson Ltd. on a Net Pen Testing Project for B.C. Fisheries. A contract to undertake this assignment was awarded to M.M. Johnson Ltd., beginning 2001 May 01, following a consultant selection process.

1.2 Purpose of the Project

Escape prevention is one of the key components of the province's salmon aquaculture policy. To date, several significant steps have been taken towards the province's goal of zero escapes. In October 2000, the provincial government amended the Aquaculture Regulation to include among other things, minimum breaking strength standards for net pens. Such standards are recognized to be an important component of escape prevention by the salmon farming industry, stakeholders and government. The objective of these standards is to set minimum enforceable benchmarks for the strength of net pens used in BC's finfish aquaculture industry.

Currently there is no standard protocol for testing the breaking strength of net pens in British Columbia. As a result, very different testing results can be obtained, depending on the instrument and method used. This affects the enforcement of the net pen standards set out Section 13(c) of the Aquaculture Regulation. In addition, more research was deemed to be necessary to validate the minimum breaking strength values which were incorporated into the Regulation.

1.3 Scope of Work

The scope of work for this project was defined in three parts, as follows:

1.3.1 Testing Device

Identify an existing device for testing the breaking strength of net pens used in B.C. finfish aquaculture that best meets the following criteria, in order of importance:

- accurate
- durable and suited to the wet environment of fish farms
- inexpensive (~$2,000)
- portable enough to be taken to aquaculture sites by fisheries inspectors
- easy to calibrate

1.3.2 Standard Testing Protocol

Develop a standard testing protocol to be used by the Ministry of Agriculture, Food, and Fisheries' fisheries inspectors and if desired by net pen manufacturers (net lofts) and salmon farmers to determine the breaking strength of net pens that:

- ensures consistent testing conditions between different testers; and
- can be performed easily in a net loft facility or on a salmon farm

1.3.3 Minimum Breaking Strength Requirements

Determine the recommended minimum breaking strength values for the various classes of net pens specified in the Appendix II, Section 13(c) of the *Aquaculture Regulation.*

1.4 Personnel

For M.M. Johnson Ltd., overall direction and supervision of the Net Pen Testing Project was provided by Murray M. Johnson, P.Eng.

Project Engineer for M.M. Johnson Ltd. was Don Johnston, P.Eng.,

Much of the of the research involved, and the actual testing work in both the lab and the field, as well as the management of the collected data, was performed by Jody Hansen. Jody was employed by M.M. Johnson Ltd. on a four-month work term in connection with her studies in the co-op education program in Civil Engineering at the University of British Columbia.

Contacts for the work with B.C. Fisheries were Satara Malloch, B.Sc., Aquaculture Research Development Assistant, and Kirk Stinchcombe, A/Manager: Finfish Aquaculture Development

1.5 Industry Assistance With Project

A crucial part of the project was enlisting the assistance of various people and companies within the B.C. aquaculture industry, to provide input on current practice, loan testing equipment, provide new net samples, provide access to existing net pens for testing, etc. The number of people who assisted is too extensive to list here, but it should be noted that the people at Campbell River Netloft Ltd., Cards Aquaculture Products (BC) Ltd., Quadra Pacific Netloft, and Warp Tech Inc. were particularly helpful with the project.

1.6 Net Samples

In order to assess testing devices, develop and check a standard testing protocol, and provide baseline data on new netting, it was necessary to obtain as many different samples of new netting as possible, of sufficient size to allow a large number of test breaks on each sample. These were obtained from area netlofts, primarily as offcuts from the construction of new net pens. A total of some 30 different new, untreated mesh samples were obtained, most of which were tested during the project. In addition, 13 samples which had been dipped in antifoulant were obtained, all of which had a corresponding sample among the new untreated mesh. All nets tested for this project were made of nylon.

All of the tested new mesh samples, undipped or dipped, were tested for strength in a lab at M.M. Johnson Ltd.'s offices, using the testing equipment decided upon during the first phase of the work.

Additionally, access was obtained to a total of ten existing net pens of various ages. These were all tested at netlofts where they had been taken for regular servicing, again using the testing equipment developed for this project.

1.7 Organization of Net Samples

As each sample of new netting, untreated or dipped, was received, and as each existing net pen was provided for testing, the mesh involved was assigned a unique identifying number and details of its manufacturer, gauge, mesh size, known history, etc. were recorded. Information on the published (manufacturer's) breaking strength was also included in this record.

Table 2 at the end of this report provides a listing and comparison of all of the new mesh samples received for this report. Some samples were received and a portion sent out to be dipped in antifoulant; these dipped samples are listed as a separate sample number in this table.

Table 3 provides a comparison of different meshes available for the finfish industry, sorted by gauge (the determinant of individual mesh strength) and including the mesh manufacturer's reported breaking strength. This table also summarizes which of these meshes are included in the samples received by M.M. Johnson Ltd., and in what form. Not all samples received were tested, such as those with mesh too small or too large for practical use in this application, or when the sample size was too small for 30 breaks.

Net samples originating with four different manufacturers were a part of this project. These are ABC Netting Inc., Badinotti Nets (Italy), MoreNot a.s, and WarpTech Inc. For reasons of confidentiality, throughout this report, each manufacturer is referred to by a number only, from 1 to 4, not corresponding with the order in which these manufacturers are listed above.

1.8 Project Limitations

The Net Pen Testing Project was initiated and conducted within a fairly short time frame, and with a specific budget.

The limitation of time did not particularly affect the work done to develop a testing device and testing protocol, as sufficient numbers of new mesh sample were obtained and tested to ensure confidence in the result. The level of sophistication of the testing device itself, and thus the procedure to accompany it, is, however, limited by the project criteria of cost, durability, and portability.

The time factor placed some limitations on the number of different nets that were available for testing, especially existing net pens. In addition, it was of course not possible to track given sections of netting from manufacture through construction into net pens and through years of service in the water. This particular limitation is especially relevant to the third portion of the project, validation of the minimum net breaking strengths. Tracking nets over a longer time period would add considerable information on net deterioration and allow for a more accurate picture of appropriate minimum net strength values. The best compromise possible with respect to this was to test new samples of net and watch out for net pens coming into netlofts for servicing which had been made from the same type of netting.

Also, the amount of time required to investigate test instruments, develop a testing device, obtain the measuring instrument and develop and test a standard testing protocol left a fairly short period of time for the finding and testing of existing net pens. As a result, only ten existing net pens were tested during the final stage of this project.

The limitation of not having a large number of existing pens tested was partially mitigated in the end analysis by calibrating the results to existing protocols already in use in other jurisdictions, and subsequently recommending the adoption of the breaking strengths from these existing protocols.

The conclusions reached are consistent with the data gathered, but these limitations should be kept in mind when considering the results. Elsewhere in this report a recommendation is made to continue gathering test data in the future, especially on the same net over years of service, to augment the data gathered during this project.

1.8 Reference Materials

The following reference materials were provided for or obtained during the project and were consulted to various degree to assist in the work.

1) “Escapes of Farmed Salmon in British Columbia 1996 –2000”, Ministry of Fisheries Briefing Note, 2000 August 18.

2) “Preventing The Loss of Farmed Fish”, BC Fisheries Backgrounder, 2000 August 17.

3) “Annotated Bibliography of Trade, Internet and Scientific Sources Regarding Farmed Salmon Escape Prevention, Recovery and Tracking”, BC Fisheries, 2000 April 7.

4) “Inter-Jurisdictional Study on the Procedures for Escape Prevention of Finfish Aquaculture Species”, BC Fisheries, 2000

5) “Escape Amendments to the Aquaculture Regulation”, B.C. Regulation – Fisheries Act, effective 2000 October 31.

6) “Code of Containment For Use of Non-Local Salmonids Strains in Sea Cage Aquaculture in Bay D’Espoir”, Newfoundland Department of Fisheries and Aquaculture, 1999 May 18.

7) “An Implementation Plan For The Code of Containment For Use of Non-Local Salmonids Strains in Sea Cage Aquaculture in Bay D’Espoir”, Newfoundland Department of Fisheries and Aquaculture, 1999 September 30.

8) ISO 1107: “Fishing Nets – Netting – Basic Terms and Definitions”, 1974

9) ISO 1530: “ Fishing Nets – Description and Designation of Knotted Netting” - 1973

10) ISO 1805: “Fishing Nets – Determination of Breaking Load and Knot Breaking Load of Netting Yarns”, 1973

11) ISO 1806: “Fishing Nets – Determination of Mesh Breaking Load of Netting”, 1973

2. TESTING DEVICE

2.1 General

The first phase of the work was intended to result in the identification of an existing testing device which would meet the criteria outlined by BC Fisheries, then obtain and calibrate such a device.

A great deal of research was conducted to identify available devices and determine what was already being used within the industry. This included telephone, facsimile, and Internet research as well as in-person discussions. Only a few devices were eventually identified, all of which only partially met the criteria. In order to allow the project to proceed, M.M. Johnson Ltd. developed and constructed a simple testing apparatus that met all of the criteria.

In the course of this work, two of the very few devices currently in use to test nets were loaned to M.M. Johnson Ltd. by Campbell River Netloft for comparison and assessment, and the authors would like to acknowledge this contribution to the project.

2.2 Testing Device Basic Requirements

The testing device is intended to be used by MAFF fisheries inspectors for the purposes of enforcing *The Aquaculture Regulation*. In addition, the device may be used by fish farm operators and net lofts to ensure that nets in use on farms meet the standards given in the *Regulation.* The device must be able to provide consistent, reproducible test results of the residual breaking strength of net pens in service. Such testing would normally be carried out at netlofts or fish farms. The testing device must be able to load to tensile failure net pen mesh of various twine gauges, mesh sizes, and breaking strengths. Furthermore, the testing device must be able to record the peak loading applied to the mesh when the failure point is reached.

2.3 Testing Device Criteria

As part of the scope of work for this project, the following criteria for testing devices were provided by BC Fisheries, listed here in the specified order of importance:

- accurate
- durable and suited to the wet environment of fish farms
- inexpensive (~$2,000)
- portable enough to be taken to aquaculture sites by fisheries inspectors
- easy to calibrate

In addition, M.M. Johnson Ltd. identified some additional criteria that would be required to achieve the desired results:

- controlled rate of application of load
- peak load reading held on instrument, maintained with shock failure
- device useable by one person with relative ease
- device sufficiently ergonomic to satisfy Occupational Health & Safety requirements
- force gauge or dynamometer to be either battery operated digital device or analog device (i.e. no auxiliary power supply required)
- different users can obtain the same result (within anticipated testing errors)
- loading linearly aligned with measuring device (for in-line type dynamometers)

The following dimensional and load parameters were additionally defined by M.M. Johnson Ltd. as required to meet the current needs of the majority of the BC finfish aquaculture industry:

- minimum mesh opening size: 1/2”
- maximum mesh opening size: 3”
- maximum breaking force required: 500 lbs.
- maximum elongation required to break mesh: 150%
- diameter of test hook material 0.15” to 0.25”

2.4 Options Considered

There are two main components common to every type of testing device considered: a means of applying a force to a piece of netting, and a means of measuring the force at the point at which the netting breaks. It is useful to understand the various types of these two components separately, and then consider the combinations thereof which form complete devices.

2.4.1 Application of Force

In applying a force to a piece of mesh until it reaches the breaking point, the mesh elongates (stretches) a certain amount before the failure load is reached. The rate at which this elongation occurs (rate of loading) has some effect on the resultant breaking strength of the mesh, and therefore in order to achieve reproducible, consistent results, there must be a way of controlling the rate. This pertains to the discussion below with respect to each method of applying load to the mesh. In Section 3 of this report this parameter is discussed in more detail.

All of the devices that were considered are manually powered in some way. There are power-driven options available, but none have been included here due to unfavourable comparison for cost, portability, durability, and simplicity. The basic different methods of applying manual force are:

a) Hydraulics: a hydraulic cylinder with manual pump is used to extend an arm that applies tension to the netting, cylinder extension is continued until the net breaks. Significant force can be generated with minimal effort using hydraulics and the rate of loading can be fairly well controlled by controlling the approximate time for completion of each stroke of the pump. One of the testing devices borrowed for evaluation, known as a “Hydaq”, is hydraulic powered, as is the device developed for this project, the “#OBE-1”.

b) Screws: an arrangement of screws/gears provides movement to a crosshead, which applies tension to the netting. For reasonable size and simplicity to be maintained, the amount of force that can be generated is more limited. Controlling the speed at which the screw wheel is turned can control rate of loading. The DFA in Newfoundland uses a test stand such as this for their net testing, however it has a capacity of only 250 lbs, and is relatively expensive.

c) Leverage: an arrangement of opposing levers (as in a scissors, pliers, or forceps) spreads open a jaw, applying tension to the netting attached to hooks on the jaw. Amount of force generated depends on the tool geometry and the strength of the person working it, ergonomics are poor with some injury potential, and rate of loading is largely uncontrolled. The geometry of the lever arrangement results in a non-linear relationship between applied force and tension at the netting. A calibration graph could be used to accommodate this, however the force also varies with the mesh size and amount of pre-break elongation of the twine. Since the elongation cannot be feasibly measured, the actual breaking force is therefore somewhat difficult to establish accurately. This type of device is in use locally and one, known as a “Torque Tester”, was borrowed for evaluation.

2.4.2 Measurement of Force

The basic methods of measuring the applied force are as follows:

a) Pressure gauge on hydraulic cylinder: hydraulic pressure is read at time of net breaking, and pressure is translated to a force using a calibration chart. Major drawbacks include lack of any type of peak reading indicator, difficulty in reading gauge due to bouncing needle, lack of accuracy on small gauge, and the need to convert readings to determine strength.

A hydraulic pressure gauge is used as the measuring method for the “Hydaq” device mentioned in 2.4.1(a) above.

b) Direct-reading tension dynamometer, analog or digital, placed in line between the net and the applied force. Peak force is easily established, especially for the digital units, accuracy is high for the instrument, and error is minimized as instrument reads force directly without any conversions.

DFA in Newfoundland uses a digital tension dynamometer with the test stand mentioned in 2.4.1(b) above, as does the device developed for this project, the #OBE-1.

A comparison of suitable digital tension dynamometers was made during this work; a summary of which appears in Table #1 at the end of this report.

c) Torque wrench, analog or digital, used with the leverage type of device as described above. Manual force on the torque wrench handle is measured as torque at the attachment point of the wrench to the lever; this can be converted to the breaking strength for the mesh by using a calibration graph. Peak force is difficult to establish for dial-type (analog) torque wrenches, due to needle bounce. Digital torque wrenches indicate maximum force, but a weatherproof one could not be located for this project.

Torque wrenches are used to measure the force in the leverage systems as described above.

2.4.3 Devices

Several tension testing devices in the desired capacity range (500 lbs) were identified, but not pursued, being unable to meet one or more of the basic criteria. These include large bulky testers intended for lab use, powered testers, overly heavy testers, testers which are not sufficiently weatherproof, etc. It should be noted that some of these devices may be perfectly suitable for net testing in some applications, such as in netlofts (where some are already used), but were not studied in detail for this project, due to the criteria employed.

The devices which were more carefully considered are:

a) "**Torque Tester**", from Campbell River Net Loft.

This is quite a simple tool, using opposing levers in an arrangement similar to "snap-ring pliers", where pushing down on the top lever cause a jaw to open. A torque wrench is incorporated into the top lever. The model borrowed and evaluated has limitations in the smallness of the netting it can test, 1" mesh can just be squeezed over the jaws. This device is not considered to be as accurate as the other devices that were examined because of the difficulty in controlling the rate of loading and the need to convert readings to net tension using a calibration chart. It is difficult to control the rate of loading with this device. Small nets break quickly with minimal force while heavier nets require significant force, not easily applied by a smaller person. For this reason it is possible that back problems may result from regularly using this device.

Readings obtained from the torque wrench must be converted to a net tension using a calibration chart, this increases the potential for error and loss of accuracy. Other reading problems with this device are described above.

The manufacturer of the digital torque wrench does not recommend that it be used outside.

The device costs about $1000 with an analog torque wrench (hard to get a peak reading on), or about $2200 with a digital torque wrench (not suitable for use outdoors).

b) "**Hydaq**", from Norway (Campbell River Net Loft).

This is a basic arrangement of a small hydraulic cylinder which spreads open a small set of jaws in the shape of a "C". Hooks at each side of the jaw engage the netting. The cylinder is connected via a hose to a separate manual hydraulic pump having a pressure gauge. There is a calibration curve to convert pressure read into tension force. The cylinder has limited travel, so to accommodate different mesh sizes there is an adjusting screw. The hand pump is of a size that breaks smaller nets with just one or two strokes of the pump, which makes controlling the loading rate difficult. The small hydraulic gauge does not read to a high precision; the numbers read must then be converted to a net tension using the calibration chart, so there is an increased potential to compromise accuracy. The device is small and quite portable.

The approximate cost for this device is estimated at somewhere between $1,000 and $2,000, dependant somewhat upon the quality of the hydraulic components used and the frame material selected.

c) **DFIS 500 Digital Force Gauge, c/w Test Stand**, used by DFA Newfoundland:

This is a digital tension dynamometer mounted on a hand screw-driven test stand. The operator rotates a wheel that engages screws and raises a crosshead, applying tension to the net. It would be relatively easy to control the approximate rate of loading. The accuracy of this device is comparably high as the dynamometer reads the tension directly, and captures the peak reading electronically. The DFIS 500 is reported to be acceptable for some outside use, but is not intended to get very wet. The test stand with the dynamometer is fairly portable, weighing in at about 37 lbs.

This device, gauge, and stand together cost about $5,000 to $6,000. This higher cost, along with an applied force capacity of only 250 lbs, are the main drawbacks to the device.

d) **#OBE-1 Net Tester**, developed by M.M. Johnson Ltd.

This device employs a digital tension dynamometer mounted on a testing stand which uses a hydraulic jack (bottle-style) to raise a pivoting arm, lifting the dynamometer and applying tension to the netting until it breaks. The dynamometer reads the tension directly, and captures the peak reading, so accuracy is high. More than one model of dynamometer can be mounted, however, the preferred one (see Table #1 for a comparison of dynamometer models) is a DynaLink MSI-7200-500, manufactured by Measurement Systems International in Seattle, Washington.

This dynamometer unit, with a capacity of 500 lbs and an accuracy of ½ lb, is sealed from the weather and is reportedly very rugged and durable. The stand, constructed of welded 6061-T6 aluminum with stainless steel hardware, is sturdy and corrosion resistant. With a total weight of under 20 lbs and a folded size of about 14 in. x 5 in. x 20 in., the unit is very portable. The rate of loading is controlled by timing the strokes of the jack handle (operator can count "one-one thousand, two-one thousand…etc..). One stroke per second corresponds to a loading rate of 10 inches per minute.

Cost for the dynamometer itself is about $1700. The prototype of the test stand involved design and experimentation and therefore the cost was higher than it would be for a production version. It is estimated that the stands, complete with the correct hydraulic jack and testing hooks, could probably be supplied for $500 or less each. Total cost for stand and dynamometer would then be about $2200.

The basic geometry and appearance of this device is shown in Figure #1 at the end of this report.

2.5 Selection of Device

As the device developed for the project, the #OBE-1 stand with DynaLink digital tension dynamometer, met the basic criteria and other available devices did not, it was chosen as the device for use in the remainder of the project.

The other devices were evaluated for the comparisons outlined above, but were not used for further testing of nets for the subsequent stages of the project.

2.6 Verification Testing by Independent Laboratory

The #OBE-1 device, or for that matter any device using a manual hydraulic pump, actually applies its loading in a series of small steps. If the steps are consistently applied at a given rate, ie one per second, it is possible to determine an average rate of loading. An average rate of loading approximates a constant rate of loading and should provide a similar accuracy in test results. To test this assumption, an independent laboratory was engaged to conduct verification testing on a sample of mesh provided by M.M. Johnson Ltd.. Intertek Testing Services (ITS), of Coquitlam, BC, has more sophisticated, lab-based equipment capable of applying the load at a steady rate.

The sample was from the mesh identified as ID #6, Manufacturer #1, knotless nylon, mesh size 1.75”, gauge 210/96. The lab testing was carried out using a Riehle Universal Testing Machine with an elongation rate of 9.6 inches per minute and using 3/16” diameter hooks (supplied by M.M. Johnson Ltd.) to engage the mesh. All variables were kept constant between the tests performed by M.M. Johnson Ltd. and those by ITS, except for the method by which the load was applied. Thirty breaks were carried out on the mesh sample, in accordance with the testing protocol developed during this project.

The full test report for the testing carried out by ITS can be found in Appendix B, at the end of this report. A summary of the data is shown in the table below. The table also shows test results obtained by M.M. Johnson Ltd., using the #OBE-1 device, for sample ID’s #6 (same as sent to ITS), #56 (a dipped sample of #6), and #39 (Pen #5, a dipped 4 year old, 1.5” mesh, 210/96 gauge from the same manufacturer). Note that the results for ITS #6, MMJ #6 and MMJ #56 are all based upon 30 tensile breaks, while the results for MMJ #39 are based upon 52 tensile breaks, 4 from each of 13 locations on a net pen.

<u>Summary of Manufacturer #1, 210/96 Gauge Breaking Strength Test Results</u>

Net ID	Description	Minimum (lbs.)	Maximum (lbs.)	Mean (lbs.)	Std. Dev.
ITS#6	New, untreated	181	236	211	15.2
MMJ#6	New, untreated	174	235	207	15.5

These additional results are offered to show the low significance of the observed variation in break strengths between ITS using a Riehle Universal Testing Machine and M.M. Johnson Ltd. using the #OBE -1. The results from the sample tested by ITS have a mean tensile strength 2% higher than the results obtained using the #OBE -1.

A paired-sample t-Test was carried out to determine whether the results obtained by Intertek are significantly different to those obtained by M.M. Johnson Ltd. using the #OBE-1. At the 5% significance level and a sample size of 30, we found the differences were not statistically significant (ie; $t = 1.15 < 1.70$). From this we conclude that the effects of applying load as provided by the #OBE-1 device is not significantly different than the effect of a completely smooth rate of application, and the device is acceptable for the intended use.

2.7 Use of Device

Subsequent to the choice of the #OBE-1 device for testing, a large number of breaks, approximately 5000, were performed on the variety of mesh samples obtained, as further described below. The device held up well and no significant problems occurred. A second version of #OBE-1 was built near the end of the testing to improve the stability of the stand and to make it easier to time the rate of loading (this second version is the one shown in Figure #1 and shipped to BC Fisheries).

2.8 Alternative Devices

The choice and use of the #OBE-1 device for this project is not intended to imply that it is the only acceptable testing device. The standard testing protocol developed and described in Section 3 and Appendix C, does not specify a particular device. Rather, the protocol is performance-based, meaning that it defines criteria for the measuring instrument, hook size, and ability to provide a defined average rate of loading, in addition to the sampling requirements for testing etc.

Any testing machine that meets the specified parameters and the needs of the user (durability, portability, cost, etc.) would be acceptable for the purpose of net pen testing. It may be possible to design modifications or adjust the operation of existing devices to accommodate the specified requirements; such work was beyond the scope of this project.

3. TESTING PROTOCOL

3.1 General

The second phase of the project called for the development of a standard testing protocol that would ensure consistent testing conditions between different testers and which could be performed easily in a net loft facility or on a fish farm.

The challenge with establishing such a protocol, once a suitable device has been identified to actually perform the testing, lies in establishing the acceptable compromise between accuracy and practicality. The former leans towards controlled, uniform, laboratory-style conditions with a large number of breaks for each test point. The latter demands that testing accommodate more variable conditions, be performable in the field (whether in a net loft, storage yard, or fish farm), be simple, and be reasonable in terms of cost. With respect to cost, for instance, performing a large number of breaks for each test point would incur a considerable expense not only to do the breaks, but also to repair the net afterwards.

The thrust of this phase of the work, therefore, was to investigate a number of parameters which might affect the test results and determine how significant each factor was, then decide to what extent it should be incorporated into the standard testing protocol. This involved creating a series of tests in which all factors were held constant except the one being investigated, performing this for a suitable number of mesh samples representative of the range available, and interpreting the results with respect to accuracy and practicality.

The end result of this phase of the work was the creation of a draft “Net Pen Mesh Testing Procedure”, which is included at the end of this report as Appendix C.

3.2 Existing Testing Standards

Regulations of other jurisdictions (Newfoundland, Maine) specify testing for residual breaking strength and require the use of “an electronic dynamometer or similar tension scale instrument”, but do not go beyond this in specifying the testing protocol. The most applicable existing written standard for this type of testing (single mesh tensile breaking strength) is International Standard ISO 1806: “Fishing Nets – Determination of Mesh Breaking Load of Netting”, 1973.

ISO 1806 allows for some variety of testing machines and testing conditions, however, as a testing standard, it is more appropriate for manufacturing testing, acceptance testing of new mesh, etc.. Some of its requirements make it rather impractical for the ongoing, field-oriented type of testing required here. These include:

- a specified time-to-break of 20 seconds ± 3 seconds. In order to meet this time requirement for a range of meshes, a machine that can be adjusted for different rates is needed, and preliminary test breaks must be made for each mesh to determine the correct rate of load to break the mesh in the specified time. For meshes that are employed in the BC finfish aquaculture industry, this results in a very slow rate of load application in order to meet this requirement.

- at least 20 individual breaks are required for each test point

- wet or dry conditions are allowed for, but must be specified in acceptance criteria.

Finally, ISO 1806 dates from 1973, and was intended for knotted nets, whereas the vast majority of nets in BC aquaculture service are of the knotless variety. It was decided that ISO 1806 is not completely suitable as a protocol for testing of existing net pens, and it is used herein as a reference and for general guidance only.

3.3 Test Parameters for Investigation

In order to undertake a series of test procedures to help define a suitable testing protocol, the first steps taken were:

a) to determine an appropriate number of test breaks for each sample to ensure accuracy, and

b) to decide upon a testing rate (average rate of loading) which is both practical and sufficiently accurate.

Once these two parameters were established, they were considered to be an established part of the testing protocol, and were fixed for the remainder of the project.

3.3.1 Number of Breaks per Sample for Project Testing

In order to determine a suitable sample size to be used for all subsequent testing in this study, three samples were each tested with a total of 50 breaks each. Sample statistics were then generated (see the following tables) at even 10 break increments. By subjectively evaluating these statistics, it was determined very little shift in the mean, standard deviation or confidence interval was obtained above 30 breaks. Based upon these observations, a sample size of 30 was selected for subsequent testing. Note that at this stage of developing the testing protocol we had not yet decided upon a testing rate of 10”/min.; the data generated in this phase of testing was at an elongation rate of approximately 3”/min. Some differences between this data and what is shown elsewhere in the report may be evident.

Sample I.D. #	Sample size 10		Sample size 20		Sample size 30		Sample size 40		Sample size 50	
	Mean	Std. Dev	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std Dev.	Mean	Std. Dev.
6	221	14.6	225	15.5	224	15.0	225	14.2	225	14.0
27	168	10.3	169	11.2	172	12.5	172	11.3	172	10.5
9	127	3.6	126	9.5	127	8.7	128	8.8	126	9.3

Sample I.D.#	95% Confidence Intervals				
	Sample Size 10	Sample size 20	Sample size 30	Sample size 40	Sample size 50
6	211-230	218-232	218-229	220-229	221-229
27	162-175	164-174	168-177	168-176	170-176
9	125-129	122-130	124-130	124-131	124-126

3.3.2 Rate of Testing

Five different net samples were subjected to thirty breaks at each of six different rates of elongation varying from 3.0 inches per minute to 15.1 inches per minute. The results are listed in Table 4, and plotted in Figure 2, at the end of this report. It was desirable for this project to set a constant rate of loading for all mesh sizes, one that was also practical for regular use, and a rate of 10 inches/minute was decided upon. The final version of the #OBE-1 tester was proportioned such that one stroke of the hydraulic pump per second provides an average rate of loading of 10 inches/minute.

The test results show that in some cases a higher strength, up to about 10%, will result if the testing is slowed down to 3 to 5 inches/minute from 10 inches/minute. Depending on the size of the mesh involved and the degree of elongation, ISO 1806 would require a loading rate of between 3 to 8 inches/minute, therefore it is likely that following the ISO protocol will give slightly higher results in some cases. However, as noted earlier, the ISO testing protocol involves adjusting the rate of elongation to provide a mesh failure at between 17 to 23 seconds, hence requiring a testing device that will accommodate a variable loading rate.

In our opinion, the difference in strengths obtained at the fixed rate of 10 inches/minute compared with the variable rate (fixed time-to-break) provided by ISO were small enough to warrant selecting this fixed rate for all of the testing. This is a practical decision aimed at providing consistent results without significantly increasing the testing time or complexity of the testing.

We note that one of the net manufacturers, WarpTech, advises that the standard rate of testing for their in-house testing is 10 inches/minute.

All subsequent testing for this project used an average testing rate of 10 inches per minute. The actual rate is approximate to some degree, subject to the timing of pump strokes by the operator, but is estimated to be within ±10% of the intended average rate.

3.3.4 Size of Hook

The testing apparatus includes two curved stainless steel hooks that engage the mesh to apply the load. These hooks are formed from round rod stock, and this test was done to determine whether the mesh strength was very sensitive to the size of the rod. Note that "hook diameter" here refers to the diameter of the rod, not the formed diameter of the hook itself.

The hook incorporated into the device is of 3/16" (5 mm) diameter. One size larger, ¼" (6.4 mm), and one size smaller, 5/32" (4 mm) were tested to determine this effect. Four samples of mesh were tested, the results are shown in Table 5 at the end of this report.

Paired-sample t-Tests were used to assess the significance of hook size to strength test results. The analysis showed that for two out of eight samples, hook size was a significant factor.Differences were found to be significant at the p=.05 level when results for larger (1/4") and smaller (5/32") hook sizes were compared to the 3/16" hook size. ($t \geq 1.70$, $p<.05$, $n=30$).

Net I.D.#	t-values	
	5/32" Hook Size	1 /4" Hook Size
5	3.95	0.53
7	1.05	0.85
11	0.17	3.42
28	0.53	0.63

For the standard testing protocol, the required hook diameter has been set at 3/16" (5 mm) to reflect these results.

3.3.5 Mesh Orientation

ISO 1806 requires that testing be done so that load is applied to the sides, or "bars" of an individual mesh, with no contact of the knots (joints) with the hooks. To test this, four samples were tested in two orientations, one as required by ISO, and one with the knots (joints) of the mesh aligned on the hooks ("diamond" style). Paired-sample t-Tests were used to analyze the results. The results are shown in Table 6 at the end of this report.

The analysis showed that mesh orientation was a significant factor in all four samples tested ($t \geq 1.70$, $p < .05$, $n=30$).

Net I.D. #	t-values
6	1.72
9	2.49
24	2.34
27	4.09

Therefore the standard testing protocol was written to require testing with the mesh being hooked on bars.

3.3.6 Number of Mesh Engaged

Some types of testing devices may require that for small meshes, more than one mesh is engaged during the test, contrary to ISO 1806. Paired-sample t -tests were used to determine whether the number of mesh engaged in the hook is a significant factor in strength test results. Three samples of mesh were tested using one, two, or three meshes engaged in the hooks; results are shown in Table 7 at the end of this report.

Two out of three tests showed significant differences between results obtained from engaging a single mesh compared to engaging multiple mesh (2 or 3). Differences were significant at the p=.05 level ($t \geq 1.70$, $p<.05$, $n=30$). Therefore we recommend single mesh testing for the standard protocol.

Net I.D. #	t-values	
	2 mesh	3 mesh
5	4.75	6.11
7	6.79	3.61
11	0.27	1.39

3.3.7 Wet or Dry Condition

ISO 1806 allows for testing of either wet or dry mesh, but requires specifying which one is to be used. The existing BC Regulation lists “wet mesh breaking strength” in the tables for required residual strength of nets.

To consider the effects of wet vs. dry testing, four mesh samples were tested under both conditions. Wet samples were soaked in accordance with ISO 1806 (minimum 12 hrs soak in tap water at room temperature, shake off excess water). The results of the tests are shown in Table 8 at the end of this report.

Paired-sample t -Tests were used to determine whether results obtained from testing of dry mesh were significantly different than results obtained from testing of wet mesh. In three of four samples the differences were found to be statistically significant (ie; $t \geq 1.70$, $p<.05$, $n=30$). Note that in all three cases where the results were significant, dry mesh strength was higher than wet mesh strength.

Net I.D.#	t-Test Result
5	1.92
6	1.51
10	3.28
11	2.35

In practical terms, it is desirable that mesh may be tested either wet or dry. Many nets are tested indoors at the net lofts, when the mesh is dry, while it may be necessary to test others outdoors in a net loft yard or at a fish farm. It may be very impractical to conduct dry mesh field tests of a net at a farm site, should this become necessary. Notwithstanding that the differences in the test results are statistically significant, the standard testing protocol was therefore written to allow the mesh to be either wet or dry at the time of testing. If this recommendation is not accepted, a decision will have to be reached on which condition (wet or dry) will be most practical to achieve for all testing. This will require industry input.

3.3.8 Number of Breaks of a Sample in Practice

While the number of breaks per sample was set at 30 for the purposes of establishing the protocol and examining the net strength standards, a much lesser number is desired for actual in-service testing. The current B.C. Aquaculture Regulation requires that each test consist of the average of three breaks. This is consistent with Newfoundland and Maine standards as well.

Over the course of this study, M.M. Johnson tested and analyzed a total of 40 new dipped and undipped mesh samples. In order to determine a minimum sample size for the proposed net pen mesh testing procedure, sample means for small sample sizes were compared to the 95 percent confidence interval for a sample size of 30. The object of this analysis was to determine the minimum number of breaks of a given mesh in order for the mean of this sample size to fall within the 95 percent confidence interval for a sample size of 30. The results for all 40 net samples are shown in Table 9 at the end of this report.

The results of this analysis are summarized in the following table. If the protocol sample size is three, then only 50% of the total number of samples have mean breaking strength values that fall within the 95% confidence interval of the sample size of 30. M.M. Johnson Ltd. recommends that the minimum sample size used for the proposed net pen mesh testing procedure be five. For the 40 samples tested, 80 percent fall within the 95 percent confidence interval at this sample size.

Sample size	Number of mean strength results that fell within 30 break 95% C.I. of the mean.	Percent of Total
3	20	50%
4	27	67.5%
5	32	80%
6	33	82.5%
7		
8	34	85%
9	35	87.5%
10	36	90%
11	37	92.5%
12		
13	38	95%
14	39	97.5%
15	40	100%

3.4 Conclusions and Recommended Testing Protocol

The result of this phase of the work is the draft “Net Pen Mesh Testing Procedure”, which is included at the end of this report as Appendix C. In summary, this protocol provides for testing with the following parameters:

- use of direct-reading electronic force measurement
- peak load recording
- constant rate of elongation = 10 in/min ±10%
- hooks 0.1875” diameter
- testing of a single mesh, oriented on the bars
- wet or dry testing
- breaking strength = average of 5 breaks for one test location
- detailed recording of results.

A sample testing record form is also included with the draft procedure.

As outlined in portions of the preceding text, this testing procedure is intended to be a compromise between accuracy and practicality, for the specific purpose of monitoring the ongoing strength of nets pens in service in BC finfish aquaculture. It does not pretend to be as precise as the procedure in ISO 1806, but is felt to be appropriate for the intended use.

4. MINIMUM BREAKING STRENGTH REQUIREMENTS

4.1 General

The third and final phase of this project involved the testing of existing net pens of various dimensions and mesh sizes in order to help determine their appropriate breaking strength values. The intention of this work was to validate and/or revise the current minimum breaking strength values given in Section 13 of the BC Aquaculture Regulation.

As the project proceeded it was realized that it would be helpful to add the following testing to this phase of the work:

a) testing of the remaining samples of new net that had not been tested during the course of establishing the standard testing protocol. This provided a larger sample for comparing strengths of new netting obtained by M.M.Johnson Ltd. to the manufacturer’s given breaking strengths. This also ensured that all older mesh tested as part of the net pen testing would have a set of test results representing the new mesh from which the net pen was originally made.

b) testing of a significant number of samples of mesh which had been dipped in antifoulant. Some of the early testing tended to indicate that new mesh was typically weaker after being dipped. Due to the increasing use of dipping and the significance of this effect, it was felt necessary to perform an increased number of tests to compare different meshes before and after dipping. A total of 13 different new mesh samples were eventually tested this way.

A total of ten existing net pens of various ages were tested at net lofts. As outlined in Section 1.7 above, testing a greater number of net pens would have been useful but was not permitted by the timeframe of this project. However, the pens tested were quite representative of the range of pens in use, and a reasonable variety of sizes and ages was obtained.

4.2 Testing Performed

4.2.1 Dipped vs. Undipped Mesh

Thirteen samples that had been dipped in antifoulant coating were tested and compared to samples of identical mesh that had not undergone antifoulant treatment. As far as we were able to determine the antifoulant was the same type in all cases, one commonly used in the local industry. Dipping when freshly done was let to dry in the normal way, then testing was performed on the dipped sample as well as the corresponding undipped mesh. The results of this testing are shown in Table 10 at the end of this report. See note below.

It is clear from the test results that all of the meshes when dipped experienced some reduction in strength, varying from about 5% to 43% for the mean breaking strength. For most of the samples the strength reduction was on the order of 20% to 30%.

Obviously this level of strength reduction due to dipping of new mesh is of interest, since many nets are dipped before being put into service. However, this information should be viewed in light of results from field testing, which indicate that although dipped nets exhibit this initial strength loss, they show considerably less additional loss of strength over time in service, and after several years typically have a greater percentage of residual strength than an undipped net. These results are apparent in Table 14, which is described in more detail later on in this report.

Note: Subsequent to the initial issue of this report, the authors became aware that the manner in which the dipped samples supplied to us for this study were prepared may not represent the standard practice used within the industry for dipping of mesh. Therefore reported strength losses may vary from industry findings. See also section 4.4.4.

4.2.2 New Mesh Testing Compared to Manufacturer's Breaking Strengths

Manufacturers of mesh provide lists of nominal breaking strengths corresponding to different gauges of the twine which make up the mesh. Determining the means by which manufacturers arrive at these figures was beyond the scope of this project, in addition this information is difficult to obtain due to its confidential nature. There are reportedly some discrepancies in the way in which different manufacturers report breaking strength; some may give the minimum strength obtained while others may give the maximum result. Some companies may also give the mean strength as their breaking strength value. In the future it may be helpful to pursue additional information on the source of manufacturers' breaking strengths

It is important to note that the net samples tested by M.M.Johnson Ltd., although "new", have an unknown history prior to arrival in our office for testing. Some may be newer than others, and some or all may have already deteriorated in some degree (from environmental conditions in shipping and storage) since they were manufactured.

For the purposes of this project, the manufacturers' breaking strengths as provided have been reported throughout the tables in this report, as a means of comparison only. Table 3, introduced earlier, summarizes manufacturers' breaking strengths as provided to us. As can be seen, breaking strength is reported by the gauge (size of the twine) which makes up the mesh, independent of the mesh size. Variations in reported breaking strength between different manufacturers for the same gauge of mesh can be seen in this table.

Table 11 shows the results of testing of new mesh compared to the manufacturer's breaking strengths (also referred to below as "reported strength").

Comments on Table 11:

- the mean value of the tested breaking strength is in most cases lower than the manufacturer's breaking strength, typically by 11% to 20% or so. As this is on the order of one to two standard deviations less than the reported strength, this would suggest that a maximum strength test value is being reported by the manufacturer.

- several samples tested at a mean strength of very close to the manufacturer's breaking strength, suggesting that the mean is reported in these cases.

- only one sample tested at a value significantly higher (14%) than the reported strength. This would suggest that a minimum strength test value is reported in this case.

- there is no particular pattern of test values being higher or lower than reported strength corresponding to manufacturer, other than to note that all of Manufacturer #3's samples tested from 12% to 24% lower.

It must be reiterated, especially in light of the last comment, that tested vs. reported differences may also be due to other factors not discovered during this project, and not just how the strengths are reported. For instance, there may be different testing protocols, such as ISO 1806, in use to arrive at the reported strengths. The presentation of these results is not meant to judge the validity of the manufacturer's reported strengths. However, the general conclusion was reached that for all further work, assessment, and comparisons for the project, the mean tested breaking strength would be used as a baseline rather than the reported manufacturer's strength.

4.2.3 Testing of Existing Net Pens

The ten complete net pens that were tested ranged in size from 188 ft. perimeter by 33 ft. depth to 400 ft. perimeter by 60 ft. depth, and in age from two years to seven years. Six of the nets were antifoulant-dipped, three were undipped, and one was partially dipped.

The pens were tested in accordance with the proposed standard testing protocol developed, with strength given as the average of 3 breaks at each point (except one using 4 breaks and one using 5 breaks). The number of points tested, however, was greater than that required by Section 13 of the current Regulation. Testing was done on the jump net and at 5 ft. intervals down the full depth of the net, giving from 8 to 15 test points, whereas the Regulation calls for a total of five points on the pen.

Detailed summaries of these tests are shown in Table 12 at the end of this report (5 pages). These summaries show the details of the net, the values obtained from testing of the corresponding new mesh sample, and the breaking strengths from the field testing. As can be seen in this Table, no particular pattern of strength loss with respect to depth below the waterline was observed.

A simple regression analysis was carried out to determine whether residual net strength of used nets is correlated to depth below water line. This data is tabulated

below for eight of the ten net pens tested by M.M. Johnson Ltd. Two net pens were rejected for this analysis as one contained mixed dipped and undipped netting, while the other contained mesh of two different ages. The results show that for seven of the eight net pens, the 95% confidence interval for the slope coefficient encompasses zero. This analysis provides strong evidence that residual net strength does not vary with depth below water line.

Pen #	Net I.D.#	Mean Strength (lbs.)	Intercept Coefficient (lbs.)	Slope Coefficient	95% C.I. Slope Coefficient
1	34	84	87	-0.26	-1.00 to 0.49
2	33	141	140	0.03	-0.39 to 0.44
4	36	108	113	-0.21	-0.32 to -0.09
5	39	141	145	-0.14	-0.32 to 0.09
6	42	135	135	-0.03	-0.34 to 0.29
7	43	202	193	0.25	-0.23 to 0.73
8	44	144	150	-0.35	-0.98 to 0.28
10	55	230	219	0.70	-0.02 to 1.43

Table 13 shows a summary of the mean tested strengths, excluding the jump fence portion, for all ten net pens tested, along with the tested strength of the corresponding new mesh. Also shown are the Dimension Class for each pen, in accordance with the current BC Regulation, and the corresponding minimum breaking strength requirement for the Dimension Class and mesh size. This comparison shows that only three of the ten pens would meet the current requirements, one of these by a small margin.

Also shown in Table 13 is a column indicating the breaking strength corresponding to 65% of the current Norwegian standard for breaking strength of new mesh used in net pens. This is the acceptance criteria for residual strength of mesh currently used in the Norwegian finfish farming industry (there is further discussion about this below). Comparing the tested net pen strengths to this standard, seven of them would meet the requirement, three of these by a small margin.

The final two columns in Table 13 shows the value of breaking strength for new mesh from the Norwegian standard and the percentage of this strength that the mean tested strength of the ten net pens represents. This percentage value varies from 42% to 100%.

4.3 Assessment of Results

Table 14 at the end of this report shows an overall summary of all the testing results which followed the proposed standard testing protocol: new untreated mesh samples, dipped new samples, and field tests on net pens.

As previously mentioned, results from testing of net pens and dipped new nets are in this report compared to the mean tested breaking strength, rather than the

manufacturer's breaking strength. Based on this comparison, the following general observations are made from a perusal of Tables 13 and 14:

a) dipped net pens in service for a period of 4 to 7 years typically show a residual breaking strength of 68% to 77% of the tested breaking strength when new.

b) one dipped net pen in service showed a residual strength of 49% of the tested breaking strength when new. This net was made up of more than one age of mesh.

c) untreated (not dipped) net pens in service for a period of from 2 to 5 years typically showed a residual breaking strength of 53% to 62% of the tested breaking strength when new.

d) the original choice of mesh strength for net pens, compared to the requirements for residual breaking strength in the B.C. Regulation, varies considerably.

4.4 Recommendations

4.4.1 Review of Breaking Strength Requirements of Other Jurisdictions

Information on the mesh breaking strength requirements was available from the following other jurisdictions:

- Norwegian Aquaculture Industry
- Newfoundland Department of Fisheries and Aquaculture
- Maine Aquaculture Industry

Excerpts from the Codes of Practice for these jurisdictions relating to mesh breaking strengths are contained in Appendices E, F & G at the end of this report.

The requirements provided by Maine and Newfoundland are brief and similar:

The requirements provided for the Norwegian industry (Appendix E) are more extensive, providing a means of classifying each net pen by its overall dimensions and mesh size and setting the required breaking strengths accordingly. The breaking strengths that are given are for the mesh when new, not the residual strengths. The acceptance criteria for nets in service is then given as 65% of the new strength for the wetted portion of the net and 60% of new strength for the jump fence portion.

Jurisdiction	Type Of Net Pen	Mesh Size (inches)	Minimum Gauge	Required New Mesh Strength (lbs)	Required Residual Mesh Strength (lbs)	Required Residual as a % of New Strength	Comments
Newfoundland	Smolt Nets	1-1/8” to 1-3/8”	210/40	114	80	70	All nets required to be UV protected and antifoulant treated
			210/60	185	80	43	
	PreMarket Nets	1-7/8” to 2-3/8”	210/60	185	120	65	
			210/80	205	120	59	
Maine	Smolt Nets	1-1/8” to 1-3/8”	210/60	125	80	64	All nets required to be UV protected
	PreMarket Nets	1-7/8” to 2-3/8	210/80	185	120	65	

The Norwegian standards are based upon an expected life span for each net of five years.

These Norwegian requirements appear to be fairly well known in the B.C. aquaculture industry. They are used by at least one major B.C. net loft as their standard for the selection and ongoing testing of nets.

The Norwegian system served as the basis for the original development of the current B.C. Regulation, with the same type of dimension classification, however, the values of the required breaking strengths were adjusted to show the residual breaking strengths required, rather than the new net strengths required.

4.4.2 Comparison of Current BC Regulation With Norwegian Standard

The existing BC Regulation is based partially upon the Norwegian standard, the two industries are closely linked, and the needs appear to be quite similar. Table 15 compares the Norwegian standard for new net pens, the Norwegian acceptance standard for in-service testing of net pens (65% of new), and the acceptance standards from the current B.C. Regulation. These values are shown for all of the Dimension Classifications (pen size and mesh size) provided by the two jurisdictions. In some cases the current B.C. requirements are less than the Norwegian requirements, and in some cases greater.

Also to be seen from comparing this table to Section 4.4.1 above is that the acceptance standards for in-service net pens in Maine and Newfoundland correspond approximately to somewhere between Dimension Classes C & D in the Norwegian standard. This means that Norway has less rigorous requirements than Maine and Newfoundland for smaller pens, and more rigorous standards than Maine and Newfoundland for larger pens.

4.4.3 Recommendations for Revisions to B.C. Regulation

This study provides no research to determine physically what strength of mesh is needed for the construction of net pens to cope with the demands of the stock, the environmental conditions, handling, deterioration, etc.. The best guidance for the determination of suitable requirements for the initial mesh strength will come by reference to the necessary strengths established and proven by the industry in various jurisdictions over the years, as outlined above.

What the results of this study do show is that a figure of 65% of new strength, as used by Norway, Maine, and Newfoundland, is representative of the typical expected loss of strength for a net after five years in the water (possibly after less time if undipped and more time if dipped).

With respect to the values provided in the B.C. Regulation for required minimum residual breaking strength for net pens in service, the conclusion of this study is to recommend the following:

- set the acceptance values for minimum breaking strength of nets in service at 65% of the values shown in the Norwegian standard for new nets, for the portion below the water line.

- set the acceptance values for minimum breaking strength of nets in service at 60% of the values shown in the Norwegian standard for new nets, for the jump fence portion above the water line.

- revise the Dimension Class table in the Regulation to correspond to the same table in the Norwegian standard, for consistency. This would add one dimension class at the small-pen end of the table, but has no effect on larger pen requirements.

These suggestions have been incorporated into a revised set of tables as contained in Section 13 of the "Escape Amendments to the Aquaculture Regulation", these are attached as Appendix A at the end of this report.

In conjunction with these recommendations, the following revisions to the text portions of Section 13 are suggested:

a) reference to the new Standard Testing Protocol, if adopted

b) revision of Section 13(i)(v) to include a testing point on the jump fence, since the tables show a required strength for it. Consideration should also be given to changing the number of test points to correspond with the other jurisdictions, all of which require "four-point" testing:
   - jump fence
   - the next two metres below the jump fence
   - halfway down the side panels
   - net bottom

c) revision of Section 13(d) to require that the five mesh break points making up a test location be spaced out by some amount, say minimum of 2 metres apart.

d) revision of Section 13(g) to be more specific about when to repair and when to discard, as is done in the Newfoundland and Maine standards.

4.4.3 Sizing of Future Net Pens

The selection of new netting strengths for pen construction with the goal of achieving the required residual strength at the time the pen has reached its intended life span should be left up to the industry. If the above recommendations for required strength are followed, the results of this study would indicate that the initial tested breaking strength of the netting should be 1/0.65 x the required residual strength, or 154%. If the industry will be referring to manufacturer's published strengths for initial sizing, rather than testing, they will want to develop a correlation between these and tested strengths. For many of the nets in this study, for instance, the initial sizing by manufacturer's breaking strength would end up being approximately double the desired residual strength at the end of the net's life.

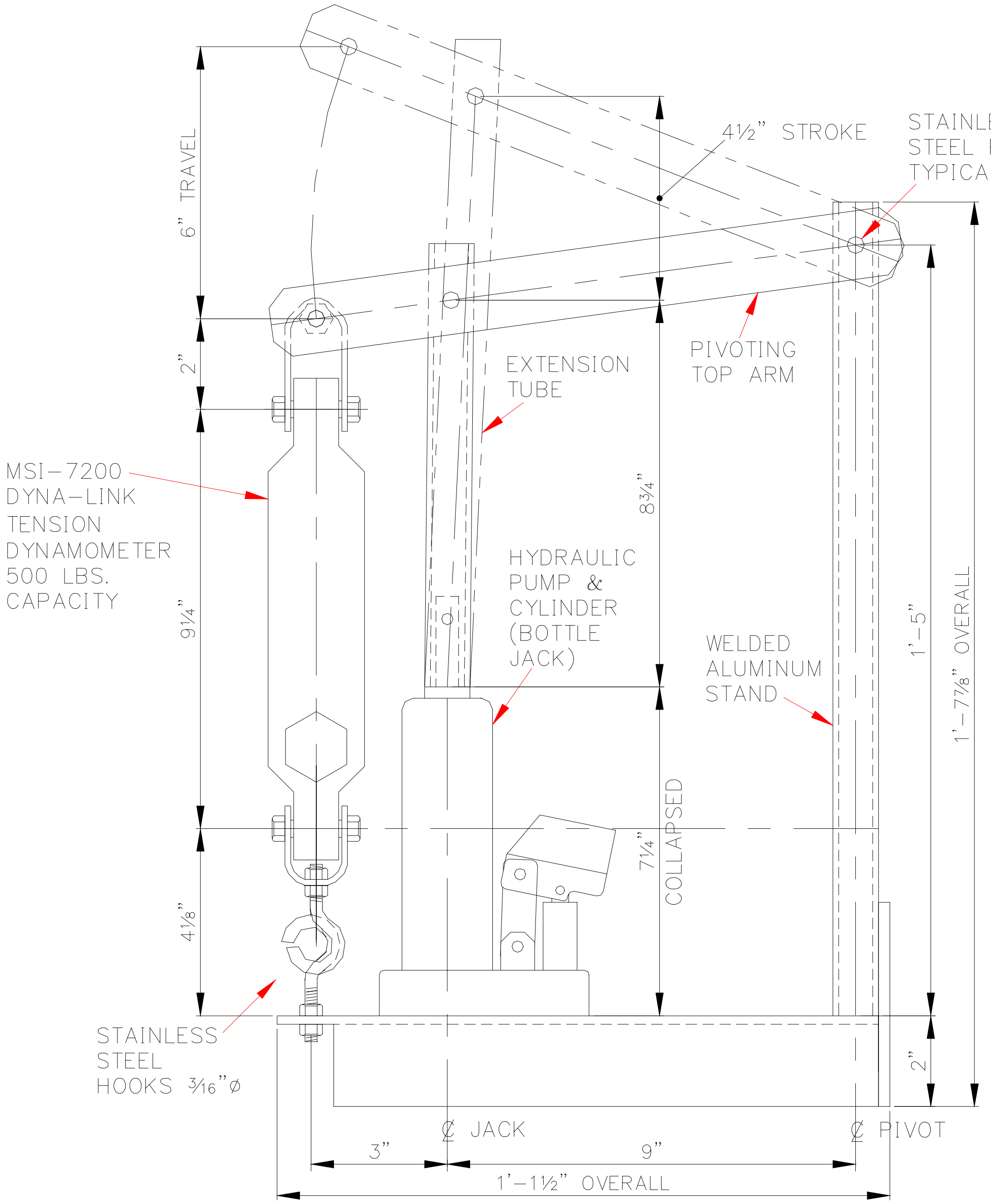
4.4.4 Recommendations for Further Research

A great deal of work went into this project in the consideration of testing devices, development of a testing protocol, and testing of a number of net samples and net pens. The amount of testing work done on existing pens, however, could not be considered exhaustive, and in the opinion of the authors, an ongoing program to continue to expand this data would be of great benefit. More extensive testing will over the long term provide increased confidence in conclusions, or be the cause for future revisions, especially if there are ongoing changes in technology. The ongoing tracking of individual nets over a period of years would provide especially valuable additional data.

Such additional research need not be expensive, it is an ideal job for a co-op engineering student or technology student who could be dedicated to the project and make the rounds of net lofts. Alternatively, individual net lofts could be requested by BC Fisheries to enter into a data-sharing arrangement that would involve tracking net pens from cradle to grave.

As noted in section 4.2.1, the samples of dipped mesh supplied to us for this study may not have been prepared in a manner representative of the standard practice used within the industry for dipping. Further research is recommended to test samples treated in accordance with a dipping procedure that incorporates industry standards for solution concentration, moisture content, drying temperature and time, etc. so that an accurate assessment of the effects of dipping of new mesh can be carried out.

FIGURES



FRONT ELEVATION

CLIENT	MAFF - BC FISHERIES
PROJECT	NET PEN TESTING PROJECT
TITLE	#OBE-1 NET STRENGTH TESTER

M.M. JOHNSON LTD.
STRUCTURAL ENGINEERS

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DRAWN BY: CTL	SCALE: 3" = 1'-0"
ENG: MMJ	DATE: 01 NOV 02
CH: —	DWG.No.: FIG. 1 / REV.No.: —

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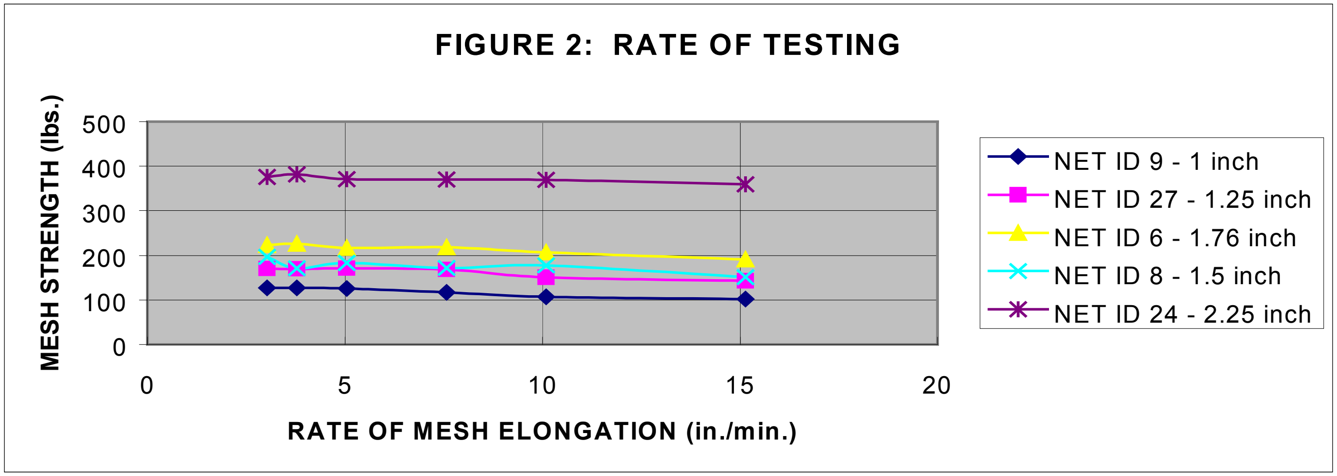
FIGURE 2: RATE OF TESTING
MESH STRENGTH (lbs.)
500
400
300
200
100
0
0
5
10
15
20
RATE OF MESH ELONGATION (in./min.)
NET ID 9 - 1 inch
NET ID 27 - 1.25 inch
NET ID 6 - 1.76 inch
NET ID 8 - 1.5 inch
NET ID 24 - 2.25 inch

TABLES

TABLE 1: COMPARISON OF TENSION DYNAMOMETERS FOR NET TESTING

Manufacturer	Chatillion	DynaLink	Dynafor	Dillon
Model	DFIS 500	7200-500	LLX-500	ED-2000
Type	Digital	Digital	Digital	Digital
Cost	$1,621	$1,700	$1,800	$1,600
Maximum Load (lbs)	500	500	500	2000
Increments (lbs)	0.5	0.5		0.5
Accuracy (%)	0.15%	0.10%	0.20%	0.10%
Accuracy (lbs)	0.75	0.50	1.0	2.0
Durability	Avoid rain, but outside OK	Weatherproof	"A little rain won't hurt it"	Weatherproof
Shock Resistant	Yes	Yes	Yes	Yes
Peak Reading Hold	Yes	Yes	Yes	Yes
Weight (lbs)	2	5	2.5	4
Length (inches)	3	4.5	3	5
Width (inches)	2	2	2	1
Height (inches)	8	11	7.5	9
Delivery Time	>2 weeks	<2 weeks	>2 weeks	1 week
Notes		This is the unit chosen for MMJ Ltd. testing. Most accurate, weatherproof, cost similar, other required parameters met.		

TABLE 2 NEW NET SAMPLE IDENTIFICATION

NET ID	MESH SIZE (inches)	GAUGE 210/	MFR BREAK STRENGTH lbs	TESTED VALUES								
				MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS	NOTES	MFR. #
5	1	48	147	150	150	9.3	6.2	129	169	30		1
6	1.75	96	260	206	207	15.5	7.5	174	235	30		1
7	1	60	196	159	157	12.7	8.1	118	177	30		1
8	1.5	60	196	175	177	25.3	14.3	127	231	30		1
9	1	36	121	108	107	10.1	9.4	87	125	30		1
10	2.125	138	379	354	353	20.0	5.7	318	390	30		1
11	1.25	60	196	147	146	19.8	13.5	104	186	30		1
12	1.25	48	147	125	129	10.5	8.1	113	152	30		1
13	1.5	48	147	135	134	15.4	11.5	90	163	30		1
14	1.25	36	121	102	98	12.2	12.4	61	121	30		1
15	2	108	304	266	266	10.9	4.1	238	286	30	Tarred	1
16	2	60	196	161	164	14.1	8.6	134	193	30		1
18	2	120	350	289	295	29.7	10.1	239	347	30		3
20	1.25	80	245	200	197	12.6	6.4	179	227	30		3
22	2.5	156	423	366	367	22.2	6.0	317	411	30		1
23	2.25	160	450	400	396	33.2	8.4	324	452	30		3
24	2.25	160	385	366	369	32.2	8.7	309	428	30		2
25	1.75	80	190	158	160	20.7	13.0	124	191	30		2
27	1.25	60	150	152	151	10.6	7.1	131	176	30		2
28	1.25	80	190	201	202	15.5	7.7	169	235	30		2
29	2.125	138	379	201	203	17.4	8.6	161	242	30	Dipped	1
30	1.5	72	212	148	148	15.2	10.3	112	171	30	Dipped	1
31	2	108	304	189	188	12.7	6.8	153	210	30	Dipped	1
32	1.625	120	334	289	294	28.3	9.6	245	362	30		2
37	1.5	72	212	214	212	16.9	8.0	142	236	30		1
38	2	108	304	250	253	34.1	13.5	175	309	30		1
41	2	96	260	174	173	12.4	7.2	148	194	30		1
45	1.25	96	203	162	169	34.0	20.2	129	341	30		4
46	2	180	337	385	384	25.1	6.5	334	421	30		4
47	1.625	80	245	184	186	16.2	8.7	151	222	30		3
48	1.25	80	190	140	141	16.7	11.8	118	167	30	Dipped	2
49	2.125	138	379	266	262	20.9	8.0	211	287	30	Dipped	1
50	2	60	196	126	126	13.3	10.6	100	158	30	Dipped	1
51	2	96	260	142	140	13.6	9.7	113	166	30	Dipped	1
52	1.25	36	121	97	91	13.2	14.5	58	104	30	Dipped	1
53	1.25	60	196	133	135	13.3	9.8	113	159	30	Dipped	1
58	1.75	96	260	173	172	12.2	7.1	146	191	30	Dipped	1
59	2	120	350	217	219	16.5	7.6	184	248	30	Dipped	3
60	2.25	160	385	234	231	15.5	6.7	203	266	30	Dipped	2
61	1.625	80	245	157	156	11.0	7.1	135	185	30	Dipped	3

TABLE 3

COMPARISON OF MANUFACTURER'S PUBLISHED BREAKING STRENGTHS

GAUGE 210/	MINIMUM MESH SIZE (inches)	MAXIMUM MESH SIZE (inches)	MFR #	MFR'S BREAKING STRENGTH (lbs)	MMJ LTD. NET NUMBERS
10	3/4"	1"	3	27	
20	1/2"	3/4"	3	65	19
20	1/2"	2"	2	65	
30	3/4"		3	104	
36	7/8"	1 1/2"	1	121	9,14,52(D)
40	1"	2 1/4"	2	101	
40	1 1/8"	1 7/8"	3	125	
42	1"	1 3/8"	1	134	
48	1"	2"	1	147	5,12,13
54	1 1/4"	1 3/8"	1	163	
60	1/2"	2 1/4"	2	150	27
60	1 3/16"	2"	3	195	
60	1 1/4"	2 1/4"	1	196	7,8,11,16,34(P),50(D),53(D)
72			4	174	
72	1 1/2"	2 1/4"	1	212	30(D),37
80	1/2"	2 1/4"	2	190	25,26,28,48(D)
80	1 3/16"	2"	3	245	20,33(P),42(P),44(P),47,59(D)
96			4	203	45
96	1 3/4"	2 1/4"	1	260	6,36(P),39(P),41,51(D),56(D)
100	1 7/8"	2 1/8"	3	275	
108	1 7/8"	2 3/8"	1	304	15(T),31(D),38
120			4	231	
120	1 7/8"	2 1/2"	3	350	18,43(P),54(P),57(D)
120	1 5/8"	2 1/2"	2	334	32
120	1 7/8"	2 1/2"	1	340	
138	2 1/8"	2 1/2"	1	379	10,29(D),49(D)
156	2 1/8"	2 1/2"	1	423	22
160	2"	2 1/8"	2	385	24,35(P),58(D)
160	2"	2 1/2"	3	450	21,23,55(P)
180			4	337	46
352			3	660	17

(T) = tarred
(D) = dipped
(P) = pen

TABLE 4 COMPARISON TESTING FOR RATE OF TEST (USING PROTOTYPE TESTER)

NET ID	9	SECONDS/ STROKE	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MINIMUM lbs	MAXIMUM lbs	NO. OF BREAKS
MESH SIZE	1”	1	15.1	101	102	10.0	9.8	82	122	30
GAUGE 210/	36	1.5	10.1	108	107	10.1	9.4	87	125	30
MFR BS	121 lbs	2	7.6	119	117	9.4	8.0	103	135	30
		3	5.1	126	125	7.6	6.1	108	139	30
		4	3.8	127	127	7.3	5.8	113	142	30
		5	3.0	129	127	8.6	6.8	99	143	30

NET ID	27	SECONDS/ STROKE	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MINIMUM lbs	MAXIMUM lbs	NO. OF BREAKS
MESH SIZE	1.25”	1	15.1	143	143	16.1	11.3	111	176	30
GAUGE 210/	60	1.5	10.1	152	151	10.6	7.1	131	176	30
MFR BS	150 lbs	2	7.6	169	168	17.0	10.1	126	201	30
		3	5.1	175	171	15.4	9.0	142	204	30
		4	3.8	172	170	10.8	6.4	141	188	30
		5	3.0	171	171	11.4	6.7	143	197	30

NET ID	6	SECONDS/ STROKE	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MINIMUM lbs	MAXIMUM lbs	NO. OF BREAKS
MESH SIZE	1.75”	1	15.1	193	191	20.1	10.5	146	223	30
GAUGE 210/	96	1.5	10.1	206	207	15.5	7.5	174	235	30
MFR BS	260 lbs	2	7.6	222	218	18.4	8.4	183	243	30
		3	5.1	219	217	16.8	7.8	173	250	30
		4	3.8	227	226	16.1	7.1	189	253	30
		5	3.0	224	224	15.0	6.7	189	254	30

NET ID	8	SECONDS/ STROKE	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MINIMUM lbs	MAXIMUM lbs	NO. OF BREAKS
MESH SIZE	1.5”	1	15.1	153	151	26.1	17.2	104	200	30
GAUGE 210/	60	1.5	10.1	175	177	25.3	14.3	127	231	30
MFR BS	196 lbs	2	7.6	174	172	32.0	18.6	113	232	30
		3	5.1	194	184	30.0	16.4	121	224	30
		4	3.8	172	171	31.6	18.4	111	234	30
		5	3.0	203	197	23.8	12.1	133	229	30

NET ID	24	SECONDS/ STROKE	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MINIMUM lbs	MAXIMUM lbs	NO. OF BREAKS
MESH SIZE	2.25”	1	15.1	361	360	33.1	9.2	293	438	30
GAUGE 210/	160	1.5	10.1	366	369	32.2	8.7	309	428	30
MFR BS	385 lbs	2	7.6	365	370	23.6	6.4	311	416	30
		3	5.1	375	371	25.2	6.8	327	432	30
		4	3.8	380	381	29.0	7.6	330	453	30
		5	3.0	370	376	21.4	5.7	350	433	30

TABLE 5 COMPARISON TESTING FOR SIZE OF HOOK

NET ID	5	HOOK DIAMETER	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size	1	5/32"	10	139	140	13.9	10.0	106	160	30
Gauge 210/	48	3/16"	10	150	150	9.3	6.2	129	169	30
Mfr BS	147	1/4"	10	152	151	9.3	6.1	131	171	30
Mean % change from 3/16" Hook:		-7% TO 1%								
NET ID	**7**	**HOOK DIAMETER**	**RATE in/min**	**MEDIAN lbs**	**MEAN lbs**	**SD**	**CV**	**MIN lbs**	**MAX lbs**	**NO. OF BREAKS**
Mesh Size	1	5/32"	10	153	153	13.7	9.0	127	184	30
Gauge 210/	60	3/16"	10	159	157	12.7	8.1	118	177	30
Mfr BS	196	1/4"	10	153	154	11.9	7.7	138	183	30
Mean % change from 3/16" Hook:		-3% TO –2%								
NET ID	**11**	**HOOK DIAMETER**	**RATE in/min**	**MEDIAN lbs**	**MEAN lbs**	**SD**	**CV**	**MIN lbs**	**MAX lbs**	**NO. OF BREAKS**
Mesh Size	1.25	5/32"	10	150	147	22.8	15.5	94	192	30
Gauge 210/	60	3/16"	10	147	146	19.8	13.5	104	186	30
Mfr BS	196	1/4"	10	162	163	17.3	10.7	120	198	30
Mean % change from 3/16" Hook:		1% TO 11%								
NET ID	**28**	**HOOK DIAMETER**	**RATE in/min**	**MEDIAN lbs**	**MEAN lbs**	**SD**	**CV**	**MIN lbs**	**MAX lbs**	**NO. OF BREAKS**
Mesh Size	1.25	5/32"	10	198	200	15.8	7.9	175	247	30
Gauge 210/	80	3/16"	10	201	202	15.5	7.7	169	235	30
Mfr BS	190	1/4"	10	204	205	18.8	9.2	181	275	30
Mean % change from 3/16" Hook:		-1% TO 2%								

TABLE 6 COMPARISON TESTING FOR MESH ORIENTATION

NET ID	9	ORIENTATION	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size (inches)	1	Bar	10.1	108	107	10.1	9.4	87	125	30
Gauge 210/	36	Diamond	10.1	116	113	8.9	7.8	87	127	30
Mfr BS (lbs)	121	% change from bar		7.4%	5.7%			0.0%	1.2%	
NET ID	**27**	**ORIENTATION**	**RATE in/min**	**MEDIAN lbs**	**MEAN lbs**	**SD**	**CV**	**MIN lbs**	**MAX lbs**	**NO. OF BREAKS**
Mesh Size (inches)	1.25	Bar	10.1	152	151	10.6	7.1	131	176	30
Gauge 210/	60	Diamond	10.1	166	165	14.5	8.8	139	197	30
Mfr BS (lbs)	150	% change from bar		8.9%	9.6%			6.1%	12.0%	
NET ID	**6**	**ORIENTATION**	**RATE in/min**	**MEDIAN lbs**	**MEAN lbs**	**SD**	**CV**	**MIN lbs**	**MAX lbs**	**NO. OF BREAKS**
Mesh Size (inches)	1.75	Bar	10.1	206	207	15.5	7.5	174	235	30
Gauge 210/	96	Diamond	10.1	216	215	15.4	7.1	177	241	30
Mfr BS (lbs)	260	% change from bar		4.7%	3.9%			1.7%	2.6%	
NET ID	**24**	**ORIENTATION**	**RATE in/min**	**MEDIAN lbs**	**MEAN lbs**	**SD**	**CV**	**MIN lbs**	**MAX lbs**	**NO. OF BREAKS**
Mesh Size (inches)	2.25	Bar	10.1	366	369	32.2	8.7	309	428	30
Gauge 210/	160	Diamond	10.1	347	350	33.9	9.7	289	447	30
Mfr BS (lbs)	385	% change from bar		-5.3%	-5.1%			-6.6%	4.6%	

TABLE 7 COMPARISON TESTING FOR NUMBER OF MESH ENGAGED

NET ID	5	NO. OF MESH	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size (inches)	1	1	10	150	150	9.3	6.2	129	169	30
Gauge 210/	48	2	10	167	164	10.3	6.3	137	184	30
Mfr's BS (lbs)	147	3	10	166	166	10.6	6.4	142	189	30
		Mean % change from single mesh: For 2: +9% For 3: +10%								

NET ID	7	NO. OF MESH	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size (inches)	1	1	10	159	157	12.7	8.1	118	177	30
Gauge 210/	60	2	10	137	137	8.9	6.5	119	163	30
Mfr's BS (lbs)	196	3	10	164	167	11.3	6.8	150	192	30
		Mean % change from single mesh: For 2: -13% For +3: 6%								

NET ID	11	NO. OF MESH	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size (inches)	1.25	1	10	147	146	19.8	13.5	104	186	30
Gauge 210/	60	2	10	154	148	29.9	20.2	61	193	30
Mfr's BS (lbs)	196	3	10	136	138	31.3	22.7	79	192	30
		Mean % change from single mesh: For 2: +1% For 3: -6%								

TABLE 8 COMPARISON TESTING OF SAMPLES IN WET & DRY CONDITIONS

NET ID	5	WET OR DRY	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size (inches)	1	Dry	10	149.8	150.1	9.3	6.2	129.0	169.0	30
Gauge 210/	48	Wet	10	145.3	145.3	11.0	7.6	122.5	163.0	30
Mfr's BS (lbs)	147	% change from dry		-3.0%	-3.2%			-5.0%	-3.6%	

NET ID	6	WET OR DRY	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size (inches)	1.75	Dry	10	206.0	206.9	15.5	7.5	173.5	235.0	30
Gauge 210/	96	Wet	10	210.3	213.8	17.1	8.0	187.0	243.5	30
Mfr's BS (lbs)	260	% change from dry		2.1%	3.3%			7.8%	3.6%	

NET ID	10	WET OR DRY	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size (inches)	2.125	Dry	10	354.3	353.0	20.0	5.7	318.0	389.5	30
Gauge 210/	138	Wet	10	337.5	335.8	21.4	6.4	298.0	387.0	30
Mfr's BS (lbs)	380	% change from dry		-4.7%	-4.9%			-6.3%	-0.6%	

NET ID	11	WET OR DRY	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
Mesh Size (inches)	1.25	Dry	10	146.5	146.3	19.8	13.5	104.0	186.0	30
Gauge 210/	60	Wet	10	132.5	135.4	24.3	17.9	89.5	183.5	30
Mfr's BS (lbs)	196	% change from dry		-9.6%	-7.5%			-13.9%	-1.3%	

TABLE 9: COMPARISON TESTING FOR NUMBER OF TESTS OF A SAMPLE

			30 BREAK STATISTICS					
NET ID	Mesh Size (inches)	Gauge 210/	Mean B.S. (lbs)	Std. Dev. (lbs)	95% C.I. Lower Limit	95% C.I. Upper Limit	Min. Sample Size	Mean B.S. (lbs)
5	1	48	150	9	147	154	3	136
6	1.75	96	207	15	201	213	3	212
7	1	60	157	13	152	162	3	159
8	1.5	60	177	25	168	187	3	169
9	1	36	107	10	103	111	3	103
10	2.125	138	353	20	346	360	3	347
11	1.25	60	146	20	139	154	4	141
12	1.25	48	129	10	125	133	3	129
13	1.5	48	134	15	128	140	5	140
14	1.25	36	98	12	94	103	3	95
15	2	108	266	11	262	270	5	270
16	2	60	164	14	159	169	3	169
18	2	120	295	30	284	306	8	284
20	1.25	80	197	13	192	202	5	194
22	2.5	156	367	22	359	375	10	359
23	2.25	160	396	33	383	408	5	402
24	2.25	160	369	32	357	381	3	369
25	1.75	80	160	21	152	167	4	153
27	1.25	60	151	11	147	155	3	151
28	1.25	80	202	16	196	208	15	197
29	2.125	138	203	17	196	209	3	200
30	1.5	72	148	15	142	154	3	146
31	2	108	188	13	183	192	13	183
32	1.625	120	294	28	283	305	14	305
37	1.5	72	212	17	205	218	11	218
38	2	108	253	34	240	265	5	251
41	2	96	173	12	168	178	4	173
45	1.25	96	169	34	156	181	3	168
46	2	180	384	25	375	393	6	380
47	1.625	80	186	16	180	192	3	191
48	1.25	80	141	17	135	148	3	140
49	2.125	138	262	21	254	269	4	267
50	2	60	126	13	121	131	3	125
51	2	96	140	14	135	146	4	146
52	1.25	36	91	13	86	96	9	87
53	1.25	60	135	13	130	140	3	137
58	1.75	96	172	12	167	177	3	169
59	2	120	219	17	213	225	4	223
60	2.25	160	231	16	225	237	3	237
61	1.625	80	156	11	152	160	4	156

TABLE 10 COMPARISON TESTING FOR DIPPED VS UNDIPPED NEW MESH

		STATUS	RATE in/min	MEDIAN lbs	MEAN lbs	SD	CV	MIN lbs	MAX lbs	NO. OF BREAKS
NET ID	10 and 29									
Mesh Size (lbs)	2.125	Undipped	10	354	353	20.0	5.7	318	390	30
Gauge 210/	138	Dipped	10	201	203	17.4	8.6	161	242	30
Mfr BS (lbs)	379	% change from undipped		-43%	-43%			-50%	-38%	
NET ID	38 and 31									
Mesh Size (lbs)	2	Undipped	10	250	253	34.1	13.5	175	309	30
Gauge 210/	108	Dipped	10	189	188	12.7	6.8	153	210	30
Mfr BS (lbs)	304	% change from undipped		-24%	-26%			-12%	-32%	
NET ID	37 and 30									
Mesh Size (lbs)	1.5	Undipped	10	214	212	16.9	8.0	142	236	30
Gauge 210/	72	Dipped	10	148	148	15.2	10.3	112	171	30
Mfr BS (lbs)	212	% change from undipped		-31%	-30%			-21%	-28%	
NET ID	28 and 48									
Mesh Size (lbs)	1.25	Undipped	10	201	202	15.5	7.7	169	235	30
Gauge 210/	80	Dipped	10	140	141	16.7	11.8	118	167	30
Mfr BS (lbs)	190	% change from undipped		-31%	-30%			-30%	-29%	
NET ID	16 and 50									
Mesh Size (lbs)	2	Undipped	10	161	164	14.1	8.6	134	193	30
Gauge 210/	60	Dipped	10	126	126	13.3	10.6	100	158	30
Mfr BS (lbs)	196	% change from undipped		-22%	-23%			-25%	-18%	
NET ID	41 and 51									
Mesh Size (lbs)	2	Undipped	10	174	173	12.4	7.2	148	194	30
Gauge 210/	96	Dipped	10	142	140	13.6	9.7	113	166	30
Mfr BS (lbs)	260	% change from undipped		-18%	-19%			-24%	-14%	
NET ID	14 and 52									
Mesh Size (lbs)	1.25	Undipped	10	102	98	12.2	12.4	61	121	30
Gauge 210/	36	Dipped	10	97	91	13.2	14.5	58	104	30
Mfr BS (lbs)	121	% change from undipped		-5%	-8%			-5%	-14%	
NET ID	11 and 53									
Mesh Size (lbs)	1.25	Undipped	10	147	146	19.8	13.5	104	186	30
Gauge 210/	60	Dipped	10	133	135	13.3	9.8	113	159	30
Mfr BS (lbs)	196	% change from undipped		-9%	-8%			9%	-15%	
NET ID	10 and 49									
Mesh Size (lbs)	2.125	Undipped	10	354	353	20.0	5.7	318	390	30
Gauge 210/	138	Dipped	10	266	262	20.9	8.0	211	287	30
Mfr BS (lbs)	379	% change from undipped		-25%	-26%			-34%	-26%	
NET ID	47 and 61									
Mesh Size (lbs)	1.625	Undipped	10	184	186	16.2	8.7	151	222	30
Gauge 210/	80	Dipped	10	157	156	11.0	7.1	135	185	30
Mfr BS (lbs)	245	% change from undipped		-15%	-16%			-11%	-17%	
NET ID	18 and 59									
Mesh Size (lbs)	2	Undipped	10	289	295	29.7	10.1	239	347	30
Gauge 210/	120	Dipped	10	217	219	16.5	7.6	184	248	30
Mfr BS (lbs)	350	% change from undipped		-25%	-26%			-23%	-29%	
NET ID	6 and 58									
Mesh Size (lbs)	1.75	Undipped	10	206	207	15.5	7.5	174	235	30

Gauge 210/	96	Dipped	10	173	172	12.2	7.1	146	191	30
Mfr BS (lbs)	260	% change from undipped		-16%	-17%			-16%	-19%	
NET ID	24 and 60									
Mesh Size (lbs)	2.25	Undipped	10	366	369	32.2	8.7	309	428	30
Gauge 210/	160	Dipped	10	234	231	15.5	6.7	203	266	30
Mfr BS (lbs)	385	% change from undipped		-36%	-37%			-34%	-38%	

TABLE 11 COMPARISON OF MANUFACTURER'S BREAKING STRENGTHS TO TEST RESULTS FOR UNDIPPED NEW MESH

AVERAGE PERCENTAGE DIFFERENCE

MFR	MEDIAN	MEAN	NO. OF SAMPLES
#1	-14%	-14%	15
#3	-6%	-5%	4
#2	-18%	-18%	5
#4	-3%	-1%	2

NET ID	MFR BS	TESTED		MFR	TESTED DIFFERENCE FROM MFR's BS	
		MEDIAN	MEAN	NO.	MEDIAN	MEAN
	lbs	lbs	lbs			
5	147	150	150	1	2%	2%
6	260	206	207	1	-21%	-20%
7	196	159	157	1	-19%	-20%
8	196	175	177	1	-11%	-10%
9	121	108	107	1	-11%	-11%
10	379	354	353	1	-7%	-7%
11	196	147	146	1	-25%	-25%
12	147	125	129	1	-15%	-12%
13	147	135	134	1	-8%	-9%
14	121	102	98	1	-16%	-19%
16	196	161	164	1	-18%	-16%
18	350	289	295	3	-18%	-16%
20	245	200	197	3	-18%	-20%
22	423	366	367	1	-13%	-13%
23	450	400	396	3	-11%	-12%
24	385	366	369	2	-5%	-4%
25	190	158	160	2	-17%	-16%
27	150	152	151	2	1%	1%
28	190	201	202	2	6%	6%
32	334	289	294	2	-13%	-12%
37	212	214	212	1	1%	0%
38	304	250	253	1	-18%	-17%
41	260	174	173	1	-33%	-33%
45	203	162	169	4	-20%	-17%
46	337	385	384	4	14%	14%
47	245	184	186	3	-25%	-24%

TABLE 12 SUMMARIES OF RESULTS FROM FIELD TESTING

PEN	1		NET ID	34	Median	% chg	Mean	% chg	Min	% chg	Max	% chg	#Data
(new ID)	7		NEW	7	159		157		118		177		30
Mesh (in)	1												
Gauge 210/	60		Depth	JUMP	77	-52%	91	-42%	61	-49%	170	-4%	5
Coating	None		(ft below WL)	3	80	-50%	85	-46%	75	-36%	100	-44%	5
Age (yrs)	5			6	85	-47%	83	-47%	69	-42%	96	-46%	5
Perimeter (ft)	188.4			9	86	-46%	80	-49%	55	-54%	93	-47%	5
Depth (ft)	33			12	93	-42%	95	-39%	91	-23%	104	-41%	5
Mfr BS	196			15	85	-47%	83	-47%	71	-40%	90	-49%	5
Mfr	#1			30	82	-49%	77	-51%	62	-47%	85	-52%	5
				BOTTOM	79	-50%	80	-49%	69	-42%	92	-48%	4

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 83

PEN	2		NET ID	33	Median	% chg	Mean	% chg	Min	% chg	Max	% chg	#Data
(new ID)	47		NEW	47	184		186		151		222		30
Mesh (in)	1.5												
Gauge 210/	80		Depth	JUMP	139	-24%	147	-21%	139	-8%	164	-26%	3
Coating	Dipped		(ft below WL)	5	137	-26%	137	-26%	133	-12%	142	-36%	3
Age (yrs)	6			10	139	-25%	136	-27%	123	-19%	146	-34%	3
Perimeter (ft)	400		diff mesh	15	138	-25%	145	-22%	132	-12%	165	-26%	3
Depth (ft)	50			20	156	-15%	152	-18%	141	-7%	159	-29%	3
Mfr BS	245			25	130	-30%	132	-29%	125	-17%	142	-36%	3
Mfr	#3			30	141	-23%	143	-23%	140	-7%	148	-34%	3
				35	154	-16%	148	-20%	129	-14%	162	-27%	3
				40	144	-22%	142	-23%	132	-13%	152	-32%	3
				45	136	-26%	135	-28%	124	-18%	144	-35%	3
				BOTTOM	135	-27%	134	-28%	126	-17%	142	-36%	3

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 140

PEN	3		NET ID	35	Median	% chg	Mean	% chg	Min	% chg	Max	% chg	#Data
(new ID)	24		NEW	24	366		369		309		428		30
Mesh (in)	2.125												
Gauge 210/	160		Depth	JUMP	184	-50%	183	-50%	161	-48%	204	-52%	3
Coating	Some		(ft below WL)	5	182	-50%	186	-50%	168	-46%	208	-51%	3
Age (yrs)	2		(diff mesh)	10	233	-37%	238	-36%	220	-29%	261	-39%	3
Perimeter (ft)	316			15	268	-27%	265	-28%	244	-21%	283	-34%	3
Depth (ft)	33			20	175	-52%	176	-52%	172	-44%	182	-58%	3
Mfr BS	385		(diff mesh) Dip	25	196	-47%	186	-50%	160	-48%	202	-53%	3
Mfr	#2		Dip	BOTTOM	216	-41%	203	-45%	166	-46%	227	-47%	3

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 209

PEN	4		NET ID	36	Median	% chg	Mean	% chg	Min	% chg	Max	% chg	#Data
(new ID)	41		NEW	41	174		173		148		194		30
Mesh (in)	2												
Gauge 210/	96		Depth	JUMP	91	-48%	93	-47%	91	-39%	96	-51%	3
Coating	None		(ft below WL)	5	108	-38%	112	-35%	102	-31%	127	-35%	3
Age (yrs)	5			10	113	-35%	112	-35%	107	-28%	116	-40%	3
Perimeter (ft)	400			15	109	-38%	109	-37%	103	-31%	116	-40%	3
Depth (ft)	55			20	93	-47%	107	-38%	91	-39%	137	-29%	3
Mfr BS	260		(diff mesh)	25	111	-36%	110	-36%	105	-29%	116	-40%	3
Mfr	#1			30	108	-38%	106	-39%	100	-33%	111	-43%	3
				35	111	-36%	109	-37%	101	-32%	116	-40%	3
				40	111	-36%	104	-40%	83	-44%	119	-39%	3
				45	108	-38%	107	-38%	100	-33%	114	-41%	3
				50	102	-41%	100	-42%	92	-38%	105	-46%	3
				BOTTOM	110	-37%	110	-36%	106	-29%	116	-40%	3

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 108

PEN	5		NET ID	39	Median	% chg	Mean	% chg	Min	% chg	Max	% chg	#Data
(new ID)	6		**NEW**	**6**	**206**		**207**		**174**		**235**		**30**
Mesh (in)	1.5												
Gauge 210/	96		**Depth**	JUMP	143	-30%	142	-31%	136	-22%	147	-37%	4
Coating	Dipped		(ft below WL)	5	155	-25%	155	-25%	148	-15%	162	-31%	4
Age (yrs)	4			10	146	-29%	142	-31%	115	-34%	162	-31%	4
Perimeter (ft)	400			15	139	-32%	139	-33%	125	-28%	152	-36%	4
Depth (ft)	60.5			20	135	-35%	140	-32%	127	-27%	164	-30%	4
Mfr BS	260			25	149	-28%	144	-30%	113	-35%	165	-30%	4
Mfr	#1			30	132	-36%	132	-36%	130	-25%	136	-42%	4
			(diff mesh)	35	137	-33%	140	-32%	126	-27%	160	-32%	4
				40	133	-36%	133	-36%	129	-26%	137	-42%	4
				45	143	-31%	141	-32%	132	-24%	147	-38%	4
				50	133	-35%	135	-35%	125	-28%	148	-37%	4
				55	149	-28%	148	-28%	139	-20%	156	-34%	4
				BOTTOM	138	-33%	132	-36%	108	-38%	145	-38%	4

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 140

PEN	6		NET ID	42	Median	% chg	Mean	% chg	Min	% chg	Max	% chg	#Data
(new ID)	47		**NEW**	**47**	**184**		**186**		**151**		**222**		**30**
Mesh (in)	1.625												
Gauge 210/	80		**Depth**	JUMP	126	-31%	132	-29%	126	-17%	143	-36%	3
Coating	Dipped		(ft below WL)	5	136	-26%	133	-28%	122	-19%	143	-36%	3
Age (yrs)	7			10	137	-25%	138	-26%	136	-10%	142	-36%	3
Perimeter (ft)	400			15	128	-31%	131	-29%	119	-21%	147	-34%	3
Depth (ft)	39			20	131	-29%	135	-27%	123	-19%	152	-32%	3
Mfr BS	245			25	136	-26%	140	-24%	136	-10%	149	-33%	3
Mfr	#3			30	135	-27%	136	-27%	125	-17%	148	-33%	3
				35	127	-31%	131	-30%	123	-18%	142	-36%	3
				BOTTOM	141	-23%	143	-23%	133	-12%	155	-30%	3

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 136

PEN	7		NET ID	43	Median	% chg	Mean	% chg	Min	% chg	Max	% chg	#Data
(new ID)	18		**NEW**	**18**	**289**		**295**		**239**		**347**		**30**
Mesh (in)	2												
Gauge 210/	120		**Depth**	JUMP	200	-31%	195	-34%	178	-26%	208	-40%	3
Coating	Dipped		(ft below WL)	5	198	-32%	193	-35%	177	-26%	204	-41%	3
Age (yrs)	6			10	194	-33%	187	-37%	169	-29%	197	-43%	3
Perimeter (ft)	404			15	171	-41%	171	-42%	163	-32%	179	-48%	3
Depth (ft)	68		(diff net)	20	205	-29%	207	-30%	203	-15%	214	-38%	3
Mfr BS	350			25	223	-23%	217	-26%	196	-18%	234	-33%	3
Mfr	#3			30	221	-23%	221	-25%	215	-10%	228	-34%	3
				35	211	-27%	204	-31%	187	-22%	215	-38%	3
				40	200	-31%	219	-26%	198	-17%	260	-25%	3
				45	196	-32%	191	-35%	170	-29%	208	-40%	3
				50	189	-35%	192	-35%	182	-24%	206	-41%	3
				55	216	-25%	206	-30%	186	-22%	217	-38%	3
				60	194	-33%	193	-35%	189	-21%	197	-43%	3
				65	226	-22%	219	-26%	199	-17%	232	-33%	3
				BOTTOM	179	-38%	183	-38%	173	-27%	197	-43%	3

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 200

PEN	8		NET ID	44	Median	% chg	Mean	% chg	Min	% chg	Max	% chg	#Data
(new ID)	47		**NEW**	**47**	**184**		**186**		**151**		**222**		**30**
Mesh (in)	1.625												
Gauge 210/	80		**Depth**	JUMP	115	-37%	121	-35%	113	-25%	136	-39%	3
Coating	Dipped		(ft below WL)	5	142	-23%	146	-21%	136	-10%	160	-28%	3
Age (yrs)	7			10	154	-16%	154	-17%	153	1%	154	-31%	3
Perimeter (ft)	400			15	146	-21%	142	-23%	134	-11%	147	-34%	3
Depth (ft)	35			20	144	-22%	145	-22%	139	-8%	154	-31%	3
Mfr BS	245			25	135	-27%	134	-28%	129	-15%	139	-38%	3
Mfr	#3			30	143	-22%	145	-22%	136	-10%	156	-30%	3
				BOTTOM	136	-26%	133	-28%	110	-27%	154	-31%	3

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 143

PEN	9		NET ID	54	Median	% chg	Mean	% chg	Min	% chg	Max	%chg	#Data
(new ID)	18		NEW	20	200		197		179		227		30
Mesh (in)	1.5												
Gauge 210/	120		Depth	JUMP	139	-31%	139	-29%	127	-29%	153	-33%	3
Coating	Dipped		(ft below WL)	5	141	-30%	135	-31%	121	-32%	144	-37%	3
Age (yrs)	2 & 7max			10	148	-26%	149	-24%	144	-20%	157	-31%	3
Perimeter (ft)	400			15	153	-24%	151	-24%	133	-26%	166	-27%	3
Depth (ft)	50			20	134	-33%	136	-31%	133	-26%	140	-38%	3
Mfr BS	350			25	136	-32%	139	-29%	132	-26%	149	-34%	3
Mfr	#3			30	157	-22%	150	-24%	136	-24%	158	-31%	3
				35	156	-22%	155	-22%	150	-16%	158	-30%	3
				40	146	-27%	145	-27%	128	-28%	160	-30%	3
				45	144	-28%	139	-29%	128	-28%	145	-36%	3
				BOTTOM	147	-27%	146	-26%	143	-20%	149	-34%	3

Overall Mean Breaking Strength in Pen,Excluding Jump Fence: 144

PEN	10		NET ID	55	Median	%chg	Mean	%chg	Min	%chg	Max	%chg	#Data
(new ID)	23		NEW	23	400		396		324		452		30
Mesh (in)	2												
Gauge 210/	160		Depth	JUMP	203	-49%	210	-47%	202	-38%	224	-50%	3
Coating	No		(ft below WL)	5	231	-42%	223	-44%	193	-41%	245	-46%	3
Age (yrs)	3			10	230	-43%	223	-44%	207	-36%	231	-49%	3
Perimeter (ft)	400			15	213	-47%	232	-41%	213	-34%	271	-40%	3
Depth (ft)	50			20	225	-44%	238	-40%	224	-31%	265	-41%	3
Mfr BS	450			25	224	-44%	233	-41%	222	-32%	253	-44%	3
Mfr	#3												

Overall Mean Breaking Strength in Pen, Excluding Jump Fence: 230

TABLE 13 SUMMARY OF FIELD TESTING RESULTS FOR MESH BREAKING STRENGTH OF EXISTING NET PENS, COMPARED WITH REGULATORY STRENGTHS

Pen #	Net I.D. #	I.D.# New Mesh	Mesh Size (in)	Perimeter (ft)	Depth (ft)	Dimension Class (Existing BC Reg)	Age of Pen (yrs)	Dipped in Antifoulant ?	Breaking Strengths (lbs): New: Mfr's Tabled Strength	Breaking Strengths (lbs): New: MMJ Ltd. Tested Strength	Breaking Strengths (lbs): In Pen: Average Tested Strength	Breaking Strengths (lbs): In Pen: As a % of MMJ Tested New	Breaking Strengths (lbs): Required to Meet: Existing BC Reg	Breaking Strengths (lbs): Required to Meet: OK?	Breaking Strengths (lbs): Required to Meet: 65% of Norway Standard.	Breaking Strengths (lbs): Required to Meet: OK?	For Pen Tests: Norway Standard	For Pen Tests: Tested as a % of Norway Standard
1	34	7	1	188	33	A	5	No	162	157	83	53%	75	yes 111%	68	yes 122%	104	80%
2	33	47	1.5	400	50	D	6	Yes	245	156	140	90%	194	no 72%	136	just 103%	209	67%
3	35	24	2.125	316	33	C	2	Partially	385	369	209	57%	194	yes 108%	136	yes 154%	209	100%
4	36	41	2	400	55	D	5	No	260	173	108	62%	227	no 48%	169	no 64%	260	42%
5	39	6	1.5	400	60.5	D	4	Yes	260	207	140	68%	194	no 72%	136	just 103%	209	67%
6	42	47	1.625	400	39	D	7	Yes	245	186	136	73%	227	no 60%	169	no 80%	260	52%
7	43	18	2	404	68	D	6	Yes	350	295	200	68%	227	no 88%	169	yes 118%	260	77%
8	44	47	1.625	400	35	D	7	Yes	245	186	143	77%	227	no 63%	169	no 85%	260	55%
9	54	20	1.5	400	50	D	2 & 7	Yes	350	295	144	49%	194	no 74%	136	just 106%	209	69%
10	55	23	2	400	50	D	3	No	450	396	230	58%	227	yes 101%	169	yes 136%	260	88%

TABLE 14 OVERALL SUMMARY OF TESTING RESULTS

Gauge	Mesh Size inches	Manufact-urer	Mfr's Stated Breaking Strength lbs	New Netting			Other Testing									Comments
							Dipped New Netting				Field Tests on Existing Pens					
				Net ID #	Mean Tested Strength lbs	Tested Strength as % of Mfr's B.S.	Net ID #	Tested Strength lbs	Tested as % of Mfr's B.S.	Tested as % of Tested	Net ID #	Age of Pen years	Tested Strength lbs	Tested as % of Mfr's B.S.	Tested as % of Tested	
210/36	1	1	121	9	107	88%										
	1.25	1	121	14	98	81%	52	91	75%	93%						
210/48	1	1	147	5	150	102%										
	1.25	1	147	12	129	88%										
	1.5	1	147	13	134	91%										
210/60	1.25	2	150	27	151	101%										
	1	1	196	7	157	80%					34	5	83	42%	53%	Pen #1
	1.25	1	196	11	146	74%	53	135	69%	92%						
	1.5	1	196	8	177	90%										
	2	1	196	16	164	84%	50	126	64%	77%						
210/72	1.5	1	212	37	212	100%	30	148	70%	70%						
210/80	1.25	2	190	28	202	106%	48	141	74%	70%						
	1.75	2	190	25	160	84%										
	1.25	3	245	20	197	80%										
	1.5	3	245		(186)						33 (dipped)	6	140	57%	75%	Pen #2
	1.625	3	245	47	186	76%	61	156	64%	84%	42 (dipped)	7	136	56%	73%	Pen #6
	1.625	3	245	47	186	76%					44 (dipped)	7	143	58%	77%	Pen #8
210/96	1.25	4	203	45	169	83%										
	1.5	1	260		(207)						39 (dipped)	4	140	54%	68%	Pen #5
	1.75	1	260	6	207	80%	58	172	66%	83%						
	2	1	260	41	173	67%	51	140	54%	81%	36	5	108	42%	62%	Pen #4
210/108	2	1	304	38	253	83%	31	188	62%	74%						
	2	1	304	38	253	83%	15	266	88%	105%						tarred net
210/120	1.625	3	350		(295)						54 (dipped)	2/7max	144	41%	49%	Pen #9-top 11' newer
	2	3	350	18	295	84%	59	219	63%	74%	43 (dipped)	6	200	57%	68%	Pen #7
	1.625	2	334	32	294	88%										
210/138	2.125	1	379	10	353	93%	29	203	54%	58%						low strength>dipping
	2.125	1	379	10	353	93%	49	262	69%	74%						
210/156	2.5	1	423	22	367	87%										
210/160	2.125	2	385		(369)						35	2	209	54%	57%	Pen #3 –part dip
	2.25	2	385	24	369	96%	60	231	60%	63%						
	2	3	450		(396)						55	2	230	51%	58%	Pen #10
	2.25	3	450	23	396	88%										
210/180	2	4	337	46	384	114%										

TABLE 15 COMPARISON OF MANDATED MINIMUM BREAKING STRENGTHS, BY CLASSIFICATION, MESH SIZE, AND REGULATION

DEPTH	PERIMETER	up to 164’				>164’ to 197’				>197’ to 230’				>230’ to 262’				>262’ to 295’				>295’ to 361’				>361’			
	Mesh Size:	7/8 & less	1 to 1-3/8	1-1/2	1-5/8 & up	7/8 & less	1 to 1-3/8	1-1/2	1-5/8 & up	7/8 & less	1 to 1-3/8	1-1/2	1-5/8 & up	7/8 & less	1 to 1-3/8	1-1/2	1-5/8 & up	7/8 & less	1 to 1-3/8	1-1/2	1-5/8 & up	7/8 & less	1 to 1-3/8	1-1/2	1-5/8 & up	7/8 & less	1 to 1-3/8	1-1/2	1-5/8 & up
0’-16’	Norway Standard - New	68	86	104	139	68	86	104	139																				
	65% Norway Standard	44	56	68	90	44	56	68	90																				
	Existing BC Regulation	50	75	127	157	50	75	127	157	50	75	127	157	111	111	127	169	127	127	169	194	127	127	169	194	127	127	194	227
	Proposed BC Regulation	44	56	68	90	44	56	68	90	56	68	90	102	79	79	102	113	90	90	113	136	90	90	113	136	102	102	136	169
>16’ to 33’	Norway Standard - New	68	86	104	139	68	86	104	139	86	104	139	157	121	121	157	174												
	65% Norway Standard	44	56	68	90	44	56	68	90	56	68	90	102	79	79	102	113												
	Existing BC Regulation	50	75	127	157	50	75	127	157	50	75	127	157	111	111	127	169	127	127	169	194	127	127	169	194	127	127	194	227
	Proposed BC Regulation	44	56	68	90	44	56	68	90	56	68	90	102	79	79	102	113	90	90	113	136	90	90	113	136	102	102	136	169
>33’ to 49’	Norway Standard - New	68	86	104	139	86	104	139	157	86	104	139	157	121	121	157	174	139	139	174	209	139	139	174	209	157	157	209	260
	65% Norway Standard	44	56	68	90	56	68	90	102	56	68	90	102	79	79	102	113	90	90	113	136	90	90	113	136	102	102	136	169
	Existing BC Regulation	50	75	127	157	50	75	127	157	50	75	127	157	111	111	127	169	127	127	169	194	127	127	169	194	127	127	194	227
	Proposed BC Regulation	44	56	68	90	56	68	90	102	56	68	90	102	79	79	102	113	90	90	113	136	90	90	113	136	102	102	136	169
>49’ to 66’	Norway Standard - New					86	104	139	157	121	121	157	174	139	139	174	209	139	139	174	209	139	139	174	209	157	157	209	260
	65% Norway Standard					56	68	90	102	79	79	102	113	90	90	113	136	90	90	113	136	90	90	113	136	102	102	136	169
	Existing BC Regulation	50	75	127	157	50	75	127	157	111	111	127	169	127	127	169	194	127	127	169	194	127	127	169	194	127	127	194	227
	Proposed BC Regulation	56	68	90	102	56	68	90	102	79	79	102	113	90	90	113	136	90	90	113	136	90	90	113	136	102	102	136	169
>66’ to 98’	Norway Standard - New													139	139	174	209	139	139	174	209	157	157	209	260	157	157	209	260
	65% Norway Standard													90	90	113	136	90	90	113	136	157	157	209	260	102	102	136	169
	Existing BC Regulation	127	127	169	194	127	127	169	194	127	127	169	194	127	127	169	194	127	127	169	194	127	127	194	227	127	127	194	227
	Proposed BC Regulation	90	90	113	136	90	90	113	136	90	90	113	136	90	90	113	136	90	90	113	136	102	102	136	169	102	102	136	169
>98’ to 131’	Norway Standard - New																	157	157	209	260	157	157	209	260	157	157	209	260
	65% Norway Standard																	102	102	136	169	102	102	136	169	102	102	136	169
	Existing BC Regulation	127	127	194	227	127	127	194	227	127	127	194	227	127	127	194	227	127	127	194	227	127	127	194	227	127	127	194	227
	Proposed BC Regulation	102	102	136	169	102	102	136	169	102	102	136	169	102	102	136	169	102	102	136	169	102	102	136	169	102	102	136	169

Note: The top line for each depth, “Norway Standard – New” is the minimum breaking strength required for new mesh for net pen construction in Norway.
The second line for each depth represents 65% of the strength required when the mesh was new, in Norway, which is the recommended minimum residual strength for continued acceptance of net pens in service.
The third line for each depth shows the required minimum breaking strength currently shown in the BC Regulation for continued acceptance of nets in service.
The last line for each depth shows the proposed required minimum breaking strength for the BC Regulation for continued acceptance of nets in service.

APPENDICES

APPENDIX A: PROPOSED REVISED TABLES FOR MINIMUM BREAKING STRENGTHS OF NET PEN MESH: SECTION 13 OF “ESCAPE AMENDMENTS TO THE AQUACULTURE REGULATION”

APPENDIX A

PROPOSED REVISED TABLES FOR MINIMUM BREAKING STRENGTHS OF NET PEN MESH, SECTION 13 OF "ESCAPE AMENDMENTS TO THE AQUACULTURE REGULATION"

TABLE 1 – NET PEN DIMENSION CLASSIFICATION

Perimeter	Up to 164 ft.	> 164 ft. to 197 ft.	>197 ft. to 230 ft.	>230 ft. to 262 ft.	>262 ft. to 295 ft.	>295 ft. to 361 ft.	>361 ft.
Depth							
Up to 16 ft.	A	A	B	C	D	D	E
>16 ft. to 33 ft.	A	A	B	C	D	D	E
>33 ft. to 49 ft.	A	B	B	C	D	D	E
>49 ft. to 66 ft.	B	B	C	D	D	D	E
>66 ft. to 98 ft.	D	D	D	D	D	E	E
>98 ft.	E	E	E	E	E	E	E

Notes: - letters A to E establish net pen classification
- perimeter refers to the line bounding the top of the net pen
- depth is from waterline rope to level of net pen bottom

TABLE 2 – DIMENSION CLASSIFICATION A

Mesh Size	Minimum Required Mesh Breaking Strength (below surface of water)	Minimum Required Mesh Breaking Strength (jump netting, above surface of water)
7/8" or less	44 lbs	41 lbs
more than 7/8" & less than 1-1/2"	58 lbs	52 lbs
1-1/2"	68 lbs	62 lbs
greater than 1-1/2"	90 lbs	83 lbs

TABLE 3 – DIMENSION CLASSIFICATION B

Mesh Size	Minimum Required Mesh Breaking Strength (below surface of water)	Minimum Required Mesh Breaking Strength (jump netting, above surface of water)
7/8" or less	56 lbs	52 lbs
more than 7/8" & less than 1-1/2"	68 lbs	62 lbs
1-1/2"	90 lbs	83 lbs
greater than 1-1/2"	102 lbs	94 lbs

…/2

TABLE 4– DIMENSION CLASSIFICATION C

Mesh Size	Minimum Required Mesh Breaking Strength (below surface of water)	Minimum Required Mesh Breaking Strength (jump netting, above surface of water)
less than 1-1/2”	79 lbs	73 lbs
1-1/2”	102 lbs	94 lbs
greater than 1-1/2”	113 lbs	104 lbs

TABLE 5 – DIMENSION CLASSIFICATION D

Mesh Size	Minimum Required Mesh Breaking Strength (below surface of water)	Minimum Required Mesh Breaking Strength (jump netting, above surface of water)
less than 1-1/2”	90 lbs	83 lbs
1-1/2”	113 lbs	104 lbs
greater than 1-1/2”	136 lbs	125 lbs

TABLE 6 – DIMENSION CLASSIFICATION E

Mesh Size	Minimum Required Mesh Breaking Strength (below surface of water)	Minimum Required Mesh Breaking Strength (jump netting, above surface of water)
less than 1-1/2”	102 lbs	94 lbs
1-1/2”	136 lbs	125 lbs
greater than 1-1/2”	169 lbs	156 lbs

APPENDIX B: REPORT BY INTERTEK TESTING SERVICES

ITS Intertek Testing Services
ETL SEMKO

REPORT OF:	Tensile Load Test on Farmed Fish Pen Mesh		
AT:	Coquitlam Laboratory	DATE:	Oct. 19/01
PROJECT:	484-2106 - 3011650		
REPORTED TO:	M.M. Johnson Ltd. #201 – 654 Harper Road Quadra Island, BC V0P 1N0 **Attention: Mr. Murray Johnson**	PAGE:	Page 1 of 2

INTRODUCTION

Intertek Testing Services NA Ltd./Warnock Hersey has conducted a Tensile Load Test on Farmed Fish Pen Mesh submitted to our laboratory by M.M. Johnson Ltd..

PRODUCT DESCRIPTION

The mesh was a knotless type manufactured by Morenot, the mesh size was 1.75" and the gauge was 210/96.

See Appendix A for orientation of net during testing.

TEST RESULTS

A Riehle Universal Testing Machine s/n R-44465 was used to apply the tensile load. The loads were measured using an Artech 1 K Load Cell s/n 199766, Data Shuttle # 1 s/n 2866 R4.06 and a digital dial gauge I.D. # D1274.

30 samples were tested and the average of the results was a breaking load of 211 lbs., the crosshead speed of the test machine was 9.6 inches per minute.

See following page Test Results

All services undertaken are subject to the following general policy 1. This report is for the exclusive use of Intertek Testing Services NALtd.'s (ITS's) client and is provided pursuant to the agreement between ITS and its client. ITS's responsibility and liability are limited to the terms and conditions of the agreement. ITS assume no liability to any party, other than to the client in accordance with the agreement, for any loss, expense or damage occasioned by the use of this report. 2. Only the client is authorized to copy or distribute this report and then only in its entirety. Any use of the ITS name or one of its marks for the sale or advertisement of the tested material, product or service must first be approved in writing by ITS. 3. The observations and test results in this report are relevant only to the sample tested. This report by itself does not imply that the material, product or service is or has ever been under an ITS certification program.

Warnock Hersey

Intertek Testing Services NA Ltd.
211 Schoolhouse Street, Coquitlam, BC V3K 4X9 Canada
Telephone 604-520-3321 Fax 604-524-9186 Home Page www.etlsemko.com

Warnock Hersey

TEST RESULTS (continued)

Sample #	Breaking Load (lbs.)	Sample #	Breaking Load (lbs.)	Sample #	Breaking Load
1	222	**11**	206	**21**	181
2	224	**12**	225	**22**	204
3	211	**13**	203	**23**	203
4	230	**14**	228	**24**	221
5	210	**15**	211	**25**	187
6	204	**16**	190	**26**	221
7	193	**17**	192	**27**	236
8	227	**18**	235	**28**	213
9	216	**19**	205	**29**	232
10	189	**20**	214	**30**	207
		Overall Average	**211 lbs.**		

INTERTEK TESTING SERVICES NA LTD.
Warnock Hersey

Reported by: Dave Rowlandson
Dave Rowlandson
Technician, Building Materials

Reviewed by
Cam Robinson, P. Eng.
Manager, Construction Products

APPENDIX C: PROPOSED NET PEN MESH TESTING PROCEDURE

APPENDIX C: NET PEN MESH TESTING PROCEDURE

(for Escape Amendments To The Aquaculture Regulation)

1. SCOPE

This procedure specifies the method which shall be used in British Columbia for the purpose of determining the tensile (breaking) strength of mesh used for the containment of farmed fish.

The requirements for performing tests, as well as the required number and location of tests are found in the Regulation, Appendix 2, Part II, Section 13.

This procedure is intended for use with nets common to the B.C. finfish aquaculture industry at the time of preparation of the procedure. These nets are generally made with knotless nylon mesh with published breaking strengths of between 50 and 400 lbs. This procedure may not be suitable for other types of nets.

2. PRINCIPLE

A mesh is extended until it ruptures under the applied load. The test is performed using a suitable apparatus that records or indicates the load at the point of rupture. The testing machine is operated at a rate of elongation which is both constant and within prescribed limits.

3. APPARATUS

3.1 Testing Machine

The machine used for testing shall meet the following criteria:

a) Machine shall include a digital load cell or dynamometer providing direct measurement (in units of force) of the load applied to the mesh. The load cell or dynamometer shall be accurate to within 2.5 lbs (11 N), or 1.0% of the mesh breaking strength, whichever is greater.

b) The load cell or dynamometer shall have an accurate means of recording the peak load applied prior to failure of the mesh.

c) Machine shall apply load to a single mesh at a constant rate of elongation equal to 10 inches per minute (25 cm. per min.), plus or minus 10%.

d) For testing machines which apply force in discrete steps (such as by way of a hydraulic cylinder with a hand pump), the rate of elongation, per (c) above, shall be the average rate of elongation. During each step the rate of elongation shall be as close as possible to the average rate required, and the maximum mesh elongation for each step shall be 0.20 inches (5 mm). Testing machines of this nature shall be designed such that the user can readily apply the load at a rate which will meet these requirements.

e) The machine shall engage a single mesh for testing with steel pins or hooks formed from round material with a diameter of 0.1875 inches (5 mm) The pins or hooks shall be so mounted as to remain in direct line with the applied load in order to provide a true reading on the load cell or dynamometer. The pins or hooks shall be smooth and free of any sharp edges or roughness.

3.2 Calibration and Maintenance

The dynamometer or load cell from each testing machine shall be calibrated annually in accordance with the manufacturer’s recommendations. Testing machines shall also be calibrated annually to ensure that the specified elongation rate is maintained. Calibration certificates shall be kept on file by the owner of the machine, with a copy kept with the machine.

The testing machine shall be properly maintained in order to continue to provide accurate results and to meet the requirements above. This will include replacement of the testing hooks as necessary due to wear, corrosion, or roughness.

4. TESTING REQUIREMENTS

4.1 Testing shall be performed at the locations and frequency as indicated in the Regulation. Test locations shall be representative of the mesh making up the whole net, and shall not be located in a previously repaired area. If a net has large areas of repair or is fabricated from different sources of mesh, the test procedure (Section 5) shall be performed on each different mesh type or age of mesh, as applicable, at each location required in the Regulation.

4.2 Testing may be done on mesh remaining in the net or on a sample cut from a net. Cut samples shall be large enough to accommodate the required number of breaks within a single sample.

4.3 Testing done on mesh remaining in the net shall be performed by pulling the net slack around the area to be tested, such that no outside forces are acting upon the mesh being tested, and maintaining such slack for the duration of the test.

4.4 Testing may be performed on dry or wet mesh. Temperature shall be within normal ambient temperatures for the B.C. coast. Tests shall not be conducted on frozen mesh.

4.5 Information about the netting shall be available and recorded, including mesh size*, gauge, age of netting, manufacturer, and manufacturer's published breaking strength.

***NOTE:** 'Mesh size' refers to the distance between the centers of two opposite joints (or knots) in the same mesh when fully stretched; this information should be obtained from the original tagging on the net pen.

5. TEST PROCEDURE

5.1 Testing shall be performed on a single mesh, oriented so that the pillars (bars) of the mesh are engaged over the pins or hooks, not the knots or joints of the mesh.

5.2 Mount the mesh over the pins or hooks, and take up the slack.

5.3 Apply load at a steady rate of elongation, as defined in 3.1, until the mesh breaks. Record the peak load indicated.

5.4 Repeat for a total of five breaks at the location being tested.

5.5 Average the five results to get the recorded breaking strength for that location.

Example: 200 lbs, 210 lbs, 230 lbs, 195 lbs, 185 lbs

Record breaking strength of (200+210+230+195+185)/5 = 204 lbs

5.6 Record breaking strength to the nearest pound force.

6. REPORTING

Test results shall be recorded on a standard form which also includes information about the net. Information recorded shall include:

a) Owner of net and net identification number.

b) Mesh manufacturer and manufacturer's published mesh breaking strength.

c) Net fabricator and date of net fabrication.

d) Size and gauge of mesh and dimensions of net pen.

e) Date and location of testing, company and name of person doing test.

f) Information on antifoulant treatment of net, if any.

g) Whether net tested wet or dry, and approximate ambient temperature at test.

h) Breaking strength test results for each prescribed location, average values, and pass/fail grades per requirements of the Regulation.

i) General comments and notes on overall condition of net.

j) Signature of tester.

A sample testing record form is attached to the Appendix.

Company Letterhead

NET PEN TESTING RECORD

Date of Testing _______________________________

Net ID __________
Job Order No. __________

Company:

Location of Testing:

Name of Contact:

Name of Tester:

Mesh Manufacturer:

Dimensions: (ft) (m) _______x_______x ______deep.

Net Fabricator:

Mesh Size (mid knot to mid knot): (in) (mm)

Date of Net Fabrication:

Gauge: 210/

Mesh Manufacturer Breaking Strength (lbs):

Tested WET or DRY ?

Required Strength: Below WL: Jump:

Test temperature (approx.):

	Dip?	Breaking Strength (lbs) Test 1	Test 2	Test 3	Average	Pass/ Fail	Initials
JUMPNET	☐						
2M BELOW WATERLINE	☐						
MIDPOINT OF DEPTH	☐						
BOTTOM PANEL	☐						

CONTAINMENT PEN:

Repairs Completed:

PREDATOR NET:

Repairs Completed:

Comments:

Signature of Tester:

APPENDIX D: EXTRACT FROM ESCAPE AMENDMENTS TO THE BC AQUACULTURE REGULATION (SECTION 13, NET PENS)

13 The requirements for net pens are as follows:

(a) holders must ensure that all tears found while handling or inspecting net pens in use or intended for use at any time are repaired immediately and a report of the repair, including whether the repair is of a permanent or temporary nature, must be recorded in the written maintenance record;

(b) all temporary repairs must be replaced with permanent repairs as soon as is practicable;

(a) according to the dimension classification identified in Table 1, net pens must meet the minimum breaking strength standards established in Tables 2 through 5;

Table 1: Net Pen Dimension Classification

Perimeter	Up to 197 ft.	> 197 ft. to 230 ft.	> 230 ft. to 262 ft.	> 262 ft. to 295 ft.	> 295 ft. to 361 ft.	> 361 ft.
Depth						
Up to 33 ft.	A	A	B	C	C	D
> 33 to 49 ft.	A	A	B	C	C	D
> 49 to 66 ft.	A	B	C	C	C	D
> 66 to 98 ft.	C	C	C	C	D	D
> 98 ft.	D	D	D	D	D	D

A to D establishes net pen dimension classification. Depth is from waterline rope to net pen bottom. Perimeter refers to the line bounding the top of the net pen.

Table 2: Dimension Classification A

Mesh Size	Wet Mesh Breaking Strength Minimum (below surface of water)	Wet Mesh Breaking Strength Minimum (jump netting above surface of water)
7/8" or less	50 lbs.	46 lbs.
1 to 1 3/8"	75 lbs.	69 lbs.
1 1/2"	127 lbs.	117 lbs.
1 5/8" to 2 1/4" or greater	157 lbs.	145 lbs.

Table 3: Dimension Classification B

Mesh Size	Wet Mesh Breaking Strength Minimum (below surface of water)	Wet Mesh Breaking Strength Minimum (jump netting above surface of water)
1 3/8" or less	111 lbs.	103 lbs.
1 1/2"	127 lbs.	117 lbs.
1 5/8" to 2 1/4" or greater	169 lbs.	156 lbs.

Table 4: Dimension Classification C

Mesh Size	Wet Mesh Breaking Strength Minimum (below surface of water)	Wet Mesh Breaking Strength Minimum (jump netting above surface of water)
1 3/8" or less	127 lbs.	117 lbs.
1 1/2"	169 lbs.	156 lbs.
1 5/8" to 2 1/4" or greater	194 lbs.	179 lbs.

Table 5: Dimension Classification D

Mesh Size	Wet Mesh Breaking Strength Minimum (below surface of water)	Wet Mesh Breaking Strength Minimum (jump netting above surface of water)
1 3/8" or less	127 lbs.	117 lbs.
1 1/2"	194 lbs.	179 lbs.
1 5/8" to 2 1/4" or greater	227 lbs.	209 lbs.

(d) for each point tested on a net pen for breaking strength tests in paragraph (c), the reported result must be the average of 3 breaks;

(e) any breaking strength test must be applied to areas of original net and not to patches of new material;

(f) any breaking strength test must be conducted with a dynamometer or other calibrated tension scale instrument;

(g) net pens that do not pass the breaking strength test requirements established in paragraph (c) must be repaired or retired;

(h) all repairs to net pens must meet or exceed the standards in paragraph (c);

(i) the requirements for complete out-of-water servicing of net pens are as follows:

- (i) subject to subparagraph (ii), all net pens must undergo complete out-of-water servicing after every 18 months of accumulated time in water;
- (ii) despite subparagraph (i), if a net pen contains a group of fish that will be in the net pen for longer than 18 months, the net pen must undergo complete out-of-water servicing prior to the introduction of the group of fish and before the introduction of a new group of fish;
- (iii) complete out of water servicing must include a complete visual inspection, and breaking strength tests must be performed at 5 points on the net pen;
- (iv) the results from subparagraph (iii) must be recorded in the written maintenance record;
- (v) the 5 points which must be tested on each net pen are
  - (A) A point 2 meters below the top of the net pen,
  - (B) A point 2 meters below the top of the net pen opposite and equidistant from the point described in clause (A),
  - (C) A point at the midpoint of depth of the net pen,
  - (D) A point opposite and equidistant from the point described in clause (C) at the midpoint of depth of the net pen, and
  - (E) A point on the bottom panel;

(j) net pens stored on dry land must be stored in a manner that prevents exposure to ultraviolet light.

APPENDIX E: EXTRACT FROM NORWEGIAN STANDARDS FOR NET PENS

Table 4.1.1

Coherence between net size and dimension class

Circum-ference of net	To 164 ft	From 164 ft and up to 197 ft	From 197 ft and up to 230 ft	From 230 ft and up to 262 ft	From 262 ft and up to 295 ft	From 295 ft and up to 361 ft	From 361 ft and larger
Depth							
0-16 ft	**A**	**A**	**-**	**-**	**-**	**-**	**-**
>16-33 ft	**A**	**A**	**B**	**C**	**-**	**-**	**-**
>33-49 ft	**A**	**B**	**B**	**C**	**D**	**D**	**E**
>49-66 ft	**-**	**B**	**C**	**D**	**D**	**D**	**E**
>66-98 ft	**_**	**_**	**_**	**D**	**D**	**E**	**E**
>98-131 ft	**-**	**-**	**-**	**-**	**E**	**E**	**E**

A To E gives the dimension class. Depth is given from the waterline rope to the bottom.

Table 4.1.2
Dimension class
Lead weights in air as given below counts for concrete leads.
Correct for buoyancy when use of other material.

Dimension class A		**Dimension class B**		**Dimension class C**	
Mesh size in inches	**Wet mesh strength min**	**Mesh size in inches**	**Wet mesh strength mm**	**Mesh size in inches**	**Wet mesh strength mm**
5/8, ¾	68 lb	5/8, ¾	86 lb		
1, 1-1/8, 1-¼	86 lb	1, 1-1/8, 1-¼	104 lb	1, 1-1/8, 1-¼	121 lb
1-½	104 lb	1-½	139 lb	1-½	157 lb
1-¾, 2, 2-¼ +	139 lb	1-¾, 2, 2-¼ +	157 lb	1-¾, 2, 2-¼ +	174 lb
Waterl. Rope	5512 lb	Waterl. Rope	7496 lb	Water. Rope	7496 lb
Verticals	2425 lb	Verticals	3748 lb	Verticals	5512 lb
Top Rope	2425 lb	Top Rope	3748 lb	Top Rope	5512 lb
Btm. Rope	3748 lb	Btm. Rope	5512 lb	Btm. Rope	5512 lb

Max lead weight per vert. 110 lb in the air — Max lead weight per vert. 132 lb in the air — Max lead weight per vert. 165 lb in the air

Dimension class D		**Dimension class E**	
Mesh size in inches	**Wet mesh strength min**	**Mesh size in inches**	**Wet mesh strength min**
1, 1-1/8, 1-¼	139 lb	1, 1-1/8, 1-¼	157 lb
1-½	174 lb	1-½	209 lb
1-¾, 2, 2-¼ +	209 lb	1-¾, 2, 2-¼ +	260 lb
Waterl. Rope	9039 lb	Waterl. Rope	11023 lb
Verticals	7496 lb	Verticals	9039 lb
Top Rope	7496 lb	Top Rope	7496 lb
Btm Rope	7496 lb	Btm Rope	7496 lb
Cross Ropes	7496 lb	Cross Ropes	7496 lb

Max lead weight per vert 220 lb in the air — Max lead weight per vert. 276 lb in the air

APPENDIX F: EXTRACTS FROM NEWFOUNDLAND CODE OF CONTAINMENT AND IMPLEMENTATION PLAN FOR CODE OF CONTAINMENT

1. Equipment Standards:

Nets:

Netting is the only barrier enclosing the stocks and therefore provides the single greatest risk for escapement. The following outlines minimum measures to ensure that all nets used are reliable and provide a level of assurance against escape.

- Nets will be only obtained from a manufacturer/ supplier equipment design specifications and standards conform to those generally in the use of the aguaculture industry;
- Net design and specification shall be commensurate with the prevailing conditions on site;
- An annual 4-point stress test of all nets which are over three years old and in active service shall be conducted by an approval inspector, and documentation of the test results shall be retained by the operator for a minimum of two years for audit purposes. The stress testing protocol and minimum breaking strength requirements as follows:
- The stress test shall be conducted with an electronic dynamometer of similar tension scale instrument;
- For each point tested, use the average of three breaks as a result;
- The four points to be tested on each net are:
  1. the jumpskirt (area between the water line and the top line)
  2. the next 2 metres below the jumpskirt
  3. the side panels
  4. the bottom
- If components 1 or 2 fail the stress test, the net may be repaired to meet the standard and put back into service. If components 3 or 4 fail the test , the net shall be condemned.
- Minimum breaking strengths for new nets and minimum strength required before replacement are as follows:

	Mesh Size (stretched) (inches)	Min. new breaking strength (lbs)	Min. breaking strength before replacement (lbs)
Smolt nets	1 1/8-1 3/8	200	80
Pre-marked nets	1 7/8-2 3/8	300	120
Predator nets	3-5	400	160

- Grading of fish by size should be done in a manner that ensures that fish are placed in a net of the appropriate mesh size
- The mesh size must be of a dimension to ensure containment of the smallest fish in the enclosure based on an upcoming experiment designed to match fish size and mesh size.
- Each net in active service shall be marked by the manufacture with its name, and year produced, original breaking strength, and net dimensions. The markings shall be punched or imprinted on a plastic tag which is threaded on to the top rope eye of one of the down lines;
- All nets in use shall be U . V . protected;
- All nets in use shall be treated with anti foulant
- Nets shall be secured to the cage collar such that the latter bears the strain (i.e., the strain

must not be borne by the hand rail); and
- Net weights shall be installed in such a manner as to prevent net chafing.

Cages:

- Cages will only be obtained from a manufacturer/ supplier whose equipment design specifications and standards meet generally accepted aquaculture industry standards. The operator agrees to provide the original construction information on the cage system, as per schedule I, as a condition of licence;
- Design and specifications shall match the normal maximum conditions likely to occur at a site;
- Cage designs cannot be used without a proven history of performance whish assesses the system to ensure compatibility with site conditions and containment objectives; and
- Cages shall be identified and production inventory per cage documented on a growth cycle with respect to mortality, harvest and detailed losses and documentation of results shall be retained by the operator for a minimum of two years for audit purposes;
- Cage structural failure has not occurred at Bay d' Espoir and is not a source of escapement.

Moorings:

- Mooring design shall be compatible with the cage equipment and site conditions, and be installed in consultation with cage manufacturer/ supplier; and
- Diving inspections shall e conducted on subsurface mooring components every two years for replacement of shackles and ropes (subject to specifications, site conditions, observed wear and tear).

IMPLEMENTATION PLAN FOR THE BAY D'ESPOIR CODE OF CONTAINMENT

1. EQUIPMENT STANDARDS: (as per Code of Containment)

NETS:

- All nets in use in Bay D'Espoir have been manufactured by suppliers whose designs meet or exceeds industry standards. The majority of nets purchase in the last three years have come from Newfoundland Aqua Service in St. Alban's. **Newfoundland Aqua Service is willing to provide a list of all nets and cages, manufactured in the last three years, complete with mesh and dernier size, net dimensions and net purchaser.** Card's Aquaculture in New Brunswick has also supplied nets to the Bay D'Espoir region in the past, but no new nets have come from them in recent years.
- As is standard practice in the industry, the nets are designed to perform in the conditions in which they are used (i.e. heavier mesh for sites of stronger current, etc.)
- **Annual 4 point stress test of all nets which are over three years old and in active service.** Nets to be tested will be determined by the records of NAS and from information provided by the growers. Testing will be performed as per protocols outlined in the Code of Containment. Testing will be performed by Lawrence Mahoney and when necessary, Elizabeth Barlow, both of the St. Alban's office of DFA. Testing will begin as soon as the tensile strength meter is completed by Card's Aquaculture (within the next few weeks). Nets will be tested prior to being placed inthe water and when the nets come out of the water to be cleaned. Each grower will be contacted to determine a schedule of nets testing based on their net replacement/cleaning schedule.
- The following page displays a sample of the document to be used for testing nets. This document will be in triplicate, one for the grower, one for DFA and one for DFO. Documentation shall be retained by the grower for a minimum of two years.

4 POINT NET STRESS TEST INSPECTION FORM

DATE: ____

COMPANY: _______________________________________

LOCATION OF TEST: _______________________________

DATE OF NET MANUFACTURE: ______________________

TAG No. DFA / MAN.	NET TYPE (mesh size, type, dimen-sions)	JUMP SKIRT (breaking strength in lbs)	NEXT 2m BELOW JUMP SKIRT (breaking strength in lbs)	SIDE PANELS (breaking strength in lbs)	BOTTOM (breaking strength in lbs)	FINAL GRADE (pass or fail)

		Min. new breaking strength	Min. Breaking strength before replacement
SMOLT NETS:	210/60	185 lbs	80 lbs
	210/40	114 lbs	80 lbs
PREMARKET NETS:	210/80	205 lbs	120 lbs
	210/60	185 lbs	120 lbs

Is Net treated with Anti Foulant? Yes _______ No _______

Signature (Inspector): ____

- Fish will be placed in cages as per industry standard of the mesh size to be 1/3 the size of the widest part of the fishes body. Current industry practice dictates the following:

½" stretch mesh	minimum size 10 grams
3/4" stretch mesh	minimum size 20 grams
1 1/8" stretch mesh	minimum size 50 grams
2 1/4" stretch mesh	minimum size 450 grams

  These guidelines are subject to review pending the outcome of experimentation by the Marine Institute.
- All NAS net products have heavy duty plastic tags with a number imprinted on them, sewn to the top rope and down line. The number corresponds to a master list listing all pertinent net data. DFA will attach their own tag after each net inspection and retain records of tag number, net type and test results.
- All nets are UV and anti-foulant treated and are secured to the cage collar at every down line. Net weights are hung at down lines one foot above the bottom of the cage. Net weights are of smooth plastic; no chaffing has been experience in the past.

APPENDIX G: EXTRACTS FROM MAINE AQUACULTURE CODE OF PRACTICE

Equipment Standard from The Maine Aquaculture Association
Code of Practice

	Mesh size (inches)	**Twine Rating**	**Revised Twine Rating for 2001**	**New Net Strength (pounds)**	**Replacement Threshold (pounds)**
Smolt Containment	1 1/8 –1 3/8	210/60	210/80	125	80
1 sw/ 2 sw containment	1 7/8-2 3/8	210/80	210/120	185	120
Predator Curtains	3-5	210/160	210/160	300	160