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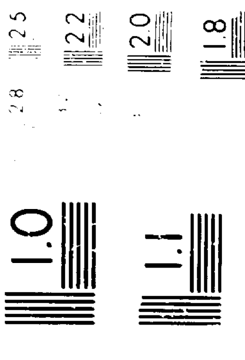
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org



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TRAINING AND INSPECTION REQUIREMENTS FOR QUALITY ASSURANCE OF STRESS GRADED STRUCTURAL WOOD PRODUCTS*

by

F. J. Keenan, P. Eng.**

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** Director - International Services, Morrison, Hershfield, Burgess and Huggins, Ltd., Consulting Engineers; Toronto, Canada.

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CONTENTS

APPENDIX

1. INTRODUCTION

This report supersedes an earlier version which was written to serve as a working document in UNIDO's December 14-17, 1981 expert group meeting on timber stress grading and strength grouping held in Vienna, Austria. It has been rewritten and expanded in the light of discussions which took place at the meeting. In that sense, the author is grateful to the participants for their contributions.

This paper deals with quality assurance of stress graded wood products used in construction, and with programmes of inspection and training which support quality assurance. It begins by proposing and illustrating a possible regulatory framework for quality assurance which can be adopted by a country. It then goes on to examine the elements of quality, and the means of routinely assessing that quality which are pertinent to a variety of stress graded wood products including visually graded lumber, machine stress rated lumber, structural glued-laminated timber, plywood, joints and assemblies. Finally, the report deals with training and educational programmes, paying particular attention to visually stress graded lumber.

The means of assessing and controlling the strength of wood products are many and varied, but at the present time there are only three which are incorporated into most product standards. They are:

- visual grading
- machine stress rating (E-rating)
- strength testing of production samples

and these can be used either alone or in combination, as follows:

- visually graded sawn lumber and timbers use visual grading only
- machine stress graded sawn lumber uses E-rating with a visual override
- laminating stock uses visual grading with an E-rating override
- plywood: visual grading of veneers
- joints and assemblies: destructive and non-destructive strength tests.

2. REGULATORY FRAMEWORK FOR QUALITY ASSURANCE

In the session of the UNIDO meeting which dealt with training and inspection, the various participants reviewed current practices in many of the countries represented. On the basis of this information, they then formulated several recommendations for consideration by a developing country which is contemplating using wood in engineered construction. Among these recommendations is a set relating to a possible regulatory framework which could be set up in the country. It has four levels; these are described below and are illustrated using the Canadian situation as an example.

2.1 Legislation

The federal government (or state or provincial government, as applicable depending upon the nature of the national confederation) will have the legislative responsibility for building codes, and for building safety in general. In Canada, it is the ten provincial and two territorial governments which have this responsibility. However, because a high level of expertise is needed to draft a satisfactory building code, this activity is actually coordinated by a federal agency, the National Research Council of Canada. NRCC has a variety of committees which, every few years, together produce an edition of the National Building Code of Canada. The NBCC is a model code with no legal status, but is adopted (largely without modification) in a statute by each of the provincial and territorial governments.

The NBCC specifies the use of (and thereby enacts) a variety of standards governing the quality of various building materials, e.g. CSA Standard 0141, "Softwood Lumber".

2.2 Building Materials Standards and Quality Assurance Organizations

Each of the separate material standards should be developed as a consensus standard. These are written by committees whose memberships are equally balanced among producers (e.g. associations of lumber manufacturers), users (house builders, consumers, consultants) and neutral interests (e.g. researchers). In the case of contentious standards, much effort is often expended in seeking consensus through debate and compromise, rather than simply basing decisions on majority votes. Ideally, these standards should include requirements both for in-plant quality control and for externally administered quality assurance programmes.

In Canada, most of the materials standards relating to wood products are produced by committees coordinated by the Canadian Standards Association, a non-profit autonomous body. In addition to the CSA Standards, there are some wood industry associations (e.g. the National Lumber Grades Authority (NLGA) and the Council of Forest Industries (COFI)) whose industrial standards are referenced by the pertinent CSA Standards. We will be dipping into this "alphabet soup" of organizations again in the following paragraphs.

Also at this second level are the organizations which assure that the materials standards are being met through the operation of quality assurance programmes. Different possibilities exist here - it might be a government agency (possibly a state-run timber research laboratory), an industry association or even some autonomous body which has gained the respect and confidence of all the various parties involved. In establishing the operations of the external quality assurance programme, it is important to foster the attitude that the quality assurance organization is not necessarily an adversary of the wood producer. On the contrary, the producer and the QA organization have the same objectives: the production of wood products of dependable quality.

Returning to the Canadian example, softwood lumber is manufactured in accordance with CSA Standard 0141, "Softwood Lumber", but the grading rules referenced by this standard are written by the National Lumber Grades Authority as the "NLGA Standard Grading Rules for Canadian Lumber". These NLGA rules for dimension lumber are virtually identical to those used in the USA. Overall control of adherence to CSA 0141 is the responsibility of the Canadian Lumber Standards Administrative Board which reports to the Canadian Standards Association Certification Policy Board. Eleven lumber manufacturing associations and three independent grading agencies are licensed by CLS to grade mark lumber. The CLS Administrative Board ensures that graders are qualified and that grading associations or agencies supervise their graders. A check-grading service is also provided to periodically verify work of graders.

2.3 The Grader and the Grading Agency

The grader may be an independent (as in the case of Malaysia) or, more commonly, will be an employee of the mill. The validity of his grading will be regularly inspected by the QA organization, which should have the power to remove the grader's licence but only after less drastic corrective measures have been tried.

The grader's licence is issued to him by the grading agency (usually an association of lumber producers) and he is supervised by an agency grader. In some cases, e.g. for lumber to be exported from Canada, the supervision is constant; for other products, it is intermittent.

2.4 The Craftsman

The fourth level is the individual who is actually making the product, eg. the saw operator. This, ultimately, is where quality comes from; his training and motivation are the best assurance of quality wood products coming out of the mill.

3. PRINCIPLES OF VISUAL STRESS GRADING

3.1 Defects

Wood, when it comes from the saw as lumber or from the lathe as veneer can contain a wide range of defects, both natural and man-made. Each of these defects will have some influence on how acceptable the wood is to the purchaser and on how the wood will be used. Some defects effect only the appearance and aesthetic qualities of the piece, while others can seriously reduce its strength. It is this latter category of defects which is of greatest concern in the structural utilization of wood products. To control the impact of these defects on manufactured wood products, various classification systems have been devised. To each class (or grade) of wood is assigned a set of rules which will prescribe the defects permitted in that grade: the types of defects, their size, extent, frequency and location. The objective of these prescriptions is to gain the assurance that the strength of almost all the pieces within a certain grade will not fall below a certain level. This minimum strength can then be divided by a factor of safety to arrive at an allowable stress for that grade. Thus this kind of grading is called stress grading.

The defects which are usually included in [illegible] grading rules (considering both hardwoods and softwoods) are the follow[illegible]

- knots - centre or edge knots, loose or tight knots
- general slope of grain
- growth rate
- decay and stain
- insect attack - ants, termites, beetles, borers
- drying defects - warp (bow, crook, cup, twist), checks, shakes, and splits
- sapwood
- pith
- parenchyma
- wane
- bark inclusions
- pitch streaks and pitch pockets

- reaction wood (compression wood in softwoods, tension wood in hardwoods)
- compression failures due to felling or to growth stresses ("brittleheart")
- manufacturing imperfections (chipped, torn, raised and loosened grain, machine burn, bite and gouges)

An example of a visual stress grading rule for tropical hardwoods is given in a recent paper by Piqué and Tejada[1]. An appendix to their paper is reproduced herein as Appendix A of this report; it contains definitions, methods of recognition, permissible limits and drawings of each of the defects considered.

Clearly, the reason for including these defects in stress grading rules is that they are thought to have a negative effect on the strength of structural members. However, it is not clear how serious these effects may be; in fact, some of the defects seem to have more to do with the appearance of the piece rather than with the strength. In spite of all of the timber mechanics research which has gone on, we still don't have adequate knowledge of the relationship between defects (and combinations of defects) and the strength of full-size structural members of tropical hardwoods. It is suggested that no fully satisfactory stress grading rule for tropical timber can be written until these relationships are known. It is hoped that this type of research, with the inclusion of wood anatomists in the research team, will receive high priority in the future, and that a mechanism for worldwide cooperation and communication can exist in such work.

[1] Piqué, J. and M. Tejada. Working stresses for tropical hardwoods of the Andean Pact countries. Junta del Acuerdo de Cartagena, Lima, Peru

There is one particular defect - brittleheart - to which more attention should be paid. This defect consists of compression failures in the wood which have been caused by growth stresses in the standing tree. The potential dangers can be illustrated by an example. In Peru, there is a species of tropical hardwood called Tornillo which is widely used in construction. It has been tested quite extensively and an enormous variation in bending strength values has been obtained, even among pieces which appear to be identical. An extreme example consists of two almost identical beams which were tested one day in a laboratory in Lima, Peru: one failed at a load of 5,140 kg, the other at 720 kg. The difference is that the weak beam contained brittleheart, and in an amount which was so small as to be difficult to detect.

Brittleheart appears as very fine creases roughly transverse to the grain direction. It is very difficult to see on sawn surfaces, a little easier to see on planed surfaces, and easier still on varnished surfaces. A low angle of incidence of light is helpful. One old technique is to rub or wipe a liquid containing a dye, or oil, across the surface. This will give a bit more contrast to the compression wrinkles.

The point of this discussion is that brittleheart is difficult to detect and is also very dangerous if it occurs in the tension zone of structural members. Thus, a decision may have to be taken simply not to use for structural purposes any species in which brittleheart occurs frequently.

3.2 Development of a Stress Grading Rule

The first step in developing a visual stress grading rule for lumber could take place right at the sawmills and in the lumberyards: it is the recording of the defects in the lumber as it comes from the saw and after it has been air-dried in the yard. This survey results in a series of observations on what types of defects can be found in various species, their sizes, locations, frequencies, and their species-dependency. Having this information, it is possible to predetermine the percentage of lumber production which will pass the grading rule, which is often a political and marketing decision as well as a technical one. For example, it is reported by Piqué and Tejada that the Andean Pact grading rule

rule referred to earlier results in approximately 40 to 45% of the lumber produced meeting the requirements of the grading rule.

Incidentally, other useful information which can be obtained at the sawmill is the ease of sawing of particular species, or the time interval between sawblade sharpenings as influenced perhaps by the presence of silica in the wood.

Sawmill surveys should be repeated in the future, because it is quite likely that defect-frequency occurrences will change with time. For example, it is possible that sawing techniques may change as greater amounts of construction lumber are produced. It is also possible that log characteristics will show greater variability as the exploited forest resource is expanded, and as more plantation-grown material is utilized.

A final word on the development of grading rules is that they should be simple. Attempts to precisely define a series of strength grades are usually thwarted by the high variability of wood and the poor ability of many stress grading rules to predict strength. It is better to have only a few grades and to make the rules easy to understand and use, even at the risk of not using wood as efficiently as possible. Greater efficiency might come in the future with the introduction of machine stress grading, but this seems to be premature in many developing countries. Incidentally, it is not clear whether brittleheart can be detected by machine stress grading.

3.3 Derivation of Allowable Stresses for Visually Stress Graded Lumber

The traditional method of deriving allowable stresses for stress-graded lumber of a particular species is to test small, clear, green specimens and then to modify these results by multiplying by a series of modification factors representing the variability of the data, the effect of duration of load, the effect of moisture content, the effect of beam depth, the weakening effect of defects which are permitted in a particular grade, and by dividing by the factor of safety.

This traditional approach has been challenged by the work on temperate conifers by Madsen[1]. His research results lead him to question the following steps in the allowable stress derivation process:

(a) the determination of the lower 5% exclusion limit value based on an assumed Gaussian distribution of strength values; this appears to be the actual distribution for small clear specimens of wood but is not the distribution of populations of in-grade lumber;

(b) the effect of duration of load at the 5% exclusion limit; again, in his tests, there is no effect in many cases;

(c) the effect of moisture content changes at the lower 5% exclusion limit; again, in his tests, there is no effect in many cases;

(d) the reliability of grading rules in predicting strength at the lower 5% exclusion limit; he found that the rules were reliable for distringuishing the strongest and the weakest grades, but not the intermediate ones. Accordingly, some consolidation and simplification of the current North American grading rules may be in order.

[1] Madsen, B. 1975. Strength values for wood and limit states design. Canadian Journal of Civil Engineering 2(3): 270-279.

Because of these findings, it appears that in order to properly derive allowable stresses for full-size, in-grade, structural members for engineered construction, it is necessary to actually test full-size, in-grade, structural members, and not rely on the traditional methods of small, clear specimen tests.

4. VISUALLY GRADED LUMBER

4.1 General

In the remainder of this report, various stress graded structural wood products will be discussed, and the particular quality assurance methods used for each of them will be presented. In the case of visually graded lumber, much has already been said: Chapter 2 described product standards for lumber and the regulatory organizations within which these standards are used; Chapter 3 then dealt with stress grading rules and their content, development and the deviation of allowable stresses. There are a few other points which might be made in connection with visually graded lumber and these are contained in the following paragraphs.

4.2 Species and Species Groups

In several parts of the world, many lumber species are harvested, manufactured and marketed together. Some of these have similar performance properties; they can be easily used together or interchangeably. In fact, some species cannot be distinguished from others by visual inspection after manufacture. For convenience, certain commercial species are combined into a single species designation and marketed under a group name. To illustrate this, the Canadian commercial species groups are shown below.

Commercial Designation of Species Combinations	Species Included
Douglas fir-larch	Douglas fir, western larch
Hem-fir	Western hemlock, amabilis fir
Spruce-pine-fir	White spruce, Engelmann spruce, black spruce, red spruce, lodgepole pine, jack pine, alpine fir, balsam fir
Eastern hemlock-tamarack	Eastern hemlock, tamarack
Western cedars	Pacific coast yellow cedar, western red cedar
Coast species	Douglas fir, western larch, western hemlock, amabilis fir, coast sitka spruce
Northern species	All above species plus red pine, western white pine, eastern white pine
Northern aspen	Aspen poplar, largetooth aspen, balsam poplar

4.3 Grade Marking

In North American practice, dimension lumber, decking and boards for wall sheathing, subflooring and roof sheathing are grade marked about two feet from one end of each piece so that the mark will be clearly visible during construction of the building, before sheathing and cladding are in place. Although the grade mark design varies between agencies each grade mark shows the name (or symbol or both) of the grading agency; the number (or name or both) of the mill; the species or species group designation; the grade; and if on lumber thinner than 4-inch nominal, either S-GRN (for surfaced green), S-DRY (for surfaced dry) or MC15 (for lumber specially dried to 15% or less moisture content).

Timber, which is five inches or more in least nominal dimension, may be grade marked or a certificate may be obtained from an inspection agency for a complete shipment. Identification requirements should be included in building specifications, especially if structurally graded material (Select Structural or No. 1 grades) is required such as for columns and beams.

Lumber that is resawn lengthwise or remanufactured must be regraded because changes in location of the characteristics will affect the performance of the material.

5. MACHINE STRESS RATED (MSR) LUMBER

5.1 General

According to the Canadian Wood Council:

In a typical MSR machine, forces are applied on both sides of the lumber, on the flat, with deflection measured every 150 mm along the length of each piece. Stiffness is measured and recorded by a small computer, and strength is assessed by correlation methods. The lumber can be processed at speeds up to 365 metres per minute, including being stamped with an MSR grade mark. The grade mark includes an f-E classification indicating allowable stress values for bending and modulus of elasticity. Species are also indicated, although this does not affect bending and MOE values, only horizontal shear and compression perpendicular to grain.

MSR requires visual monitoring in addition to mechanical grading. Size restrictions are applied to edge knots to improve the correlation between machine assessment (on the flat) and performance on edge as in a joist. Additional visual grading controls characteristics that cannot be assessed by existing machines, such as wane, warp, checks and manufacturing imperfections.

In Canada, most MSR lumber presently produced is used by fabricators of trusses and component systems. These uses require engineering design, where MSR lumber is ideal because of increased allowable strength properties compared to visually graded lumber. It is expected that use will expand to other framing applications, such as joists, as designers become more familiar with the product and greater production becomes available. In comparison to visually graded lumber MSR lumber represents a very small part of overall production.

5.2 Grades and Allowable Stresses

Canadian MSR lumber is graded to the "NLGA Standard Grading Rules for Canadian Lumber", published by the National Lumber Grades Authority. The

NLGA rule lists 14 "grades" or f-E classifications, with allowable stresses approved by the CSA Technical Committee on Engineering Design in Wood. The f-E classifications relate directly to allowable values: for an 1800f-1.6E grade the allowable stress in bending is 12.4 MPa (1800 psi) and the modulus of elasticity is 11 000 MPa (1.6 million psi) under normal duration of load. Allowable values for tension parallel to grain and compression perpendicular to grain are also listed. Shear and compression perpendicular to grain are dependent on species, and are listed separately according to the species strength group.

5.3 Marking of MSR Lumber

Lumber associations and grading agencies are specially certified by the Canadian Lumber Standards (CLS) Administrative Board to grade mark MSR lumber. Certification by the CLS Administrative Board for MSR lumber includes approval of rules for the mechanical stress rating of the species, approval of the machine and approval of the supervisory service, in accordance with CSA Standard 041 "Softwood Lumber".

The grade mark of a CLS-certified agency on a piece of MSR lumber indicates its assigned f-E classification, species or species combination, moisture condition at the time of surfacing, the name or number of the mill of origin, the CLS-certified agency under whose supervision the grading and marking was done and the phrase "Machine Rated".

5.4 Quality Control and Training

An off-line procedure for controlling the modulus of elasticity (E) is to select five pieces per size per grade per species per shift and to do an edgewise bending test to obtain E and compare it with the machine value. The operator can then adjust the machine to correspond.

The pieces are also proof-loaded in bending to 2.1 x the allowable bending stress. If the pieces survive, there is no problem; if some fail, then the machine has to be adjusted.

It has been noted that the E readings are sensitive to temperature: low temperatures result in higher E readings.

Calibration of the machine is checked by the supplier, who uses aluminum bars. They also bring a man on site to train the operators; this takes a few days only. In the U.S., the lumber association (eg. WWPA) does the training. Appendix B contains the WWPA procedures for Qualification and Quality Control of Machine Stress-Rated Western Lumber.

5.5 Recommendation

At the UNIDO meeting, a number of participants expressed the opinion that the relatively sophisticated types of stress rating machines commercially available need not be recommended to developing countries at this time. This technology might be more appropriate at a later time after considerable experience with visually graded lumber has been accumulated. If modulus of elasticity is to be used for species-independent strength predication, then some simple stiffness measuring device could be constructed. As an example, one could support the piece of wood as a plank on two supports, apply a standard fixed weight to it, and measure the resulting deflection.

It was also suggested that some intermediate technology, much as a simplified form of proof stressing would warrant investigation.

6. STRUCTURAL GLUED-LAMINATED TIMBER

6.1 Standards

In Canada, glulam is manufactured in accordance with CSA Standard O122, "Structural Glued-Laminated Timber", and the manufacturing plants are certified in accordance with CSA Standard O177, "Qualification Code for Manufacturers of Structural Glued-Laminated Timber". CSA O177 does not certify the glulam produced, only the manufacturer.

The Administrative Board of the Structural Glued-Laminated Timber Division of CSA administers CSA Standard O177 and requires that certified plants have acceptable standard procedures and manufacturing equipment as well as fully qualified personnel. Quality control departments in certified plants operate independently from the production department to avoid conflict of interest. Manufacturers may be certified for one or more of the following classes:

- Class I — (Interior) Qualified to manufacture and fabricate glued-laminated materials intended for interior use, using water-resistant glues.
- Class XS — (Exterior-Softwood) Qualified to manufacture and fabricate glued-laminated materials intended for exterior use (or conditions other than dry) using waterproof adhesives and softwood species of laminating stock.
- Class XH — (Exterior-Hardwood) Qualified to manufacture and fabricate glued-laminated materials intended for exterior use using waterproof adhesives and hardwood species of laminating stock (intended primarily for ships).

Qualified manufacturers will supply a certificate for their products upon request. They are also authorized to place labels on their products indicating manufacture in a certified plant.

6.2 Grades

There are three classifications of grades for glued-laminated timber: Service Grade (depending on moisture conditions the product will be satisfactory under in service), Stress Grade (governed by the type and level of stresses imposed) and Appearance Grade (the class of finish).

6.3 End Joints

Laminations are usually made from two or more pieces of laminating stock, end jointed together before assembly into a glulam member. The type of end joint is not specifically limited in CSA Standard O122, but manufacturers either use finger joints or scarf joints. Routine quality control requires that mean strength must be at least 3 times the allowable tensile design stress of the laminating stock; the lower 5% exclusion limit strength, at least 2.3 times the allowable tensile stress. Tension testing is based on not less than 25 specimens.

6.4 Laminating Stock

Laminating stock is graded both visually and with E-rating.

The visual grading is based on the worst face and on the full length of the piece in accordance with the following characteristics:

- density
- moisture content
- knot size, type, spacing and location
- compression failure
- compression wood
- crook
- cup
- decay
- machine marks, skips
- pitch
- shakes, checks, splits
- stain
- torn grain
- wane
- warp, twist, bow
- worm holes
- general slope of grain

The visual grades (in decreasing order of quality) are B-F (for the bottom face of a beam), B, C and D. In addition to the visual requirements referred to above, the laminating stock must have E-values not less than the following, as shown in a standard layup for a beam:

Minimum Modulus of Elasticity (E)* and
Visual Grade Requirements for Stress Grades 20f-E and 24f-E Bending (MPa)

Zone	Visual Grade	20f-E Minimum E		24f-E Minimum E	
		Lodgepole Pine and/or Spruce	Douglas Fir-Larch	Douglas Fir-Larch	Hem-Fir and Douglas Fir-Larch†
Outer 1/8 Compression, or more	C	11 000	13 100	13 800	13 800
The remainder of outer 1/4 Compression	D	9 700	11 700	12 400	12 400
The Inner 1/2 or Less	D	No Requirement	No Requirement	No Requirement	No Requirement
The Remainder of Outer 1/4 Tension	C	9 700	11 700	12 400	12 400
Outer 1/8 Tension, or more Face Lamination	B B-F	10 700 11 000	13 100 Not Required	13 800 14 500	13 800 14 500

7. PLYWOOD

A. W. Kempthorne, writing in 'Wood World' (Vol. 9, No. 2, 1981), described the plywood quality control program of the Council of Forest Industries of British Columbia (COFI):

The COFI Quality Control and Certification Program was formally implemented in 1973 to provide an industry wide standard for grading and testing of plywood produced by COFI member companies. Now in its eighth year of successful operation, the program is recognized internationally and many of its test procedures have been adopted by quality control and standards writing organizations.

In the COFI program the responsibility for the maintenance of plywood quality is placed squarely in the hands of the only person able to control it — the manufacturer. COFI licenses individual plants to identify panels conforming to our standards with the registered certification mark — COFI EXTERIOR. The plant is required to carry out a minimum number of daily tests covering veneer thickness, veneer quality, panel grade, general workmanship, panel thickness and glue bond quality. A standard format is used by all plants for recording and reporting the results of these tests.

COFI's Plywood Quality Control Department staff visits each plant regularly to assess the product and ensure that in-mill quality control is maintaining plywood quality above required levels. COFI visits are made on a varying schedule and tests are carried out on in-stock plywood rather than panels produced during the visit.

In-mill test results are reviewed and panel grade, thickness, size and general quality are checked. Samples are selected from each panel thickness for glueline quality testing at the COFI laboratory.

Without question the item of prime importance is the integrity and durability of the glueline that bonds the veneers together. The phenol formaldehyde resins used to make COFI EXTERIOR plywood are thermosetting and, after curing in the hot press, form an inert glueline unaffected by heat, cold, moisture and virtually any environment to which it might be exposed. The secret, if it can be so called, is to ensure that the glueline is bonding the veneer properly. Wood as a natural material has natural variability. Ambient conditions within the mill such as temperature and humidity will also vary from time to time and production methods are not exactly the same in all mills. It is therefore necessary for each manufacturer to design a combination of glue mix, glue spread, press temperature and pressing time which will suit his operations. The COFI program contains test procedures that can be used to monitor these critical items. In addition, samples are selected daily by each manufacturer for a routine Glue Bond Test specified in CSA Plywood Standards.

Samples selected by COFI Inspectors during their plant inspections are subjected to two glueline quality tests. Ten test specimens are cut from each sample. Five are put through the Vacuum Pressure test which uses cold water in a special pressure chamber. The remainder are boiled for four hours, dried and boiled again. After this severe treatment the individual specimens are pulled apart so that the internal gluelines may be evaluated.

The evaluation is by 'percent wood failure.' This is done by measuring the percentage of the area through which the specimen has broken in the wood as opposed to separating at the glueline.

Glueline quality has always been paramount in the plywood industry and introduction of the quality control program was not expected to significantly raise the general average bond quality. It was, however, expected to curtail the occasional low quality bond and this it has accomplished. . .

A Soak test has been developed and is used by COFI and selected mills to subject large specimens to severe wetting. Any bond failure, no matter how small, is recorded and related to its cause. Similarly, a Panel Exposure test has been established and, with the co-operation of the mills, selected 'full size' panels are being set out for a minimum of two months exposure to the weather.

With the range of climatic conditions experienced throughout British Columbia, we are able to simulate virtually all exposures likely to be encountered by our plywood. As with the soak test, any signs of bond failure will be identified, recorded, and related to cause . . .

Historically the strength properties of plywood were assumed to be equal to the strength properties of small clear solid wood specimens 'adjusted' by various factors to take into account the peeling of veneer, knot size, and other variables. In 1963 COFI initiated development of 'ingrade' testing procedures to evaluate the properties of the plywood as manufactured thus removing the need for assigning factors to the above variables. After having the procedures accepted by recognized international scientific bodies, a test program was developed which included evaluation of all commercially significant species used for plywood manufacture in Canada. The performance of various panel constructions was also evaluated.

The COFI Quality Control Certification Program has provided the checks required to provide the necessary level of confidence in improved performance. The strength of a plywood panel is dependent on the species and quality of its veneer and the thickness, locations and orientation of that veneer in the panel lay-up.

In-mill tests of veneer thickness and accurate segregation of veneer by grade and species are the responsibility of the manufacturer. COFI inspectors evaluate panels from inventory to ensure that species, grade and lay-up conform to requirements. Overall panel thickness is obviously critical if strength and performance are to be maintained. This is tested by both in-mill quality control and COFI. The thickness of individual plies is also highly significant and this is monitored by measurements at the COFI laboratory. . .

Tight control and frequent monitoring of Tongue and Groove profiles are required to maintain the present dimensions required for proper performance and problems which might occur if cutters were not resharpened as frequently as they should be. As cutters wear and become dull the tongue becomes larger and the groove smaller with the obvious result that fitting them together is difficult. Precision machined gauge blocks are used to measure tongues and grooves so that they are maintained within the very close tolerances required . . . . .

In summing up it must be said that the COFI program increased the efficiency of utilization of the resources reaching the mill. Generally better performance has been maintained using available wood supplies . . .

8. JOINTS AND ASSEMBLIES

8.1 End Joints

For visually graded dimension lumber, end joints are acceptable if produced by plants certified under CSA 0268, "Qualification Code for Manufacturers of Glued End Jointed Structural Lumber", and properly identified.

For glulam, as indicated in Section 6.3, manufacturers may use either finger joints or scarf joints. Routine quality control requires that mean strength must be at least 3 times the allowable tensile design stress of the laminating stock; the lower 5% exclusion limit strength, at least 2.3 times the allowable tensile stress. Tension testing is based on not less than 25 specimens.

For joints between lumber members made by pressing on truss plates, the allowable loads are not standard for all proprietary designs of truss plates but are based on individual testing of the particular plate designs. Standard CSA tests include the lateral resistance of the teeth, the tension and shear strengths of the truss plate and the ultimate tension strength of the steel from which the truss plates are punched. An account of the development of the Canadian test standard, and of the factors which can influence the test results, is given in a paper by Quaile and Keenan[1].

8.2 Assemblies

There exist CSA standards for the acceptance load testing of light trusses. Basically, there are two tests. The first is a deflection test, in which 1.33 times the roof design snow load is applied for one hour, at which time the truss cannot have exceeded certain deflection limitation. The second test is a strength test where the test trusses must withstand 2.67 times the design roof snow load without failing.

[1] Quaile, A. T. and F. J. Keenan. 1979. Truss plate testing in Canada : test procedures and factors affecting strength properties. Proceedings, Metal Plate Wood Truss Conference. Forest Products Research Society, Madison, Wisconsin.

9. EDUCATION AND TRAINING PROGRAMMES

Three levels can be considered:

- universities
- technical schools and institutes
- industrial

Programmes which prepare professionals for leadership roles in the use of wood as an engineering material are often presented as 'Wood Science and Forest Products' or 'Wood Science and Industry' programmes generally within Faculties of Forestry at universities. In the summer of 1981, the author developed such a program for Universiti Pertanian Malaysia; the proposed curriculum is contained in Appendix C. Other professional-level programmes are found in university departments of civil engineering.

An example of the second type is found at the British Columbia Institute of Technology; an outline of their programme in Forest Products is in Appendix D.

However, almost all of the practical training in timber grading is done by the industry rather than by educational institutions.

The following is a description of industrial training in visual lumber grading as conducted in a typical western Canadian mill. The instruction is given in the mill by a staff grader who is approved to teach grading by one of the grading agencies (e.g. COFI). The companies encourage their employees to take the grading courses, which are given outside regular working hours. The 'prize' is that production personnel become eligible for some of the better-paying jobs (e.g. sawyer, trim saw operator, edgers, graders). Management stream people also take the courses; they don't immediately receive raises, but it adds to their prospects for promotion. The duration of the course is one or two evening sessions two hours long for three months. The aids used are books with descriptions and sketches of the defects, as well as a multiplicity of timber samples. In class a limited number of samples are used but they are analyzed in depth. Outside of class, a set of 100 sample boards is available for individual practice.

The exam is 2 to 3 hours long and consists of a written portion plus a practical portion. In the latter, a number of sample pieces are presented to the candidate and he is required to grade them correctly according to a particular rule. The examination is conducted by the grading agency; the agency also issues certificates to the successful applicants.

There are no mandatory refresher courses or requalification examinations, although grading competitions are sponsored from time to time.

For MSR lumber, it is generally the manufacturer of the machines who provides the training at the present time.

At the UNIDO meeting, the training of graders for visually graded lumber was discussed extensiviely, and a series of recommendations was produced. They are as follows:

Duration: Although durations of three months are not uncommon for countries with well-developed grading systems, this is possibly more than necessary for a developing country. Perhaps five or six weeks would be sufficient. This shorter period would lessen the reluctance of the grader's employer to pay his wages during the grading course.

Location: At sawmill rather than at a research laboratory.

Background: It was generally felt that it would be useful for the grader trainee to have had some previous practical experience in the sawmill. Further, if a suitable aptitude test could be developed, this might help to screen out people who might not benefit from the training. Lacking this, a minimum level of education could be specified.

Recognition: The grader, once he has passed the course, should take pride in his accomplishment and, concurrently, be aware of the technical responsibility which he has now assumed. Because he has developed a skill, he should also receive some financial recognition because he is now capable of contributing more to his employer's success.

Instructional Aids: Those developed by TRADA, by the Malaysian Timber Industry Board and by Australia could be used immediately as they are, and subsequently modified to suit the needs of a particular country. It was also recommended that the visual impact of the aids be professionally developed making appropriate use of colour and animation.

Progression: If a country has a series of grades to be learned, it might be better to train a grader in just one of those grades at first, and to permit him upon graduation to deal only with those grades in the mill, and subsequently to return for instruction in other grades at a later time.

APPENDIX A

Visual Grading Rule for Tropical Structural Timber

Reproduced from:

Piqué, J. and M. Tejada. Working stresses for tropical hardwoods of the Andean Pact countries. Junta del Acuerdo de Cartagena, Lima Peru.

APPENDIX A

VISUAL GRADING RULE FOR TROPICAL STRUCTURAL LUMBER

The Visual Grading Rule for Tropical Structural Lumber is presented below. The following documents have been considered as references:

- AMERICAN SOCIETY FOR TESTING AND MATERIALS. Standard Methods for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber, ASTM D 245-70, Part 16, Philadelphia, July 1975.

- PANAMERICAN STANDARDS:

  COMISION PANAMERICANA DE NORMAS TECNICAS. Aserrado y cepillado de madera. "Definición de Defectos". Norma Panamericana COPANT 57/CDU, 1973.

  ____________________. Aserrado y cepillado de madera. "Métodos para Medición de Defectos". Anteproyecto de Norma Panamericana COPANT 30:3-003, 1974.

  ____________________. Aserrado y cepillado de madera. "Criterios de Evaluación para Clasificación de Maderas". Anteproyecto de Norma Panamericana COPANT 30:3-004, 1974.

1. WARPS

It is the distortion undergone by a piece of lumber due to the curvature of its longitudinal or transversal axis or both.

Includes : 1a. Cupping

1b. Bow

1c. Spring

1d. Twist

1. a. Cupping

It is the warping of a piece of lumber perpendicular to the grain.

Recognition

The piece of lumber on a plane surface will rest on the center of the face and the edges will be raised, presenting a concave shape.

Tolerance

Not allowed.

1. b. Bow

It is the warping or bending along the length on the face of the piece.

Recognition

On a plane surface a separation will be observed between the face of the piece and the support surface.

Tolerance

3 cm per 300 cms or its equivalent are allowed: $\frac{H}{L} < 1\%$

1.c. Spring or crook

It is the warping or curvature along the length of the edge of the piece.

Recognition

On a plane surface separation will be observed between the edge of the piece and the support surface. The largest separation should be considered.

Tolerance

1 cm per 300 cm or its equivalent is allowed: $\frac{H}{L} < 0.33\%$

1.d. Twist

It is the warping observed when the corners of a piece of lumber are not in the same plane.

Recognition

On a flat surface a rise of either corner will be observed.

Tolerance

It is allowed only when slightly present and in only one edge.

1 cm per 3m length

2. SAPWOOD

It is the portion of the log following the bark, which in the standing tree contains live cells and reserve materials.

It is generally light colored and more susceptible to fungii and insects attacks than heartwood.

In general, its mechanical properties are not different to those of the heartwood.

Includes: 2.a. Sound sapwood

2.b. Rotten sapwood

2.a. Sound sapwood

Recognition

It is sapwood free of fungii and insects attacks, except what is indicated in "borer holes".

Tolerance

Allowed without restriction when duly preserved. Without treatment it may be up to 25% of the piece.

2.b. Rotten sapwood

Recognition

Sapwood with fungii attack.

Tolerance

Not allowed.

3. WANE

Recognition

It is the lack of wood in one or more faces or edges of the piece.

Tolerance

Allowed with a maximum length of 50 cm and a side not larger than 5 cm for pieces 3 m long. In pieces with shorter lengths, tolerance will be proportional.

4. BRITTLE HEARTWOOD

It is the innermost part of the log, generally of darker color and longer durability than sapwood, even though is not always clearly differen - tiated.

Normally it constitutes the largest central portion of the log.

Recognition

Portion of lumber in a 10 cm diameter zone adjacent to the pith in ten - sion, characterized by an abnormal brittleness. It appears as half moon shaped shakes. More frequent in old trees and can show decay.

Tolerance

Not allowed.

5. SCALE OR CUP SHAKES

Separation of two contiguous growth rings.

Recognition

Superficial scales or shakes are observed in the flat sawn faces of a piece of wood.

Tolerance

Its presence is allowed only over one face up to 1/4 of the piece length and a separation between rings not larger than 3 mm.

6. COMPRESSION FAILURE

It is the rupture of the wood fibers as a result of excessive compression or bending in standing trees caused by its own weight or by wind action. They may also be a result of harvesting and log handling or defective storage of sawn lumber.

Recognition

They can be only be observed in the dressed surfaces of a piece and as fine wrinkles perpendicular to grain.

These failures originate zones with low mechanical capacity. They are found in trees with spindle-shaped or conic stems.

Tolerance

Not allowed.

7. GRAIN

It is the direction, size and arrangement of fibers in wood in relation to the longitudinal axis of the piece. It may be found as straight, sloped and cross grain.

Includes: 7.a. Sloping grain

7.b. Cross grain

7.a. Sloping grain

Recognition

It is the angle between the grain in relation to the longitudinal axis of the piece.

It is necessary to use the grain detector over the faces and edges of the piece.

Tolerance

Allowed in face or edge up to a maximum slope of 1/8

7.b. Cross grain

Recognition

Grain arranged in interlaced and interweayed direction along the piece.

In flat sawn faces hardly observable, it can only be observed in edges or quarter sawn faces using the grain detector.

Tolerance

When the angular deviation is pronounced in the central third of a piece, a maximum slope of 1/16 is allowed. Cross grain without discontinuities is allowed.

8. CHECKS

It is a crack along the grain not affecting two faces of a piece, or two opposite points of the surface of a round timber.

Recognition

Discontinued and superficial cracks are observed, of approximately one millimeter separation and 2 to 3 mm depth. This defect is the result of stresses during seasoning.

Tolerance

Moderately allowed with a depth not larger than 2 mm.

9. END CHECKS OR SPLITS

Fractures following the grain in sawn wood extending from one face to an opposite or adjacent one or two points of a round timber.

Recognition

They are observed as separations of the fibers along the grain.

Tolerance

Allowed only in one of the ends of the piece and of length not larger than the width or face of the piece.

10. PITH

It is the central part of the heart consisting esentially of paren chyma, generally soft tissue or dead cells.

Recognition

It is the small zone of spongy tissue located in the center of the heart. It is susceptible to fungii and insects attacks.

Tolerance

Very small, sound and or preserved pith is allowed. Decayed, rotten, perforated or cracked pith not allowed.

11. KNOT

It is the ligneous tissue resulting from the growth left by a branch, whose organoleptic characteristics and other properties are different to those of the sorrounding wood.

Includes: 10.a. Sound knot

10.b. Hollow knot

10.a. Sound knot

Recognition

It is the knot ingrown with the remainder of the board. Will not become loose on seasoning and use. It does not decay nor rot.

Tolerance

Allowed up to a diameter of 1/4 of the face width, up to a maximum diameter of 4 cms. and with a separation between knots no less than 100 cms.

Knots equal to or less than 1 cm diameter are allowed with a minimum separation of 40 cms.

10.b. Hollow knot

Recognition

Are the hollow spaces left by the knots where they have fallen out. Loose or unsound knots should be considered as hollow knots.

Tolerance

Not allowed in tension zones (L/3). Allowed those with a 1/4 of the face width diameter up to a maximum of 4 cms. with a minimum spacing of 100 cms. Hollow knots of a diameter equal or less than 1 cm are allowed with a separation of 40 cms.

11. PARENCHYMA

Wood cells, typically in form of parellelepipeds with thin walls. They act as storage of nutrients. Susceptible to fungii and insects attacks.

Recognition

Cells associated with soft tissue, generally of lighter color than the fibrous portion of the log. Distributed in concentric bands visible at first glance in the transversal section of a piece of wood previosly wetted.

Tolerance

Not allowed in pieces which will be subjected to compression parallel to the grain.

It is allowed for other uses.

Parenchymatic bands should not be thicker than 2 mm.

12. PIN HOLES OR BORER HOLES

Holes or galleries caused by attack of insects or larvae.

Includes: 12.a. Pin holes

12.b. Grub holes

12.a. Pin holes

Recognition

Holes with diameters of 3 mm. or less produced by insects of the Ambrosya or Lyctus type.

Tolerance

Moderately allowed, with a maximum of 6 holes in 100 cm^2. Small aligned perforations are not allowed.

12.b. Grub holes

Recognition

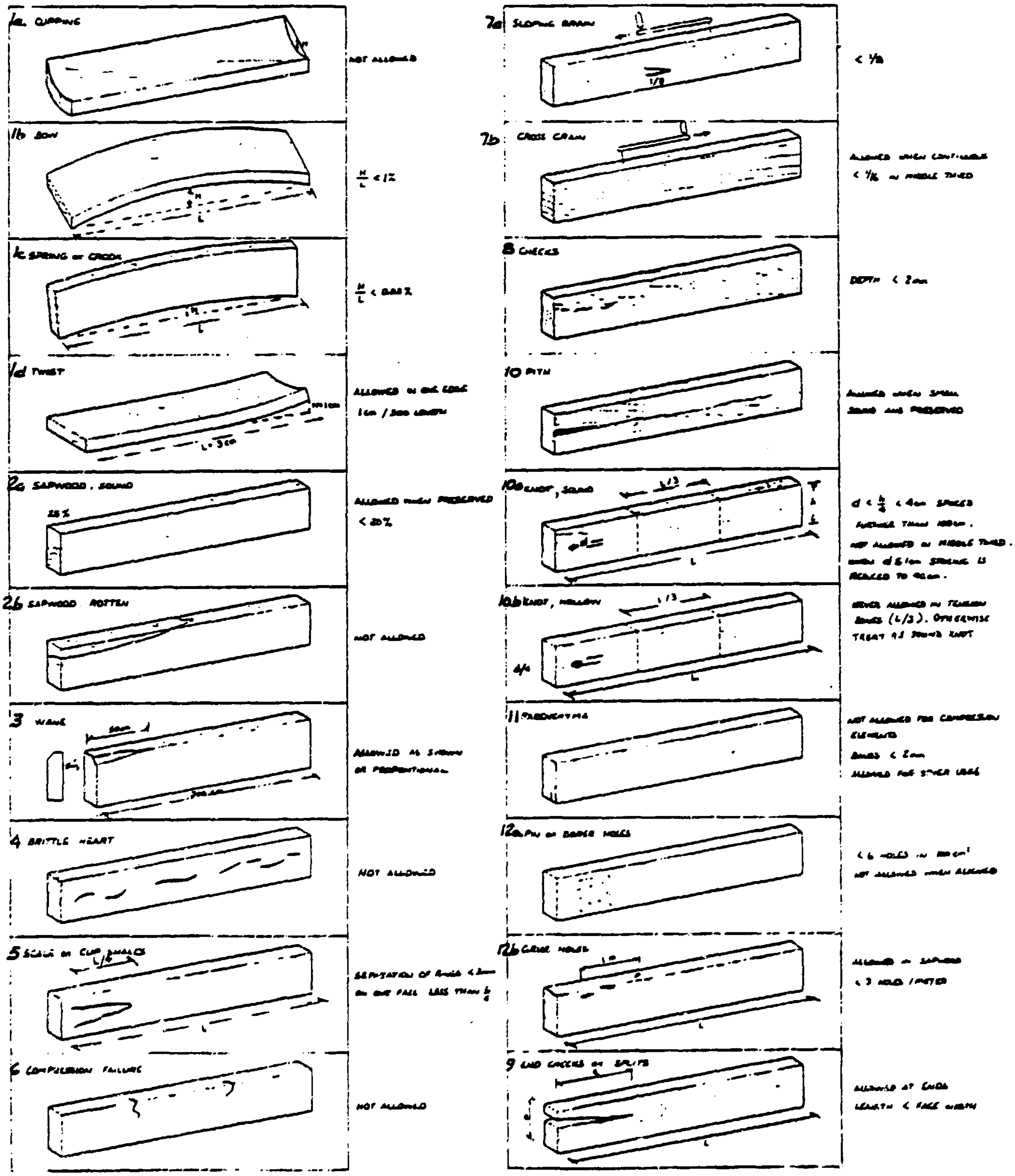
Holes with diameters larger than 3 mm produced by insects or borer larvae "home drillers" Bostrychidae borers.

Tolerance

Allowed in sapwood and no more than 3 holes per meter.

VISUAL GRADING RULE FOR TROPICAL STRUCTURAL LUMBER

PADT REFORT-JUNAC



APPENDIX B

Procedures for Qualification and Quality Control of Machine Stress-Rated Western Lumber.

Published by

Western Wood Products Association

52.00 MACHINE STRESS-RATED LUMBER

The following grading rule has been excerpted from Western Lumber Grading Rules 80, effective May 1, 1980. All references in the portions excerpted apply to those grading rules.

All species 2" and less in thickness 2" and wider

Grade Rules

Machine stress-rated lumber is lumber that has been evaluated by mechanical stress rating equipment. MSR lumber is distinguished from visually stress graded lumber in that each piece is non-destructively tested to indicate its modulus of elasticity. The stress rating machine sorts the material into various modulus of elasticity classes. MSR lumber is also required to meet certain visual requirements as set forth herein.

STANDARD SIZES FOR MACHINE STRESS-RATED LUMBER For 2" Thick, 2" and Wider

NOMINAL THICKNESS	ACTUAL THICKNESS Surfaced Dry	Surfaced Unseasoned
2"	1½"	1-9/16"

NOMINAL WIDTHS	ACTUAL WIDTHS Surfaced Dry	Surfaced Unseasoned
2"	1½"	1-9/16"
3"	2½"	2-9/16"
4"	3½"	3-9/16"
6"	5½"	5-5/8"
8" and wider	¾" off nominal	½" off nominal

Standard lengths are 6' and longer in multiples of 1'.

A grade stamp on machine stress-rated lumber indicates the stress rating system used meets requirements of the grading agency's qualification and quality control procedures. The grade stamp will show the agency trademark, the mill name or number, will include the phrase "Machine Rated," the species identification and the "E" rating for the grade. The "E" rating is the rated modulus of elasticity in millions of pounds per square inch. Stress rating machines are adjusted so that the output will average the "E" level shown on the grade stamp.

To meet the structural needs for a broad range of engineered construction, a number of "Fb-E" classifications are available. "Fb" indicates the fiber stress in bending applicable to lumber loaded on edge and is shown on the grade stamp. Fiber stress in bending design values are based on the correlation of the modulus of rupture to "E". Machine output is controlled by testing pieces and adjusting machines so that the minimum assigned fiber stress in bending value, derived from a 5% exclusion level of modulus of rupture, is met after applying the same reduction factors as are applied to visually graded lumber in accordance with ASTM D 245. Compression parallel to grain (Fc) values are established as 80% of fiber stress in bending values. Compression perpendicular to grain (Fc⊥) and horizontal shear (Fv) values are the same as assigned by ASTM methods to visually graded lumber. Tension parallel to grain (Ft) values are based on tests of nominal 4" wide machine stress-rated lumber.

For any given "Fb" value, the average "E" value may vary depending upon species, timber source and other variables. The "E" values shown in the design value tables that follow are those usually

MACHINE STRESS-RATED LUMBER 2" and Less in Thickness 2" and Wider Design Values in Pounds Per Square Inch (1)

Extreme Fiber Stress in Bending "Fb" (2) Single	Repetitive	Modulus of Elasticity "E"	Tension Parallel to Grain "Ft"	Compression Parallel to Grain "Fc"
900	1050	1,000,000	350	725
1200	1400	1,200,000	600	950
1350	1550	1,300,000	750	1100
1450	1650	1,300,000	800	1150
1500	1750	1,400,000	900	1200
1650	1900	1,500,000	1020	1320
1800	2050	1,600,000	1175	1450
1950	2250	1,700,000	1375	1550
2100	2400	1,800,000	1575	1700
2250	2600	1,900,000	1750	1800
2400	2750	2,000,000	1925	1925
2550	2950	2,100,000	2050	2050
2700	3100	2,200,000	2150	2150

(1) Compression perpendicular to grain (Fc⊥) and horizontal shear (Fv) values are the same as assigned by ASTM methods to visually graded lumber.

(2) "Fb" design values are applicable to lumber loaded on edge. When loaded flatwise, the values may be increased by multiplying by the following factors:

Width (in.)	3"	4"	5"	6"	8"	10"	12"	14"
Factor	1.06	1.10	1.13	1.15	1.19	1.22	1.25	1.28

associated with each "Fb" level. Grade stamps may show higher or lower values (in increments of 100,000 pounds per square inch) if qualification procedures and subsequent quality control verification indicates the assignment is appropriate. However, when an "E" value associated with an "Fb" level is lower than those listed in the accompanying table, special testing and quality control procedures are required to assure the listed "Ft" values associated with the "Fb" values are applicable.

Visual Grading Requirements

Mechanically stress-rated lumber must be well manufactured and visually graded to limit certain characteristics even though the actual strength is not affected. All pieces shall be visually graded to assure that the characteristics affecting strength are no more serious than the following limiting characteristics:

- Checks – Seasoning checks not limited. Through checks at ends limited as splits.
- Shake – On ends limited to 1/2 the thickness. Away from ends through heart shakes up to 2 feet long, well separated. If not through, single shakes may be 3 feet or up to 1/4 the length, whichever is greater.
- Skips – Hit and miss, and in addition 5% of the pieces may be hit or miss or heavy skip not longer than 2 feet. See Section 720.00(e), (f) and (g).
- Splits – Equal in length to 1½ times the width of the piece.
- Wane – 1/3 thickness, 1/3 width, 5% of pieces may have wane up to 2/3 thickness and 1/2 the width for 1/4 the length.
- Warp – Light. See table, Section 752.00.

In addition to the visual limitations listed, knots, knot holes, burls, distorted grain or decay partially or wholly at edges of wide faces, must not occupy more of the net cross section than:

	Fb Class
1/2 for	0 to 900
1/3 for	950 to 1450
1/4 for	1500 to 2050
1/6 for	2100 and over

REINSPECTION

In the event of a claim, a representative sample of the shipment shall be checked by the Association for conformance to assigned values and visual grading requirements.

Gradestamp Facsimile

MACHINE RATED
WWP® 12 S-DRY HEM FIR
1650f 1.5E

PHYSICAL REQUIREMENTS

Machine stress-rated lumber is required to meet certain physical requirements for both modulus of elasticity and extreme fiber stress in bending.

The average edge modulus of elasticity ($\bar{E}$) of MSR lumber must equal or exceed the modulus of elasticity assigned to the grade (Eg):[1]

$$\bar{E} \geq E_g$$

The lower 5th percentile of edge modulus of elasticity (E_{5th}) of MSR lumber must equal or exceed a factor of 0.82 times the modulus of elasticity assigned to the grade (Eg):

$$\bar{E}_{5th} \geq 0.82\ E_g$$

This provides that for design purposes the grade E can be regarded as having a coefficient of variation not exceeding 11%, as stated in the National Design Specification for Wood Construction.

The lower 5th percentile of the modulus of rupture of the population of a grade of machine stress-rated lumber (MOR_{5th}) when subjected to a short-term load shall equal or exceed 2.1 times the assigned fiber stress in bending for the grade (Fb):[2]

$$MOR_{5th} \geq 2.1\ F_b$$

(1) The edge modulus of elasticity is determined under the following conditions:
Selection of loaded edge – random.
Loading location – third points on the span.
Span to depth ratio – 21 where possible but at least 16.
Lengthwise orientation – piece centered in test span.
Rate of loading – maximum rate of stress of 16,000 psi per minute.

(2) The modulus of rupture in bending of an individual piece is determined under the following conditions:
Selection of loaded edge – random.
Loading location – third points on the span.
Span to depth ratio – 21 where possible but at least 16.
Rate of loading – maximum rate of stress of 16,000 psi per minute.
Lengthwise orientation – the maximum edge defect located between or as close to the load points as possible.

PROCEDURES

Machine stress-rated lumber (MSR lumber) is lumber that has been rated for stiffness and related to fiber stress in bending by nondestructive tests in the production process. MSR lumber must also meet visual grade requirements as set forth in WWPA grading rules.

Mills that meet the following qualification and quality control procedures are authorized to use WWPA grade stamps indicating their products meet requirements for machine stress-rated lumber.

QUALIFICATION

Mills qualifying for MSR grade stamps must possess a proof loading testing machine capable of testing sizes and grades to be qualified. Proof loaders must be of a design that permits deflection measurements to .001". The measuring systems of the proof loader, from which MOE and MOR are determined, shall have an accuracy of ± 3 percent, as determined by WWPA. This accuracy shall apply within the range of the sizes and grades to be qualified. Loading rate must be controllable to limit the rate of stress on the piece to no more than 16,000 psi per minute. The ratio of testing span to depth capability shall be 21 where possible but at least 16.

Each size and grade category for which stamps are desired must be qualified. Each species or species grouping, seasoned or unseasoned, must be qualified.

1.00 – Qualification

Qualification shall be based upon pieces selected by WWPA from output of the machine. The machine shall have been properly calibrated and set for the size, species and machine grade to be qualified. All test pieces shall meet visual requirements of the grade to be qualified. Qualification for modulus of elasticity shall be based upon tests of at least 30 pieces. Qualification for extreme fiber stress in bending may be made on the same 30 pieces or additional pieces as explained in Section 1.21C.

1.10 *Testing Method*

1.11 The edgewise modulus of elasticity of each piece shall be determined from a load/deflection relationship obtained below the proportional limit of the test piece. The test span shall be at a span to depth ratio of 21 where possible but at least 16. The piece shall be centered in the test span with the load applied at third points or by placing the characteristic judged to be the most weakening edge defect between or as close to the load points as possible.

1.12 Each piece shall be loaded to a stress of 2.1 times the Fb level to be qualified at a maximum rate of stress of 16,000 psi per minute. The characteristic judged to be the most weakening edge defect shall be included between or as close to the load points as possible. The load and resulting modulus of rupture (MOR) shall be recorded for pieces that fail and shall constitute a proof loading failure.

1.20 *Test Results*

1.21 Test results shall indicate whether grade stamps may be issued for the grade, size, species, or seasoning condition being tested. Grade stamps for MSR lumber may be issued if:

A. The mean edge E of the sample pieces equals or exceeds 95 percent of the MOE value assigned to the grade being qualified.

B. Ninety-five percent of the sample pieces have a value greater than 82 percent of the MOE value assigned to the grade being qualified (calculated as shown in Appendix A).

C. No more than one proof loading failure occurs in a 30-piece sample. Additional samples of 20 pieces each may be tested to qualify for MOR as long as no more than two failures occur in a 50 piece sample, three in a 70-piece sample, or four in a 90-piece sample.

1.22 If test results do not meet the requirements of 1.21, A, B, and C:

A. Adjustments of machine settings may be made until the sample qualifies under 1.21 A and B.

B. If no more proof loading failures are found than specified in 1.21 C, qualification requirements are met. If after testing 90 pieces, test requirements are not met, changes in machine settings may be made and a new 30-piece (and subsequent 20-piece) sample may be tested.

QUALITY CONTROL

Continuing use of WWPA grade stamps for Machine Stress-Rated (MSR) products is made contingent upon the manufacturer following certain required in-plant quality control procedures as set forth in Section 2.00.

2.00 – General

2.01 Plant quality control records shall include: (1) test equipment calibration checks, (2) production periods, (3) quality control tests, and, (4) production stoppages due to quality control requirements and actions taken. Records shall be retained for at least one year.

2.02 Quality Control, including sampling and testing prescribed in Sections 5.00 and 6.00 shall utilize the Cumulative Sum (CUSUM) procedure, and test results shall be recorded on CUSUM Control Forms and Charts provided by WWPA utilizing the CUSUM constants as shown in Appendix B.

2.03 Grade stamping shall be stopped immediately for any machine rated product which fails to meet test requirements ("out of control") and shall not be resumed until the process is back "in control" (see Section 7.00).

3.00 – Record Keeping

3.01 The manufacturer shall keep records of daily production, sampling and testing on control forms provided by WWPA.

3.02 The plant shall maintain a record of all production stoppages occasioned by the in-plant quality control along with an explanation of the corrective action taken.

3.03 All records as required in Section 2.01 shall, upon request, be made available to WWPA during working hours.

4.00 – Test Equipment Calibration

4.01 Proof loading equipment shall be calibrated once each week and at any other time there is reason to suspect the equipment may be out of calibration.

4.02 Records of all calibration checks shall be maintained.

5.00 – Sampling

During each eight-hour shift, one five-piece sample from production of each size, grade, and species being produced shall be selected at the machine outfeed as set forth below:

A. Count five pieces as rated by the machine.

B. Select the next piece rated of the grade being tested and which meets the visual grade requirements.

C. Repeat the sequence five times at approximately equal intervals during the shift period.

6.00 – Sample Testing

Samples shall be tested in static bending by third-point loading and at a rate of stress not to exceed 16,000 psi per minute. The span shall be 21 times the depth of the sample, if possible (and in no case less than 16), with load points and supports positioned to ± 1/8" of required span. The grade stamp or color mark on the sample shall face the person conducting the test, and shall be consistently to either the tester's right or left to provide random placement of edge defects with respect to loading in tension or compression.

6.01 The edge MOE shall be determined for each piece from measurements with the sample centered in the test span, or by placing the maximum edge defect between the load heads of the testing equipment.

A. Deflection shall be measured to the nearest .001 inches.

B. Edge MOE shall be calculated to the nearest 10,000 psi and recorded on the forms provided.

6.02 Each piece shall be loaded to a stress of 2.1 times Fb for the machine grade being produced. The characteristic judged to be the most weakening edge defect shall be included between or as close to the load points as possible.

A. Pieces which carry the full proof load without fracture, or carry the full proof load with only partial failure, are recorded as meeting test requirements.

B. If a piece fails at less than the proof load (and upon further loading will not carry the full proof load), the MOR at failure shall be recorded.

7.00 CUSUM Control Conditions

Control conditions shall be determined by results of data compilations on CUSUM control forms and charts.

7.10 *CUSUM In Control (MOR, Average E and Minimum E)*

If tests show the CUSUM for MOR, Average E and Minimum E to be in control, all lumber represented by the sample is satisfactory for shipment.

7.20 *CUSUM Out of Control (MOR, Average E and Minimum E)*

If any tests show the CUSUM for MOR, Average E or Minimum E out of control, all lumber represented by the sample shall be held pending confirmation tests set forth below.

Such out of control conditions may be indicated for any of the following reasons:

A. Visual characteristics exceed limitations provided in grading rules;

B. MSR machine is out of adjustment;

C. Statistical chance, or

D. The manufacturing process has changed since the last samples were tested.

Each condition shall be checked in the following sequence, and steps taken as required until the process is brought back in control.

7.21 Test – Visual Characteristics

The visual grade of each sample piece that has failed the proof loading test shall be checked. If it is found out of conformance with visual edge defect limitations prescribed by the grading rules, a substitute piece which does conform shall be selected and tested according to procedures prescribed in Sections 5.00 and 6.00.

If, after substitution, the five-piece sample shows the process is in control, the production volume held pending completion of tests may be released for shipment, and use of grade stamps may be continued.

7.22 Test – Machine Adjustment

The MSR machine shall be checked for basic calibration and grade boundary levels. If required, appropriate adjustments shall be made. Then a sample of 30 pieces shall be selected at the machine outfeed of approximately every third piece from the production run, sequentially numbered in six samples of five pieces each. Tests shall be made in accordance with Section 6.00.

When CUSUM control forms indicate in control, after one or more of the six samples have been tested and evaluated, and the machine requires three percent or less adjustment for grade boundary levels, the production volume held pending completion of tests may be released for shipment, and use of grade stamps may be continued.

If the machine requires more than three percent adjustment for basic calibration or for grade boundary levels, even though the test indicates the process is in control, the production volume held pending completion of tests shall be regraded.

7.23 Test – Statistical Chance

If under 7.22, the MSR machine is found to be accurate for grade boundary levels, or requires an adjustment of three percent or less to meet appropriate operating disciplines, but the test indicates production is still out of control, a second 30-piece sample shall be selected and tested as prescribed in 7.22.

If after testing one or more of the six five-piece samples, the CUSUM forms indicate in control, the production volume held pending completion of tests may be released for shipment, and use of grade stamps may be continued.

If the machine requires more than three percent adjustment for grade boundary levels, even though the test indicates the process is back in control, the production volume held pending completion of tests must be regraded.

7.24 Test – Manufacturing Process

If after completion of 7.21, 7.22, and/or 7.23, the process is still out of control, the cause shall be identified, corrected and confirmed before use of grade stamps may be resumed. All grade stamps on lumber held pending completion of tests shall be obliterated.

The manufacturing process shall be considered back in control after appropriate steps have been taken to correct the process and a subsequent test (in accordance with 7.22 or in accordance with Section 6.00, as appropriate,) shows the production is back in control.

If the machine requires more than three percent adjustment for grade boundary levels, even though this test indicates the process is back in control, the production volume held pending completion of tests must be regraded.

APPENDIX A

Edge E Lower 5th Percentile

The lower 5th percentile of the sample edge E values (E_{5th}) shall be at least 82% of the E value assigned to the grade (Eg), and is calculated as follows:

$$E_{5th} = \bar{E} - 1.645\,s$$

where:

E_{5th} = 5th percentile of the sample E values

$\bar{E}$ = sample average E

s = standard deviation of a distribution of sample E values such that the upper half of the distribution is a mirror image of the lower half.

APPENDIX B

CUSUM Constants (5-Piece Samples)

Grade E	W	X	Y	Z
1.2	98	1150	120	333
1.3	106	1250	141	365
1.4	115	1350	163	378
1.5	123	1450	186	402
1.6	131	1550	211	428
1.7	139	1650	236	455
1.8	147	1750	262	483
1.9	156	1850	288	511
2.0	164	1950	316	542
2.1	172	2050	344	574
2.2	180	2150	372	606

Reference

Warren, W. G. 1978. Recent Developments in Statistical Quality Control Procedures for MSR. Proceedings of the 4th Nondestructive Testing of Wood Symposium. Washington State University.

APPENDIX C

Example of MSR Proof Loads (Third-Point Loading)

Dimension	2x4	2x6	2x8	2x10	2x12
Span	73.5	115.5	152.25	186	186
ℓ/d	21	21	21	20.1	16.5
Fb (psi)	P (lbs.)	P (lbs.)	P (lbs.)	P (lbs.)	P (lbs.)
900	480	750	980	1310	1930
1000	525	825	1088	1449	2143
1200	630	990	1310	1740	2580
1450	770	1200	1580	2100	3110
1500	790	1240	1640	2180	3220
1650	870	1370	1800	2400	3540
1800	950	1490	1960	2610	3860
1950	1030	1610	2130	2830	4180
2100	1110	1740	2290	3050	4500
2250	1190	1860	2450	3260	4830
2400	1260	1980	2610	3480	5150

$P = 4.2\,Fb\,S/a$ where:

Fb = extreme fiber stress in bending of the grade.

S = section modulus = $bd^2/6$

b = thickness

d = width

a = one-third the span = $\ell/3$

ℓ = span

APPENDIX C

Proposed Undergraduate Programme in 'Wood Science and Industries' for the Universiti Pertanian Malaysia

3.2. Curriculum Overview

The B.Sc.F. Programme in Wood Science and Industries spans four years, each with two semesters, for a total of eight semesters. Semesters 1, 2 and 3 are identical for the Forestry Programme and the Wood Science and Industries Programme. In the succeeding semesters, there will be some other courses which are common to the two programmes, but the level of specialization increases as one proceeds through the programme.

In general, the courses may be considered as being in four categories:

* Basic Disciplines: physics, chemistry, geology, biology, mathematics, statistics, economics, sociology, social anthropology, languages.
* Fundamentals of Forestry: introduction to natural resources, soils, dendrology, surveying, mensuration, biometrics, technical drawing, forest engineering, harvesting.
* Science and Technology of Forest Utilization: wood anatomy and identification, wood chemistry, wood physics, elements of machine design, analysis of wood structures, mechanics of materials, wood engineering (elements and systems), wood drying, pulp and paper, wood deterioration and protection, wood machining, adhesives and gluing, wood composites, microtechnique, electron microscopy, research project.
* Professional Development and Business Aspects of Forest Utilization: effective communication (public speaking and report writing), accounting, business administration, marketing of forest products, forest administration and policy.

3.3. Proposed Curriculum

FIRST YEAR

Semester 1

- English
- Biology III
- Principles of Economics
- Applied Physics
- Organic Chemistry
- lgebra and Calculus
- Introduction to Social Anthropology
- Introduction to Sociology

Semester 2

- Bahasa Malaysia
- Biology IV
- Introduction to Natural Resources
- Physical Inorganic Chemistry
- Statistics
- Rural Sociology
- Geology and Soil Formation

SECOND YEAR

Semester 3

- Elementary Surveying
- Technical Drawing
- Dendrology I
- Forest Soils
- Mensuration
- Forest Biometrics

Semester 4

- Wood Anatomy and Identification
- Wood Chemistry
- Wood Physics
- Elements of Machine Design
- Accounting
- Effective Communication - Public Speaking

THIRD YEAR

Semester 5

- Analysis of Wood Structures
- Forest Engineering
- Marketing of Forest Products
- Wood Drying
- Pulp and Paper
- Effective Communication - Report Writing

Semester 6

- Mechanics of Materials
- Harvesting
- Business Administration
- Wood Deterioration and Protection
- Wood Machining
- Adhesives and Gluing

FOURTH YEAR

Semester 7

- Wood Engineering I (Elements)
- Wood Composites
- Microtechnique
- Forest Administration and Policy
- Elective
- Project

Semester 8

- Wood Engineering II (Systems)
- Electron Microscopy
- Advanced Wood Chemistry
- Environmental Impacts
- Elective
- Project

APPENDIX D

Forest Products Programme

British Columbia Institute of Technology

Forest Products

The forest products industry in B.C. continues to grow yearly with the adoption of new technology in the manufacture and marketing of pulp, newsprint, plywood and lumber products.

Job Opportunities
Both men and women with a sound knowledge of technological advances in forest products and their application are needed in plant process operations, plant managment, research and development, technical services and sales.

Graduates in the Lumber and Plywood Program are employed in the sawmilling and plywood industries as management trainees in production, production control, quality control or sales.

Graduates from the Pulp and Paper Program are in demand in pulp production, process control, pulp and paper quality control, pollution abatement and control, and research.

The Program
Students enrolling in the Forest Products Technology choose one of two programs of study — lumber and plywood or pulp and paper. In addition to the basic sciences, the first-term curriculum includes an introduction to forest utilization, wood technology, sawmilling, plywood and pulp and paper manufacture. In the succeeding terms, there is increased emphasis on specialization within the chosen program.

The Lumber and Plywood Program includes the study of the techniques and economics involved in converting wood to products such as lumber, plywood and particleboard.

The Pulp and Paper Program curriculum includes the theory and application of technology in pulping processes, and the conversion of pulp to finished products such as newsprint, paper and paperboard. Quality control and pollution abatement are an integral part of the program. A pilot plant, which is recognized by the Technical Section of the Canadian Pulp and Paper Association as a member mill, is used to provide hands-on experience.

In both programs, classroom and lab instruction are augmented by field trips.

Prerequisites
Graduation from the Selected or Combined Studies Program is a general prerequisite. The following special prerequisites are required for individual programs.

Pulp and Paper: Algebra 12 or Math 12 and Chemistry 11

Lumber and Plywood: Algebra 12 or Math 12 and one science 11 (Biology, Chemistry or Physics). Industrial experience strengthens an application for any of the options and skill in report writing is essential.

Initiative, efficiency and leadership ability are important qualities.

Scholarships
Industry-sponsored, two-year combined scholarship-mill employment awards are now available to selected students entering both the Pulp and Paper and Lumber and Plywood Programs.

These awards vary in amounts up to $1,200 per student. Information may be obtained from your high school counsellor, or by contacting the Forest Products Technology staff at BCIT.

Course of Studies

Clrm hrs/wk

		Pulp & Paper	Lumber & Plywood
Year 1	**Term 1**		
30.103	Applied Chemical Principles	6	—
31.146	Technical Communication	3	3
32.146	Basic Technical Mathematics	5	5
33.118	Applied Physics	5	5
41.107	Engineering Materials	2	
46.101	Forest Utilization	7	7
46.115	Lumber Grading I	—	2
46.198	Lumber Tallying*	—	2
46.199	Log Utilization	—	4
49.101	Drafting Fundamentals	2	2
	Tutorial	1	1
	Library and Research	4	4
		35	35
Year 1	**Term 2A**		
30.203	Applied Chemical Principles	6	—
31.246	Technical Communication	3	3
32.246	Calculus	5	—
32.264	Statistics and Quality Control	—	5
33.218	Applied Physics	5	5
41.207	Engineering Materials	2	—
41.208	Engineering Materials	—	3
46.212	Pulp and Paper Technology I	7	—
46.215	Lumber Grading II*	—	8
46.220	Wood Properties	—	4
49.205	Drafting	—	2
49.206	Drafting	2	—
	Library and Research	5	5
		35	35
Year 1	**Term 2B**		
30.203	Applied Chemical Principles	6	—
31.246	Technical Communication	3	3
32.246	Calculus	5	—
32.264	Statistics and Quality Control	—	5
33.218	Applied Physics	5	5
41.207	Engineering Materials	2	—
41.208	Engineering Materials	—	3
46.212	Pulp and Paper Technology I	7	—
46.215	Lumber Grading II*	—	8
46.220	Wood Properties	—	4
49.205	Drafting	—	2
49.206	Drafting	2	—
	Library and Research	5	5
		35	35

46.399 A summer technical report will be required for students continuing into second year.

		Clrm hrs/wk Pulp & Paper	Lumber & Plywood
Year 2	**Term 3**		
14.320	Computer Applications	2	—
14.321	Computer Applications	—	3
22.346	Operations Management I	—	3
31.346	Advanced Technical Communication	2	2
32.346	Statistics	4	—
41.341	Unit Operations	6	—
43.354	Electrical Equipment Applications	—	4
46.301	Pulp and Paper Technology II	7	—
46.305	Pulp and Paper Testing I	8	—
46.307	Wood Chemistry	2	—
46.315	Wood Processing I	—	10
46.370	Mill Services I	—	8
46.399	Summer Technical Report	1	1
	Library and Research	3	4
		35	35
Year 2	**Term 4A**		
14.408	Linear Programming	—	3
14.420	Computer Applications	2	—
22.446	Operations Management II	—	4
30.312	Instrumental Analytical Methods	3	—
31.446	Advanced Technical Communication	2	2
32.446	Statistics	3	—
41.441	Unit Operations	6	—
43.453	Process Measurement and Control	2	—
46.401	Pulp and Paper Technology III	7	—
46.405	Pulp and Paper Testing II	5	—
46.415	Wood Processing II	—	11
46.470	Mill Services II	—	8
49.471	Mechanical Equipment	—	3
	Library and Research	5	4
		35	35
Year 2	**Term 4B**		
14.408	Linear Programming	—	3
14.420	Computer Applications	2	—
22.446	Operations Management II	—	4
30.312	Instrumental Analytical Methods	3	—
31.446	Industrial Communication	2	2
32.446	Statistics	3	—
41.441	Unit Operations	6	—
43.453	Process Measurement and Control	2	—
46.401	Pulp and Paper Technology III	7	—
46.405	Pulp and Paper Testing II	5	—
46.415	Wood Processing II	—	11
46.470	Mill Services II	—	8
49.471	Mechanical Equipment	—	3
	Library and Research	5	4
		35	35

**The attainment of a recognized industrial certificate with a minimum mark of 70 per cent is required as a condition of graduation.*

Subject Outlines

14.320, 14.321 Computer Applications — Applications of the computer in engineering technologies; how a computer works, recognizing problems suitable for computer solution, flow-charting and communicating with computer personnel. Emphasis is on the use of computers to solve problems related to the technology. Where available, "package" programs will be demonstrated and used by students. FORTRAN or BASIC programming language is taught.

14.321 See 14.320

14.408 Linear Programming — Graphical method; algebraic method; simplex method; analysis of simplex results; LP problem formulation; use of computer to solve problems; analysis of computer solution; use of reduced costs and shadow prices; sensitivity analysis; practical applications and limitations of LP; implementation of results.

14.420 Computer Applications — More advanced applications of the computer in the pulp and paper industry using WATFIV, FORTRAN and BASIC computer languages. Concept of computer simulation and its application to the design of a production process. Use of minicomputers and micro-processors in process control.

22.346 Operations Management I — The course is an organized approach to problem-solving with emphasis on the forest resource industry. It covers such method study techniques as problem selection, process charting, multiple activity charting, activity sampling, motion economy and critical examination and development of alternatives. The course includes an introduction to work measurement. Throughout the course, the importance of establishing good human relations with the employees is stressed.

22.446 Operations Management II — The techniques required to solve plant layout and materials handling problems are covered and the student applies these techniques to solve a comprehensive in-house project. As a term project, the student selects for study a job in an industrial plant in the forest resource industry. The student applies the techniques learned in 22.346 and the first part of 22.446 to the solution of his plant project and submits a written report on his findings including conclusions and recommendations.

30.103 Applied Chemical Principles — An applied course of basic inorganic chemistry, including simple stoichiometry, solubility product, selective precipitation, solution preparation, pH, buffer solutions, oxidation-reduction, acid-base theory and titration calculations. Lab work consists of simple qualitative and quantitative analysis. Good lab techniques are emphasized.

30.203 Applied Chemical Principles — A continuation of 30.101 that includes theory of gravimetric and volumetric analysis, titration curves, chemical kinetics, simple physical chemistry, atomic structure, ionic and covalent bonding, periodicity and descriptive organic chemistry of selected groups. Lab work consists of qualitative and quantitative analysis and physical separations.

30.312 Instrumental Analytical Methods — This course introduces basic theoretical concepts, instrument construction and operation, and general application of the following methods: potentiometry, polarography, refractometry, polarimetry, visible, ultra-violet and infra-red and includes absorption and emission flame photometry and gas chromatography.

31.146, 31.246 Technical Communication — This course prepares the student for writing technical material relevant to the forest products industry. In a one-hour lecture and a two-hour lab each week, the student studies and practices the principles of clear, concise and precise writing. The student learns to apply this skill to various business formats: descriptions of hardware and processes, directions, summaries, letters and memos and technical reports.

31.246 See 31.146

31.346, 31.446 Advanced Technical Communication — In a two-hour lab each week, students discuss and practice the writing process in general and technical reports and correspondence in particular. Students are expected to complete about one writing assignment per week, ranging from one-page letters and memoranda to ten-page formal technical reports. In addition, students study and practice oral communication skills and principles of logical reasoning.

31.446 See 31.346

32.146 Basic Technical Mathematics — Topics in algebra, logarithms and trigonometry with emphasis on technical applications, including linear programming.

32.246 Calculus for Pulp and Paper — An introductory course in calculus and its applications involving the differentiation and integration of algebraic, trigonometric, logarithmic and exponential functions. The course also includes some numerical methods using the computer to solve applied problems.

32.264 Statistics and Quality Control — An introduction to statistics (covering the organization and presentation of data, measures of central tendency and dispersion, probability distributions, estimation and hypothesis testing), and in addition, linear regression, non-parametric statistics and topics in quality control.

32.346 Statistics — Organization and presentation of data, measures of location and dispersion, probability, frequency distributions, sampling and estimation.

32.446 Statistics — Hypothesis testing, correlation and regression and quality control charts.

33.118, 33.218 Physics — An introductory level course covering statics, dynamics, momentum, force, friction, energy, power, angular momentum, simple machines, properties of solids, fluids, fluid mechanics, thermal properties of matter, thermal energy, basic electricity and magnetism, optics and atomic and nuclear phenomena.

33.218 See 33.118

41.107, 41.207 Engineering Materials for Pulp and Paper Option — Comparison of materials of importance in pulp and paper technology including wood and wood products, concrete, metals, alloys, polymers and ceramics. Common causes of failure in service including corrosion, wear, fatigue and embrittlement.

41.207 See 41.107

41.208 Engineering Materials for Wood Option — Comparison of materials of importance in wood products industries, including wood and wood products, concrete metals, alloys, polymers and ceramics. Common causes of failure in service including corrosion, wear, fatigue and embrittlement. Lab sessions emphasize physical testing and non-destructive testing.

41.341, 41.441 Unit Operations — First and second law of thermodynamics; enthalpy, entropy, phase rule, thermodynamic diagrams and tables; fluid flow and measurement in pipes and channels, piping, pipe fittings and valves; filtration, flow of heat, conduction, convection, radiation, film and over-all transfer coefficients, heat exchangers; principles and application of equipment for evaporation, distillation, absorption, extraction; humidification and dehumidification; drying.

41.441 See 41.341

46.101 Forest Utilization — An introduction to the manufacture of forest products. Topics include elementary botany, identification of British Columbia commercial tree species, forest management and logging, macro- and micro-wood technology and wood defects as they relate to lumber quality. The processing and handling of wood in preparation for lumber manufacturing—debarking, chipping, screening, conveyance and storage.

46.115 Lumber Grading I — This course is given to Wood Option students in Term I in preparation for Lumber Grading II. The course covers material fundamental to the grading of western softwood lumber, including tree growth and wood structure, species identification, classification of products and the recognition of characteristics as found naturally and as caused in manufacture.

46.198 Lumber Tallying — A full course on the tallying and shipping of lumber followed by an industrial examination. Material covers the conversion of order data to quantities in foot-board measure, specified lengths, pieces, bundles and packages. Also covered is information on moisture content and shrinkage of wood, metric conversion and lumber price calculations. Final examinations for certification are given by C.O.F.I., at which time the student must achieve a 70 per cent pass mark as a requisite to obtaining the BCIT Diploma of Technology. Students must also obtain the required 50 per cent term marks for the in-school portion of the course.

46.199 Log Utilization — Course introduces basic log-scaling procedures used for coastal mills. Material also includes different log-sorting methods and recovery calculations used in the sawmill and plywood industries. Considerable time is spent practising scaling techniques on selected log booms.

46.212 Pulp and Paper Technology I — An introduction to the commercially important pulping process with the emphasis on the kraft and mechanical systems. Raw material analysis includes water, fibre and chemicals. The use of the microscope as an aid to manufacturing is covered. Major and auxiliary items of mill equipment will be covered. The lab portion of the course is designed to equip students to undertake summer employment in a routine mill-testing function.

46.215 Lumber Grading II — Students attend the industry lumber grading classes sponsored by the Council of Forest Industries (C.O.F.I.) and receive further instruction at BCIT classes. Final examinations for certification are given by C.O.F.I., at which time the student must achieve a 70 per cent pass mark as a requisite to obtaining the BCIT Diploma of Technology. Students must also obtain the required 50 per cent term marks for the in-school portion of the course.

46.220 Wood Properties — Topics covered include wood and chip units and conversion factors, mechanical and rheological properties, chemical properties, micro- and ultra-structure, wood protection and preservation.

46.301, 46.401 Pulp and Paper Technology II and III — Pulp and paper technology concerned mainly with the kraft process, chemical and heat recovery, bleaching, papermaking, newsprint manufacture and wood chemistry. Pulp and paper instrumentation, with emphasis on the theory and application of process control, including computer control systems. Pollution abatement technology—application of physical, chemical and biochemical methods to reduce air and water effluents.

46.305, 46.405 Pulp and Paper Testing I and II — Standard lab techniques. Process control and product testing, including pulp viscosity, bleachability, screening and cleaning efficiency and dirt count utilizing electronic test equipment. The study and application of advanced techniques in the physical, optical and chemical evaluation of paper pulps and manufactured papers. Projects are undertaken in conjunction with the lab section of the Pulp and Paper course. A large portion of this course will be devoted to pollution control testing.

46.307 Wood Chemistry — A lecture course designed to provide the student with a basic understanding of the structures of the major components of British Columbia wood species and the changes imposed in pulping and bleaching.

46.315, 46.415 Wood Processing I and II — Students receive instruction in sawmill and planer-mill operation, sawing technology, lumber seasoning, plywood and particle-board manufacture and shipping procedures. Also, methods to control quality, recovery and productivity are examined. Coastal and inland operations are compared in the classroom and by way of field trips.

46.370, 46.470 Mill Services I and II — The course is designed to supplement material covered in Wood Processing I and II (46.315, 46.415). Topics include cost analysis, principles of supervision, accident prevention, fire prevention, industrial relations, maintenance organization, maintenance trades, mobile equipment, materials handling and pollution abatement. A large portion of the time is spent on specific assignments in various manufacturing plants.

46.399 Summer Technical Report — A detailed report on a phase of the technical operation of a forest products plant from first-hand experience or from approved research sources.

46.401 See 46.301

46.405 See 46.305

46.415 See 46.315

46.470 See 46.370

49.101 Drafting Fundamentals — Techniques of reading and producing orthographic drawings using standard format and the development of basic skills in applying these techniques. Use of instruments, line work, geometric constructions, orthographic projects, isometric drawing and sketching, sections, dimensioning and threads and fasteners, as required.

49.205 Drafting — Covers topics on intersections, developments, descriptive geometry, isometrics and piping drawings and mechanical equipment detail and layout projects associated with lumber production. Prerequisite: 49.101 Drafting Fundamentals.

49.206 Drafting—Forest Products, Pulp Option II — Includes isometric plant layout, intersections, descriptive geometry, a typical pump base design project, isometric single line piping. Drawing, recausticizing and brown stock washing, flow sheets and other applicable pulp mill diagrams. Prerequisite: 49.101 Drafting Fundamentals.

49.471 Mechanical Equipment — A study of mechanical equipment relating to the transmission, application and control of power with particular reference to the wood processing industry. Topics include line shafting, flexible couplings, V-belt and roller chain drives, gearing, variable speed drives, hydraulic and pneumatic systems, centrifugal pump applications and lubrication and bearings. Reference to steam generation, steam processes and power generation, as well as preventive maintenance are made.

Faculty and Staff

I.M. Anderson, M.I.GasE., C.Eng.
Acting Department Head
S. Berghold
G.R. Harris, B.A., M.A., Chief Instructor
H. Kettner
B.R. Leslie, B.A.
J.T. Neilson, B.A.Sc., P.Eng.
G.A. Smook, B.S., P.Eng.