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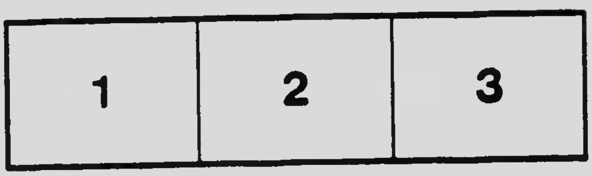

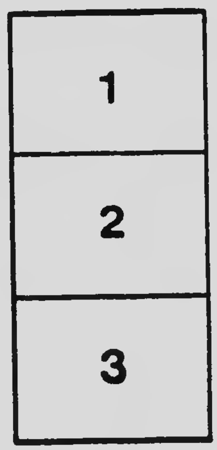

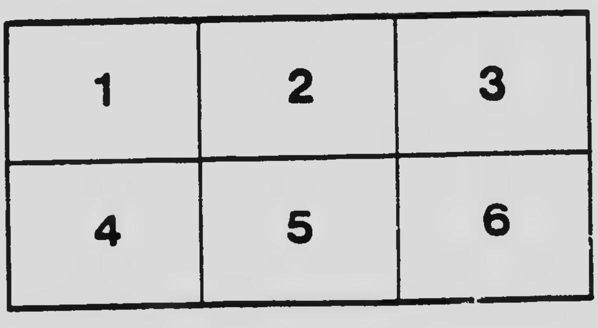

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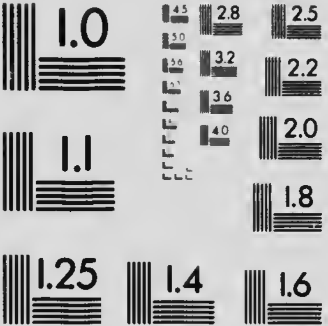

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FORESTRY BRANCH—BULLETIN No. 59

R. H. Campbell, Director of Forestry

CANADIAN WOODS

FOR

STRUCTURAL TIMBERS

PREPARED AT
THE FOREST PRODUCTS LABORATORIES
OF CANADA

OTTAWA

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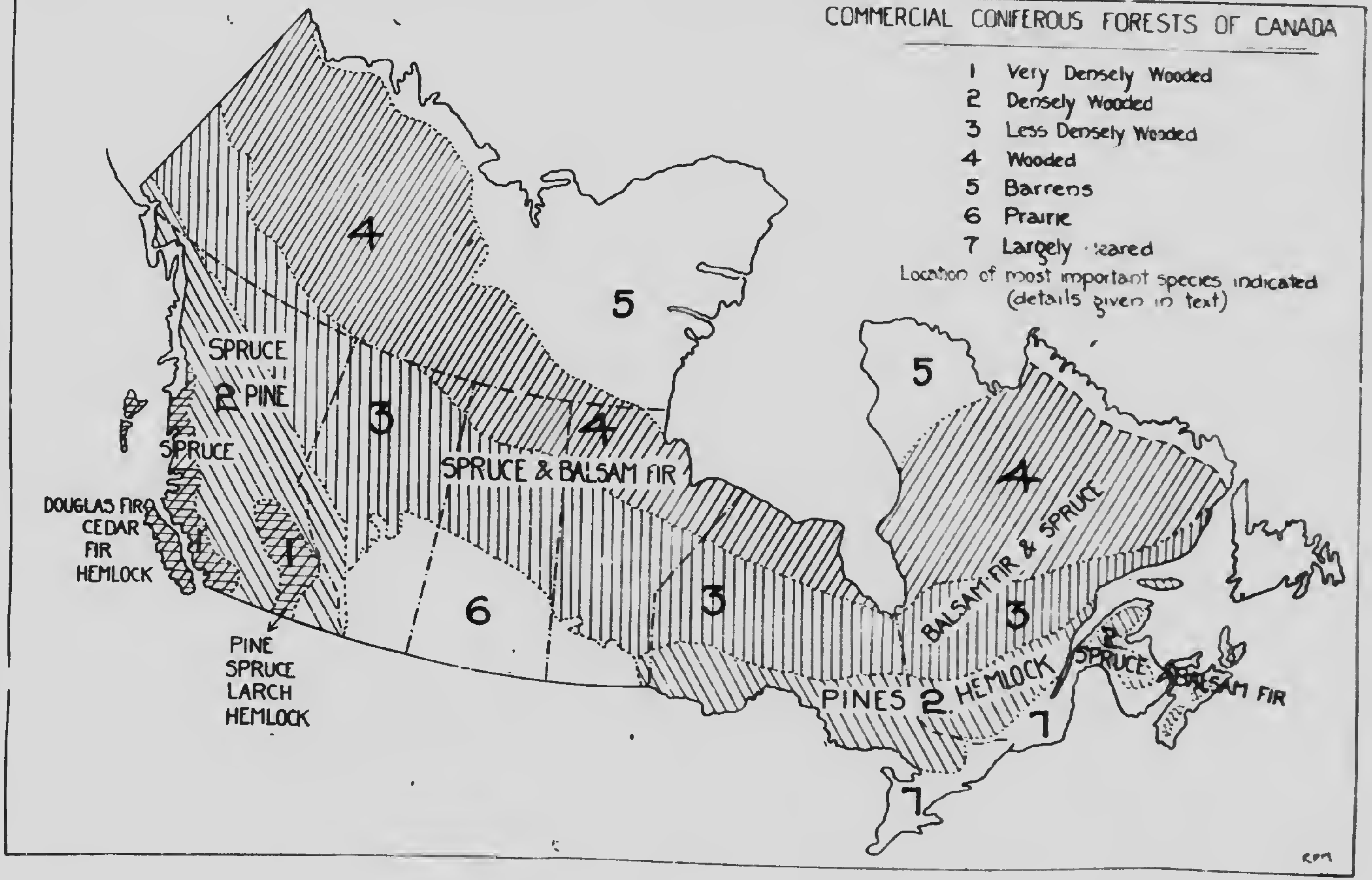
FIGURE 1.


COMMERCIAL CONIFEROUS FORESTS OF CANADA
1 Very Densely Wooded
2 Densely Wooded
3 Less Densely Wooded
4 Wooded
5 Barrens
6 Prairie
7 Largely cleared
Location of most important species indicated
(details given in text)
SPRUCE
2 PINE
SPRUCE
DOUGLAS FIR
CEDAR
FIR
HEMLOCK
PINE
SPRUCE
LARCH
HEMLOCK
SPRUCE & BALSAM FIR
BALSAM FIR & SPRUCE
PINES 2 HEMLOCK
2 SPRUCE
BALSAM FIR
KPM

DEPARTMENT OF THE INTERIOR, CANADA
Hon. W. J. Roche, Minister; W. W. Cory, Deputy Minister.
FORESTRY BRANCH BULLETIN No. 59.
R. H. Campbell, Director of Forestry.

CANADIAN WOODS

FOR

STRUCTURAL TIMBERS

Prepared under the direction of J. S. Bates, Chem. E., Ph.D., Superintendent
of the Forest Products Laboratories of Canada, by H. N. Lee,
in charge of Timber Physics.

OTTAWA
PRINTED BY J. de L. TACHÉ,
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1917.

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CONTENTS

CANADIAN WOODS FOR STRUCTURAL TIMBERS.

Introduction.

The Forest Products Laboratories of Canada, established at Montreal by the Department of the Interior, in co-operation with McGill University, have undertaken an investigation of the woods of the different species of trees in Canada so that reliable and authoritative information may be available as to the strength, durability, and other qualities of Canadian woods and their adaptability for use in structural work and manufactures of various kinds. Such investigations have only begun at the Canadian Laboratories and the only Canadian species in regard to which fairly complete information has been obtained is Douglas fir, but as there is a special interest at the present time in information in regard to structural timbers, particularly in a comparison between Canadian and foreign timbers, it has been considered advisable to issue a preliminary study on structural timbers, using the information now available from many sources and particularly the results of investigations made at the laboratory of the Forest Service of the United States. It will be found that Canadian timbers rank high for structural purposes. The results of an exhaustive series of mechanical and physical tests of Douglas fir made at the Forest Products Laboratories of Canada are now in course of publication and similar tests of other important Canadian woods are in progress, the results of which will be published as soon as they are available.

In the following discussion the main characteristics of coniferous woods native to Canada as well as the chief imported structural woods, the southern pines, are discussed. A sketch of the forest resources of Canada gives some idea of the wood available and the present development of trade. It is followed by a discussion of the qualities that affect the usefulness of timber for structural purposes and a description of the chief Canadian species suitable for this purpose, besides comparisons and tables and charts which it is hoped will make the conclusions clear. There is a short discussion of the grading of timber which it is hoped will prove useful.

Definition of Structural Timber.

Broadly speaking, all wood which is so used that its strength is a factor of first importance may be called structural timber. In this discussion, however, we shall pay special attention to the woods which are, or may be, used in building construction. No special mention will be made of timbers suitable for ties, paving blocks, or for use in mines, and the discussion is limited to coniferous woods. Lower freight rates and recent specifications by the Canadian Government and by certain of the large corporations providing that native wood should be used in preference to imported species will probably result in an increased use of Canadian woods, especially Douglas fir

Canada's Forests and Timber Supply.

Canada's present supply of commercial timber[1] has been estimated at from 500 to 800 billion feet, board measure, covering an area of approximately 250,000,000 acres. This estimate, which is about one-half the forested area of the Dominion, refers only to saw-timber: material suitable for pulpwood, firewood, poles, etc., not being included.

[1] Campbell, R. H., "Timber in Canada," address before International Engineering Congress, San Francisco, 1915.

British Columbia,[1] with 50 million acres containing 400 billion feet, board measure, has more large saw-timber than any other province in the Dominion. In 1915 more than two-thirds of the total lumber cut[2] of the province was Douglas fir, with red cedar, 8 per cent; spruce, 8 per cent; western yellow pine, 5 per cent; western larch, 4 per cent; western hemlock, 3 per cent; and the remainder mostly western white pine, fir, and lodgepole pine. The coast region of British Columbia contains the bulk of the best timber; Douglas fir, western hemlock, western yellow or soft pine, spruce, and western red cedar being the important species. The interior produces spruce, Douglas fir, western yellow pine, mountain fir, and lodgepole pine. The quantity of lumber cut in this province was very much below normal in 1915. (See plates 1, 2, and 3.)

Alberta is estimated to contain 5,400,000 acres of commercial saw-timber, amounting to 21 billion feet, board measure. In 1915 spruce formed almost 80 per cent of the timber cut, lodgepole pine and jack pine, 17 per cent; and Douglas fir, tamarack, and hardwoods the balance. Engelmann spruce, white spruce, mountain fir, balsam fir, lodgepole pine, Douglas fir, tamarack, jack pine, and black spruce are the important species growing within the limits of the province.

The Northwest Territories and Yukon have no commercial forest areas at present, and for the future can hardly be expected to supply more than the local demand.

Saskatchewan's timber area is 3,584,000 acres and contains about 14 billion feet, board measure. The lumber at present cut consists almost entirely of spruce with a very small proportion of larch, jack pine, and poplar.

Manitoba contains some 1,920,000 acres of saw-timber land with about 6,850,000,000 feet, board measure, of timber. Spruce formed 93 per cent of the lumber sawn in 1915; tamarack, jack pine, and balsam fir being the other coniferous woods reported.

Ontario is one of Canada's largest lumber-producing provinces, its productive forest area being from 70 to 90 million acres, containing approximately 150 billion feet, board measure, of merchantable timber. White pine, spruce, red pine, jack pine, balsam fir, tamarack, hemlock, white cedar, and in the southern part, a large variety of hardwoods are to be found within the limits of the province. In 1915 white pine formed 60 per cent of the timber cut; hemlock, over 10 per cent; red pine, 10 per cent; spruce, 8 per cent; maple, elm, and twenty other species supplied the remaining 12 per cent.

Quebec in 1915 produced a little more timber than Ontario and contains about 80 to 100 million acres of merchantable saw-timber, the species present being the same as in Ontario, as far as conifers are concerned. The province is estimated to contain about 160 billion feet, board measure, of saw-timber. In 1915 spruce formed over 55 per cent of the timber cut; balsam fir, almost 16 per cent; white pine, 15 per cent; hemlock, about 3·5 per cent; the remainder being birch and mixed woods similar to Ontario. It will be noticed that Quebec is the province producing the greatest amount of spruce, while Ontario produces most of the white pine.

New Brunswick has a total forest area of about 12 million acres with standing timber estimated at 22 billion feet, board measure. Spruce, balsam fir, pine, hemlock, and white cedar are the important coniferous trees. In 1915 the timber cut consisted of spruce, 82 per cent; balsam fir, 7 per cent; white pine, almost 6 per cent; hemlock, 2·4 per cent; and the remainder largely hardwoods.

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[1] What is considered saw-timber in British Columbia is, of course, of very much larger size than what is designated saw-timber in the other provinces.

[2] Forestry Branch Bulletin, No. 58A, "Forest Products of Canada, 1915: Lumber, Lath and Shingles."

PLATE 1.

Douglas fir.—This shows the typical, big, clear trunks which are characteristic of Douglas fir.

PLATE 2.

Western larch growing in British Columbia.

Nova Scotia is estimated to have 5,744,000 acres of forested land, with about 10 billion feet, board measure, of coniferous saw-timber. The species are much the same as in New Brunswick. In 1915 spruce formed practically 63 per cent, hemlock 18 per cent, white pine, nearly 9 per cent; with birch and fourten other species supplying the remaining 10 per cent.

Prince Edward Island has 1,397,760 acres, only a small part of which is forested. Spruce supplied about half and balsam fir one-third of the 7,543 thousand feet, board measure, of lumber produced in 1915..

The estimated total supply of merchantable timber in Canada is from 500 to 800 billion feet, board measure, while the United States[1] has 2,500 billion feet or about four times as much. Russia is believed to have the largest timber resources of any country in the world; the United States is second, and Canada third on the list. In Canada there is an enormous loss of timber every year due to fire and large quantities are cut, so the supply is constantly growing less. Better protection against fire and in some cases more careful lumbering methods would go far towards conserving the forest wealth, which is one of Canada's great natural resources.

Imports and Exports.

According to the 1915 report of the Department of Trade and Commerce the imports of unmanufactured southern pine into Canada were valued as follows for the fiscal years:—

1910–11.	1911–12.	1912–13.	1913–14.	1914–15.
$2,111,818	$1,929,923	$2,435,376	$2,912,363	$1,608,788

Although a much larger amount of other woods was imported, these figures probably cover the greater part of timber brought into Canada for structural purposes.

The following figures give the value of square timber, manufactured from coniferous woods, which was exported from Canada:—

1910–11.	1911–12.	1912–13.	1913–14.	1914–15.
$598,807	$852,720	$1,007,878	$346,852	$389,164

Inasmuch as Canada can produce a large amount of as fine structural timber as can be secured anywhere, it appears that more should be known of the qualities of Canadian woods so that the imports of ailar or inferior material may be avoided and, at the same time, any surplus produced over the needs of the Dominion may be exported to other countries, or, more especially, to other parts of the Empire.

As is stated above, the wood largely imported into Canada for structural purposes is the southern pine of the United States. While it cannot be denied that the highest grades of the true longleaf pine from the Southern States make one of the best structural timbers, it is a fact that selected Douglas fir is quite as good. Moreover, the supply of prime longleaf pine is decreasing and the timbers sometimes delivered as such may prove to be lower grades of longleaf or the much inferior loblolly or shortleaf pines. Cases are known where the use of such inferior wood has occasioned much trouble, often ended only by resort to legal procedure, because of the failure of timbers to meet the requirements expected of the best longleaf pine. On the other hand, vast quantities of the very highest grade of Douglas fir are available in Canada, and the use of this would certainly give equal, and in some cases superior, results to those obtained from the use of such longleaf pine as can be secured.

Principal Structural Woods.

The heavy structural species of Canada named in order of merit and resources are: Douglas fir, western hemlock, eastern hemlock, western yellow pine, western larch, red pine, and eastern larch.

[1] United States Forest Service Bulletin 83, "Forest Resources of the World," by Raphael Zon, 1910.

Western yellow or soft pine which often yields a wood particularly easy to work.

Beside the above, the spruces are used largely in the East for all except the heaviest purposes, and certain pines, true firs, and cedars are sometimes employed. These woods, however, are in many cases more valuable for other purposes and will probably be less used for structural purposes as the stronger woods become more available. The following is a brief statement of the properties, characteristics, and more important uses of these woods, and includes also a discussion of the comparative value of the southern pines and Douglas fir.

General Properties of all Woods.

Structure.—Wood is not a homogeneous substance like steel but is made up of hollow fibres averaging, in the case of the conifers, about 3 millimetres or one-eighth of an inch in length. Most of these fibres are placed parallel to each other in the direction of the vertical axis of the tree, with about 10 per cent scattered in small groups running in the horizontal direction through the wood. Where knots or any abnormal growth occur the fibres are usually found running in various directions. As will be described later any variation from straight grain, that is from the fibres running parallel to the axis, has a deleterious effect on the strength of the wood.

Weight per Cubic Foot.—The average weight per cubic foot[1] of absolutely dry Canadian structural woods is from about 25 to 30 pounds. In any particular species the weight ordinarily varies about 4 per cent from the average, with occasional values as much as 16 per cent below or above the average. Douglas fir and longleaf pine in general fall within 2 per cent of the average, with occasional values up to 8 or 10 per cent greater or less than the average. The actual density of the solid substance is the same for all woods, the difference in density being accounted for by the size of the air space in the hollow fibre. For example, in cedar the solid wall substance is much less in proportion to the open space than in Douglas fir, with the result that a cubic foot of the latter wood is much heavier than the same volume of the former.

Relation of Strength to Density.—The crushing strength and stiffness in a beam increase approximately directly as the density or weight per cubic foot of the absolutely dry wood increases, i.e., the heavier the wood the stronger and stiffer it will be. Hardness and strength in compression perpendicular to the grain increase as the square of the density, i.e., a specimen of a certain weight per cubic foot, absolutely dry, will be only one-quarter as hard or as strong in compression perpendicular as another sample which is twice as heavy, absolutely dry. Increase in density causes a still greater increase i. the shock-resisting properties.

Moisture Content.—The wood of the conifers or evergreen trees shows a wide variation in moisture content. In the same tree, as a rule, there is a great difference between the per cent of moisture in heartwood and in sapwood and, in some cases, between the upper and lower parts of the tree. The heartwood of most conifers has a low moisture content, while the sapwood has a very high per cent of moisture. Tamarack has a fairly uniform moisture content throughout, while western larch, because of resinous material as well as water, is very heavy at the butt.

Effect of Moisture on Strength.—Increase in the moisture content of approximately green material affects the strength values very little since the increase in moisture above about 25 to 30 per cent, the fibre saturation point, does not materially affect the mechanical properties of timber. A decrease bringing the moisture content below 25 per cent causes a very considerable increase in strength as the per cent of moisture diminishes, and as a result, the strength value may be doubled if the moisture is reduced from 25 to 12 per cent, i.e., to the approximate summer air-dry condition. In practice, however, the seasoning of timber generally causes checking or other defects to an extent sufficient to offset much if not all of the gain in strength due to

[1] "Variation in Weight and Strength of Timber," by J. A. Newlin; Reprinted from St. Louis Lumberman.

PLATE 4

A modern factory being constructed in Eastern Canada. All of the framing timbers are of selected Douglas fir.

PLATE 5

Mill construction, showing timbers and laminated flooring, two very important uses for Douglas fir.

the drying. Moreover, many structural timbers are likely to become wet and therefore the strength values for green timber are the safest to use.

Shrinkage.—All woods shrink as a result of seasoning but there is a great difference in the amount of shrinkage taking place in different species. The method of drying also causes a great variation in the shrinkage and therefore in the warping. In any wood there is a greater change in the tangential than in the radial direction, with the result that slash or flat-sawn lumber shows more shrinkage than vertical or quarter-sawn material. Most woods shrink very little in drying until the contained moisture is reduced to the fibre saturation point, which is about 25 or 30 per cent of the weight of the specimen. When the moisture is lower than this, contraction takes place, the shrinkage becoming greater as more moisture is removed. From the green to the absolutely dry condition the shrinkage longitudinally is usually negligible, radially it is from 2 to 6 per cent and tangentially 5 to 8 per cent; while the shrinkage in volume is 7 and 13 per cent in the extreme cases, i.e., cedar and larch respectively, but in general approximately 10 per cent.

Decay and Durability.

Dry-rot.—Decay, rot or dry-rot in wood was originally supposed to be a chemical action similar to the rusting of iron, and the delicate lace-like plants, tough brackets, or brown leathery growths were supposed to be attracted by the decayed wood rather than to be the cause of the rotting.[1] Since 1870, however, it has been definitely established that these growths are the outer, visible sign of fungi, the delicate threads of which thoroughly penetrate the wood and absorb much of its substance, the result being the so-called rotten wood, the strength of which is entirely destroyed. In the course of constructing a building care should be taken to prevent the timber from becoming thoroughly wet. In many cases wood contains fungus to an entirely negligible extent, but if this same wood is soaked in water and placed in a building with a moderately high temperature the fungus immediately grows and causes a greater or less deterioration of the wood. Provided proper care is taken in the selection and handling of timbers the danger from dry-rot is low except under very moist or humid conditions, and in such cases treatment with creosote, zinc chloride, mercuric chloride, sodium fluoride, or some other substance which prevents fungous growth, is advisable.

Durability.—The natural resistance of wood against decay is known as durability. Any wood placed in a situation favourable to the development of fungi will decay, but there is considerable difference in various woods as to resistance to decay. The cedars are perhaps the most resistant to fungous action of all Canadian woods. Douglas fir and longleaf pine are quite durable and western larch and eastern tamarack offer considerable resistance to fungi. The pines, spruces, hemlocks, and firs offer less resistance to decay when they are placed in positions favourable to the development of fungi. This does not mean that these latter woods cannot be used for many purposes with perfect satisfaction, but it does certainly indicate that many species should not be put into conditions favourable to the development of fungi, unless they are properly protected. And this naturally leads to the point that many of the less resistant and lower-priced species may be used in place of more durable but higher-priced woods, if the former have been properly treated with creosote, mercuric chloride or in some other way which prohibits the action of the fungi in them. Very little is known of the influence of density on durability. The heavier woods are not, necessarily, the more durable since some of the lightest woods, for example, the cedars, have excellent lasting properties, while some of the heavier woods are less durable. Likewise the resin content of such species as contain resin, is not definitely proven to increase the durability. The toxic value of resin is low but the presence of resin

[1] Hoxie, F. J., "Dry-Rot in Factory Timbers": Associated Factory Mutual Fire Insurance Companies, 1915.

View after a fire in a factory in Montreal. Note steel work twisted and useless while timber is still in place and supporting a load.

in wood seems to keep out moisture and air, and apparently acts in this way as a kind of natural preservative. It is a well-known fact that posts of pitchy wood last much longer than similar posts having a low resin content. It is reasonable, therefore, to consider that a high per cent of resin increases the durability of a wood. Douglas fir has, so far as it has been used, proved to be very durable. In moist situations western hemlock is unfortunately somewhat subject to dry-rot and eastern hemlock is considered to be one of the less durable of the woods used for structural purposes, at least as far as resistance to decay is concerned. Either of these woods gives good satisfaction under many conditions, but if they are to be placed in moist situations they should be treated with some preservative. It is, however, important to note that hemlock is perfectly satisfactory if it is entirely submerged in water. (See plates 12 and 13.) Canadian woods are quite as durable as any of the species ordinarily imported.

Strength.[1]

As has been stated above, it is a general rule that the heavier a wood is the stronger and harder it will be. This is not only the case in comparing one species with another but also where timbers of the same species are examined. The effect of knots and other defects is taken up in detail in the section on grading but some of the more general results may be stated here.[2]

The density or absolutely dry weight of wood is usually a direct measure of its strength. Wood with a considerable development of summer-wood is generally heavier and stronger than wood with a smaller proportion of summer-wood.

Checks and shakes in beams reduce the area which resists horizontal shear and are most harmful when they are in the centre half of the height of the beam

Very rapid or very slow growth in conifers usually produces a wood lacking in density and of inferior strength.

The strength of posts or columns containing knots decreases as the knots increase in size.

Sound knots do not weaken wood subjected to compression perpendicular to the grain.

Large specimens tested in compression perpendicular to the grain show but little increase in strength due to seasoning.

If structural timbers are seasoned slowly, in order to avoid checking, there should be an increase in strength, but it is not safe to base working stresses on results secured from any but green material.[3]

Relation of Loading to Failure.—A beam loaded over a period of several months has been found to fail under a load only two-thirds as great as that required to cause failure when the ultimate load is reached within a few minutes.

Relation of Species and Grade to Strength.—It has been found that the strength value of woods of different species ordinarily used for structural purposes does not vary as much as has been commonly believed. For example, 25 per cent of the timber from shortleaf pine, an inferior structural timber, will give average strength values higher than the average of longleaf pine, which is considered to be one of the best woods for structural purposes. It will thus be seen that it is quite as important to inspect the quality of the timber in a given shipment as it is to determine the exact species.

Comparative Strength of Different Species.—The results of numerous tests of small clear specimens made by the Forest Products Laboratories of Canada and the

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[1] Methods of making laboratory tests of the strength properties are described in Forestry Branch Bulletin, No. 60.

[2] United States Forest Service Bulletin 115, "Mechanical Properties of Western Hemlock," by O. P. M. Goss, 1913.

[3] United States Forest Service Circular 189, "Strength Values for Structural Timbers," by McGarvey Cline, 1912.

Plate 7.

A Douglas fir timber 46 by 46 inches and 70 feet long, to be used in Montreal harbour work

Plate

Flagpole being erected in front of Court House, Vancouver, B.C. This is a single stick of Douglas fir 210 feet long.

United States Forest Service show that woods may be classed in the order shown in table 5 of this bulletin on the basis of different strength values. Further tests now being carried on at the Forest Products Laboratories of Canada on Canadian timbers may give figures slightly different from those stated in table 4, but in general the woods may be classed as shown in table 5.

Mill Construction as an Example of the Use of Structural Timber.

Slow-burning or mill construction consists in so disposing the timber and plank in heavy, solid masses as to expose the least number of corners or ignitable projections to fire, to the end also that when fire occurs it may be most readily reached by water from sprinklers or hose. Special care is taken to separate different floors by stops and to see that all spaces between floors or partitions are so protected as to allow no draught in case of fire. A mill built with these ideas in view, when protected by automatic sprinklers and sufficient water supply, offers one of the best fire insurance risks, and may be insured at a minimum rate.

Although wood is combustible it has been shown repeatedly that most fires are due to the contents of a building rather than to the material of which it is constructed. Timber posts, for example, offer more resistance to fire than either wrought-iron, steel or cast-iron pillars, and in mill construction are preferable in many respects. Cases are known where 8- by 10-inch wooden timbers were only charred in a fire that twisted 10-inch steel beams to a degree which required rebuilding. (See plate 6.) Therefore, although under certain circumstances it may be better to use concrete or other non-combustible materials, it appears that a properly constructed and protected mill of wood is no more liable to destruction by fire, under ordinary conditions, than a mill built of any other material.

The use of wood in such construction is attended by many other favourable considerations. (1) It has a low first cost. (2) It offers better insulation to heat and cold than concrete. (3) It is more comfortable and more nearly noiseless. (4) It is subject to alterations in case of any desired change to better adapt the mill space to changed conditions in manufacture.

Comparing mill construction with the ordinary type of wooden construction it is found that there is but little difference in cost between the two; the fire insurance rate for the former is one-half the latter, if both are sprinkled; and again, the former is better adapted to any changes in occupancy. When a building is being considered not only should a competent architect be employed but it would be well to find out from the insurance companies the standards they require to give the minimum insurance rates. This very brief description of mill construction is given to illustrate the fact that wood can be used to great advantage for certain types of buildings which must carry heavy loads and must be well protected from fire.[1]

Discussion of the Most Important Coniferous Woods of Canada.

DOUGLAS FIR.

In 1913 there was more Douglas fir timber cut in Canada than any other single species. Only the spruces, collectively, produced more timber than did Douglas fir, while in 1914 the spruces and white pines both produced more. Although in 1915 the cut of Douglas fir decreased, it may be expected to increase rapidly hereafter in yearly production, as it is the only timber in North America of which great areas, accessible to easy development, remain untouched. British Columbia cut practically all of the 601,643,000 feet, board measure, of Douglas fir, worth $6,810,000 at

[1] For complete discussions see—
"Heavy Timber Mill Construction Buildings," National Lumber Manufacturers' Association, Chicago, 1916.
Report No. 5, "Standard Mill Construction": Boston Manufacturers' Mutual Fire Insurance Co., 1915.

Bridge trestle on the Canadian Pacific Railway, built of Douglas fir in 1896.

an average value of $11.32 per thousand feet, which were cut in 1914. In 1915 the production was 453,534,000 feet, board measure, with an average value of $11.76 per thousand.

Scientifically the wood is known as *Pseudotsuga mucronata, P. taxifolia,* or *P. Douglasii.* Besides being called "Douglas fir," it is known in trade as "red fir," "yellow fir," "British Columbia fir," or "pine," "Douglas spruce," and "Oregon pine." "British Columbia pine" or "Oregon pine" are the most common export names. Formerly it was called "spruce" or "pine" because to call it "fir" would class it with the true firs (the genus *Abies*), which are totally different in properties, but now that it is better known there is no reason why it should not be marketed under its own name. Although botanically there is only one species, the mountain form which grows where rainfall is light is a tree much inferior in size and in general qualities to the coast form growing in the more moist climate. Only the coast form is exported.

Douglas fir is at present one of the most important of Canadian woods, and within a few years it will probably be the most widely used and valued of Canadian timbers. It is the largest structural timber growing in Canada or the United States. In Canada it is found in British Columbia and to a limited extent in Alberta. Trees have been measured up to 380 feet high with a maximum diameter of 15 feet, the largest trees scale as high as 60,000 feet, board measure. This great size places the timber in the highest class for large timbers free from defects. (See plates 1, 8, and 10.)

The wood is one of the hardest, heaviest, stiffest, and strongest to be found in Canada. The sapwood is usually narrow, being not over 2 inches wide. The heartwood varies in colour from a decided reddish tinge to a light yellow. Timber from the eastern limit of its range, from second-growth, or from the centre of old trees is likely to be coarse-grained and red but most of the coast variety produce the fine-grained, clear wood of a yellow colour, that has made Douglas fir famous. Absolutely dry it varies in weight from about 24 to 34 pounds per cubic foot, with an average of approximately 28 pounds. The dark summer-wood is well developed, is hard, flinty, and clearly marked, while the spring-wood is soft and much lighter in both colour and weight. (See plate 18.) The number of rings per inch is rarely less than eight and is commonly from twelve to sixteen. In general wood having less than eight or more than sixteen rings per inch is weaker than that ranging from eight to sixteen. It is usually of uniform growth and comparatively free from knots and pitch. The average moisture content in green-sawn timber is up to 40 per cent and is fairly evenly distributed throughout. In air-seasoned timber the average moisture may be reduced to less than 20 per cent, with less near the surface but more in the middle of the stick. Rapid drying of the surface produces checking but drying, properly handled, produces a fine, sound, clear wood.

So far as structural timber in the Dominion is concerned Douglas fir is by all means the most important, although there are several other species which produce very good structural timber. According to recent estimates of the Commission of Conservation, the total supply of merchantable Douglas fir timber is about 75 billion feet, board measure, and since the tree grows satisfactorily under reforestation there is little reason to believe the supply will be exhausted for many years. In fact, proper protection should insure a perpetual supply.

Utilization.—Douglas fir is manufactured into almost all forms known to the saw-mill operator and a very large amount of the wood is also utilized in the form of round or hewn timber. In building trades it is most important, being used for beams, columns, and heavy flooring in mill construction as well as for all kinds of dimension stock, joists, floor beams, rafters, flooring, siding, and finish of all kinds in general construction. (See plates 4 and 5.) For bridge, trestle, and harbour work Douglas fir is superior in many ways to any other Canadian timber. It is largely used by the railways in the form of ties, piling, car, and bridge material. (See plate 9.) It has long been the most important timber for boats and ships on the Pacific

Another view of the big Douglas fir timber 46 by 46 inches by 70 feet, for use in Montreal harbour work.

coast, being suitable for both outside and inside work, especially for decking, planking, keels, yards, ribs, and finish. (See plate 15.) Increasing amounts of Douglas fir are being used in furniture making and in this line it is particularly adapted to "mission" furniture. Tight and slack cooperage, tanks of all kinds, conduits and water pipes, paving blocks, boxes, and pulpwood may be mentioned as further illustrations of its utilization.

Although the properties of Douglas fir enable it to be employed in such a variety of ways, it is probably most widely known as a structural material. For this purpose it is inferior to no other wood and its straight, clear trunks can supply timbers of the largest size and highest quality. Plates 7 and 10 show a stick 46 by 46 inches in section and 70 feet long which is being used in Montreal harbour, and pieces 2 by 2 feet in section and 100 or more feet long can readily be supplied by mills in British Columbia equipped to handle such lengths. (See plate 8.) It may be said, then, that Douglas fir is not only of first value as a timber for all kinds of structural work but is also suitable for a greater variety of uses in the manufacture of various products than any other Canadian wood, with the possible exception of white pine.

Comparison of the Southern Pines with Canadian Species, especially Douglas Fir.

The southern pines include several species, the more important of which are longleaf (*Pinus palustris*), loblolly (*P. taeda*), and shortleaf (*P. echinata*). They grow commercially only in the southern United States, generally within 200 miles of the coast. *P. palustris* is commercially known as "southern," "Georgia," "yellow" or "pitch" pine, the last being the name under which it is known in England. Shortleaf and loblolly are seldom sold for use as heavy structural timbers under their own names but are called "southern" or "yellow" pine, or else are classed as longleaf, to which they are much inferior for structural purposes. Because so much inferior timber has been put on the market as select longleaf many producers are now branding their product in order to guarantee the timber to be of good quality. Only the highest grade of longleaf is of equal quality to first-class Douglas fir.

The wood of all the southern pines is much alike in appearance. The sapwood and heartwood are distinctly marked, the sapwood being yellowish-white and the heartwood reddish-brown. The layers of growth, or annual rings, show distinctly in the wood of these pines and the width of the annual rings generally varies with the age period of the tree, being greatest in early life and least in the sapwood of mature trees. The alternating bands of dark summer-wood and lighter-coloured spring-wood are distinct in the southern pines, being generally more strongly marked in longleaf than in other species. Because of the close botanical relationship between the various southern pines it is practically impossible to distinguish the wood of different species. Recent grading rules neglect the actual botanical species but specify certain physical and structural requirements that bar out any but highest grade loblolly and shortleaf. In contradistinction to the southern pines the wood of Douglas fir may be positively and easily identified by microscopical examination, although it is not always easy to distinguish from other woods by gross examination. It is important to note that Douglas fir is lighter than longleaf pine of equal quality, and on this account as well as on others it is entirely wrong to attempt to judge of the value of a Douglas fir timber according to all the specifications laid down for prime longleaf pine. Results of comparative strength tests of Douglas fir and longleaf pine at the United States Forest Products Laboratory show that for practically all structural or building work Douglas fir is the equal of southern pine. Moreover the wood of Douglas fir averages 20 per cent lighter than southern pine, a fact of considerable importance in some types of construction.

A most important point regarding southern pine is the great difference in quality between the best longleaf and the other two species, namely, shortleaf and loblolly, which are often delivered in place of it. The timber of these species is lighter, has much wider sapwood, less resin, is less resistant to decay, and is in particular not so

PLATE 11.

Douglas fir timbers for use in Toronto harbour construction. Nineteen million feet, board measure, of Douglas fir are being used in this work.

PLATE 12.

Hemlock being used in Toronto harbour construction.

strong as the timber of the true longleaf pine. Although the best grade of longleaf is of about equal quality to Douglas fir the other two species are, on the average, much inferior and, since the supply of the best grade of longleaf is becoming less abundant, much of the other two species is likely to be included in shipments, especially if the specifications and inspection are not extremely rigid. As a result the timber delivered as longleaf pine will often be far below the quality expected, whereas the enormous supply of the very best Douglas fir in Canada makes it so easy to secure this timber for use that there is little desire on the part of the producers to try to include inferior timber, or other species, in shipments. Another valuable point in favour of Douglas fir over longleaf pine is the fact that the largest timbers of the former may be secured free of sap, whereas in longleaf a considerable percentage of sap is usually present in big sticks and this reduces its durability, especially for any outside construction.

Comparative strength of Douglas Fir and Longleaf Pine.[1]

Undoubtedly the two most important American structural timbers at the present time are Douglas fir and the southern pines. It may be of interest in this connection to draw attention to certain characteristics of the two timbers as brought out by parallel tests made by the United States Forest Service and by the Forest Products Laboratories of Canada.

As far as the designing engineer is concerned and apart from considerations of durability, etc., the properties of a timber which may affect the design of a structure of this material are as follows:—

1 Timber beams—
 (*a*) Strength in bending.
 (*b*) Strength in longitudinal shear.
 (*c*) Stiffness.

2. Timber columns—
 Strength in compression parallel to grain.

3. Bearing areas of timber beams and sills—
 Strength in compression perpendicular to grain.

4. All members—
 Dead weight of material.

The following table (Table 1) has been calculated from the sources indicated (largely United States Forest Service tests) to show the comparative properties of Douglas fir and longleaf pine in respect to the various factors mentioned above. In all cases the strength values of Douglas fir have been expressed as percentages of the corresponding values given for longleaf pine. In cases where the strength of Douglas fir exceeds that of longleaf pine the figures are shown in bold-face type; in cases where the reverse is true the figures are shown in ordinary type. By noting the grouping of the bold-face and ordinary type the comparative strength of the two species can be readily seen.

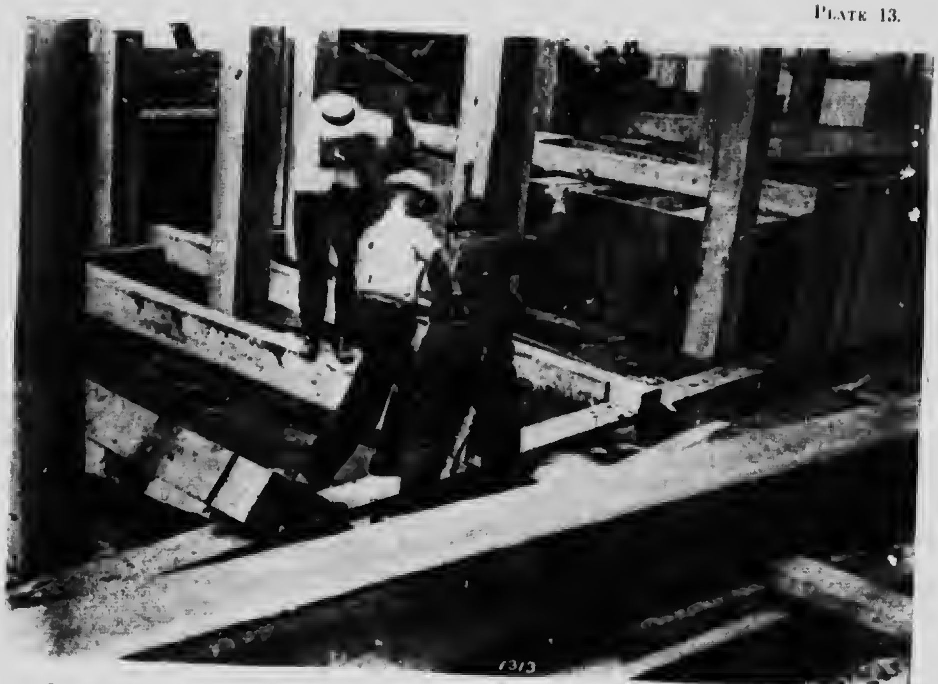
Taking up in order the factors mentioned above as affecting the design of timber structures reference to table 1 leads to the following conclusions:—

1. *Strength in bending.*—In modulus of rupture the majority of tests show Douglas fir to be weaker than longleaf pine by about 10 per cent. On the other hand all tests with the exception of two show Douglas fir to be stronger than longleaf pine by varying amounts, say 10 per cent on the average, in fibre stress at elastic limit.[2]

[1] By R. W. Sterns, in charge, Division of Timber Tests, Forest Products Laboratories of Canada.

[2] NOTE.—For definitions of technical terms see page 27.

Plate 13.



Closer view of hemlock in Toronto harbour construction. Seven million feet, board measure, of this wood are being used in this work.

Plate 14

Red and black spruce being used in shipbuilding in Nova Scotia.

Tests of long duration on timber have shown that if a beam is loaded in excess of its elastic limit it will eventually fail. In accordance with this it appears that the elastic limit stress is the greatest stress which can be safely used in timber structures, and it would therefore be logical to base working stresses for design on the elastic limit stress and *not* on the ultimate breaking strength as determined in the testing machine. This practice is at present followed in determining suitable standard working stresses for other structural materials such as steel, and it is now being recognized that the elastic limit is the logical basis for design in the case of timber as well.[1]

Douglas fir should, therefore, be capable of taking a greater working stress in bending than longleaf pine by the amount mentioned, for the same degree of safety. This, however, would not apply in the case of extremely short beams.

2. *Strength in longitudinal shear.*—All tests show Douglas fir to be weaker than longleaf pine by from 20 to 25 per cent. In the case of beams so short that strength in shear rather than bending strength becomes the deciding factor, longleaf pine should accordingly be allowed a working stress greater by the amount mentioned.

3. *Stiffness.*—Not infrequently, as in the case of ceiling joists under certain conditions, the maximum deflection of a beam becomes the deciding factor in its design rather than its strength. A stiff timber of high modulus of elasticity would in this case be desirable. Referring to the table it will be seen that in the majority of cases Douglas fir is credited with a higher modulus of elasticity than longleaf pine by from 4 to 10 per cent, although there are a few exceptions to this rule. It would look as though the safe working modulus of elasticity for Douglas fir might be taken to be about 5 per cent greater than that for longleaf pine. In any case the same modulus could certainly be used.

4. *Strength in compression parallel to grain.*—All tests, almost without exception in the case of stress at elastic limit and without any exception in the case of maximum crushing strength, show Douglas fir to be from 10 to 20 per cent weaker than longleaf pine. A greater working stress for longleaf pine than for Douglas fir in the case of columns would in accordance with this be good practice.

5. *Strength in compression perpendicular to grain.*—All tests without exception show Douglas fir to have somewhat greater strength in compression perpendicular to grain than longleaf pine, by amounts ranging up to 10 per cent, indicating that greater working stresses for Douglas fir in compression perpendicular to grain would be permissible.

6. *Weight of material.*—All the tests show Douglas fir to be lighter than longleaf pine by about 20 per cent on the average. The obvious advantages of a structural material of light weight over one of heavier weight, both having the same strength, are two-fold:—

(1) Less dead weight to be supported in the structure, leaving greater net strength effective for supporting live loading.
(2) Less weight to be handled.

In the present instance the former consideration is of little importance because of the magnitude of the loads supported in proportion to the weight of the material used. The latter consideration, however, involves a very considerable difference in charges for transportation and labour of handling.

In the above comparison an effort has been made not to favour either one timber or the other, existing reliable comparative figures having been taken and analyzed without regard to their bearing on the result. It is probable that the comparison is fairly equitable, or even conservative as to the strength of Douglas fir. In the case

[1] See Appendix II, to report of Committee D-7, American Society for Testing Materials, 1915. H. S. Betts, "Basis for 1,600 pounds working Stress." (Southern pine).

of Ref. 3 below Table 1 it is noted in the bulletin presenting the figures that "in all of the tests upon which this table" (that from which Ref. 3 figures were taken) "is based, green material was used except for longleaf pine, which was partially air-dried and contained an average moisture content of 25 per cent. This fact explains in part the apparent superiority of longleaf pine over Douglas fir."

In all cases (with the exception of Ref. 8, and, of course, of the clear material) no mention is made of grade. It is, however, presumable that the material tested was of average quality and fairly representative of the comparative properties of the two species, with the exception noted in the preceding paragraph.

In all references to working stresses in the above it is assumed that grading rules of equal efficiency apply for both timbers.

TABLE 1. COMPARATIVE PROPERTIES OF DOUGLAS FIR AND LONGLEAF PINE. VALUES FOR DOUGLAS FIR AS PERCENTAGES OF CORRESPONDING VALUES FOR LONGLEAF PINE.

Reference No.	Class of Specimen.	Static Bending.			Compression Parallel to grain.		Compression Perpendicular to grain C.S. at E.L.	Longitudinal Shearing Strength.	Weight.
		F. S. at E. L.	M. of R.	M. of E.	C. S. at E. L.	C. S. at M. L.			
1	Small specimens	105·7	91·3	103·7	....	91·6	....	78·6	....
2	"	99·1	90·1	97·4	....	....	....	83·5	....
3	"	110·0	92·3	103·9	....	....	....	79·4	....
4	"	105·5	91·3	103·7	....	91·6	....	....	....
5	"	102·4	94·9	104·5	100·2	93·7	109·0	89·9	83·
6	"	102·7	95·9	96·1	....	94·2	....	76·0	87·1
1	Structural timber	106·3	97·5	103·7	79·6	72·8	100·3	....	80·0
2	"	123·8	110·7	90·8	94·1	88·7	111·6	....	71·8
3	"	105·2	83·4	96·8	80·0	72·9	100·0	....	80·6
7	"	126·0	109·8	111·0	....	....	....	....	....
8	"	117·9	112·6	112·3	....	....	....	....	....
9	All sizes—Average	98·0	87·4	111·4	....	....	....	....	....

Ref. No. *References.*

1 U.S. Forest Service Bulletin 108, p. 20, Table 1.
2 " " " 108, p. 21, " 2. Air-dry material (both species).
3 " " " 88, p. 18, " 3. Longleaf pine partially air-dry.
4 " " " 189, p. 4, " 1. Doubtless the same series of tests as No. 1.
5 " " Circular 213, for value for longleaf, and Forestry Branch Bulletin No. 60 for value for Canadian Douglas fir.
6 " " " 213, for value for longleaf, and U.S. Forest Service for value for Douglas fir.
7 " " " 189, p. 24, Tables 1 and 2. (8-inch by 16-inch and 2-inch by 2-inch, only comparable sizes).
8 " " Bulletin 108, p. 65, Table 8. Structural timbers graded by same rules. (Grade 1).
9 " " Circular 189, p. 4, Table 1. (Average all sizes).

Technical Terms Defined.

The modulus or coefficient of elasticity (M. of E.) indicates stiffness and may be defined as that quality which determines the ability of a beam to resist bending within its elastic strength.

The fibre stress at elastic limit (F. S. at E. L.) is proportional to the maximum load which a beam will carry without showing a permanent deformation when the load is removed.

A beam loaded beyond its elastic limit will ultimately break. The modulus or coefficient of rupture (M. of R.) is proportional to the load sufficient to cause such a failure.

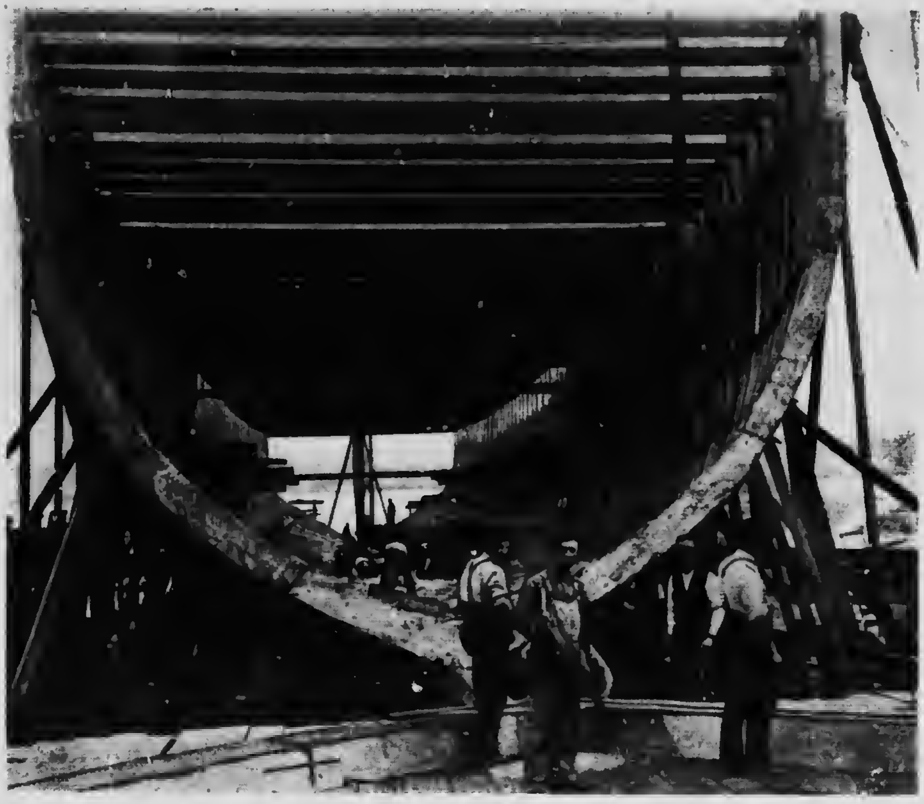
In compression parallel to the grain the specimen being tested is placed with its grain vertical while in compression perpendicular (Comp. perp) the grain is horizontal, i.e., in the former the load is applied so that the line of force is parallel to the longitudinal axis of the fibre while in the latter it is perpendicular. The compressive stress at maximum load (C. S. at M. L.) is the actual load being carried in compression parallel when failure takes place.

Shearing strength is that property which prevents the fibres of wood from sliding over immediately adjacent fibres when the specimen is carrying a load which tends to cause such sliding to take place.

Prices of Douglas Fir.

Although in Tables 2 and 3 the grand average prices for the different species of timber are given, attention is called to the fact that these figures are f.o.b. at the mill. In order to arrive at the actual price in Montreal, for example, it is necessary to add freight charges, reckoning that 1,000 feet, board measure, weigh in the vicinity of 3,300 pounds. For a more specific example take Douglas fir which at the present time sells for about $13 per thousand at the mill. The price delivered in Montreal will be $13 plus thirty-three times 70 cents (the freight rate being 70 cents per hundredweight and 1,000 feet, board measure, of Douglas fir weighing 3,300 pounds), or about $36.10

PLATE 15.



Douglas fir, used in shipbuilding in British Columbia.

per thousand feet, board measure, for carload lots. At this date (1916) Douglas fir and longleaf pine sell in Montreal at the same price in the size 12 by 12 inches square and 22 feet long; larger sizes are less in Douglas fir but smaller sizes are less in southern pine. It is an important fact that southern pine must be reckoned at over 4,000 pounds per thousand feet as compared with Douglas fir at 3,300 pounds, and furthermore that increased facilities leading to lower rates in Canada will very greatly reduce the price of Douglas fir in the East. In the West, Douglas fir is much cheaper than longleaf pine, and is used much more commonly than in the East.

WESTERN HEMLOCK.

Western hemlock (*Tsuga heterophylla*) is found in Canada as a commercial species only in British Columbia, where it occurs as an excellent timber tree. In 1915, 24,959,000 feet, board measure, worth $285,637, were cut. The average value was $11.44 per thousand feet.

Western hemlock has often been considered an inferior wood, especially in localities where it is not well known. The results of recent investigations of its properties show this prejudice to be unfounded and that it deserves a place as an important western wood.

Western hemlock is known under a variety of names in different localities and is often given a fictitious name for the purpose of assisting in marketing the lumber. Certain commercial organizations, however, are beginning to place hemlock on the market under its own name. The common names in use are "hemlock," "western hemlock," "hemlock spruce," "western hemlock spruce," "western hemlock fir," "Prince Albert fir," "grey fir," and "Alaska pine" and "silver fir." The names "grey fir" and "Alaska pine" are sometimes used in the West, while in England "western hemlock fir" and "Prince Albert fir" are used.

The heartwood of western hemlock is almost white. The yellowish-white sapwood forms a very small proportion of the trunk and is generally not over one inch in thickness. The green wood has a distinctly sour odour, which is not present in seasoned material. It is noted for holding nails, is non-resinous, and is reputed to be shunned by insects, vermin, white ants, rats, and mice. It works smoothly and takes paints and varnish well. The lumber is sometimes mixed with Douglas fir and sold and used for the same purposes.

Western hemlock is suitable for all but the heaviest construction work. It has a limited use in bridge and trestle building and has been employed in caisson construction. For use in harbour construction it is suitable for under water work. (See plates 12 and 13.) In house construction it is used a great deal as a framing material. For this class of work it is satisfactory, and, locally, brings the same prices as Douglas fir. Western hemlock in cargo shipments commands about the same price as Douglas fir.

WESTERN LARCH.

Western larch (*Larix occidentalis*) is found commercially only in British Columbia. It is sometimes known as western tamarack or hackmatack but yields a wood much superior to the eastern species. In 1915, 28,023,000 feet, board measure, worth $362,089 at $12.92 per thousand feet, were produced. It ranked seventh among Canadian woods cut in 1913 and tenth in 1915.

In the wood the annual rings show distinct dark-coloured and light-coloured bands. The heartwood is reddish-brown in colour and the sapwood yellowish-white. The latter runs from one-half to one and one-half inches in thickness for trees up to 3 feet in diameter. Knots are generally sound and not over one and one-half inches in diameter. They are common and frequently occur in groups or clusters. Western larch is subject to ring shakes and trees are frequently butted to get rid of this defect.

Western larch is a hard, heavy wood, having many of the qualities of Douglas fir and is often found in the same uses. It is used to some extent for cross-ties and has given satisfaction because it is durable and holds spikes well. Its hardness, fine grain and pleasing reddish colour are making it more and more popular for flooring and other forms of finish. The chief use of western larch as a structural wood is in local railroad and mining structures, and for framing. Larch is not as strong as Douglas fir, and considering also its limited supply, will have no such importance as that wood as a structural timber, but as the grading of structural woods becomes more refined, on the basis of fundamental qualities, larch will undoubtedly have its markets extended.

EASTERN HEMLOCK.

Eastern hemlock (*Tsuga canadensis*) is sometimes known as "hemlock spruce" or "hemlock fir." It is found in all the provinces east of Manitoba but Ontario produces much more of the timber than all the others together. In 1915 the average value per thousand feet, board measure, was about $14; the total cut, 214,033,000 feet; and the total value of timber produced, $2,985,975. Hemlock ranked fourth in quantity of timber cut and in value in 1915.

The wood is reddish-brown in colour. The sapwood is difficult to distinguish from the heartwood. The annual rings are distinct. The wood is fairly stiff but rather harsh and splintery; it holds nails well and is suitable for many purposes in place of more costly woods, as for example, when used in under-water construction. A large proportion of the hemlock timber cut is used in its rough form for joists, rafters, boxes, concrete forms, construction lumber, etc. The remainder is further manufactured into finished products before reaching the market.

WESTERN YELLOW PINE.

Western yellow, western soft or bull pine (*Pinus ponderosa*) is limited to British Columbia where in 1915, 35,166,000 feet, board measure, of a total value of $457,758 and average value per thousand feet of $13.02, were cut. It ranked eleventh in amount among Canadian woods for 1915.

Western yellow pine has furnished a large part of the bridge and trestle timbers for railroad building in the western mountains and the plateaus. Its uses range from the coarsest construction to the making of patterns, as a competitor of white pine. It is used largely in house construction, for flumes, as a mine timber, and for bridge work. The lumber is widely exported, and reaches New Zealand, Australia, England, Ireland, Scotland, the continent of Europe, and elsewhere.

The wood is softer and lighter than Douglas fir or longleaf Southern pine. Western yellow pine is not primarily a structural timber, but one more adapted to shop uses, planing mill products and finish, and because of its soft texture, white colour, and non-resinous character, is marketed largely as "western white pine." There seems to be a great variation in the wood, which is sometimes hard and strong, while in other cases it is very soft and easily worked.

TAMARACK.

Tamarack (*Larix laricina*) is found throughout Canada but is nowhere cut to any great extent, only about 8,000,000 feet, board measure, valued at approximately $130,000, being produced in 1915. Most of this was cut in Ontario and Quebec.

It is at present a structural timber of minor importance and is used only locally. It is known also as "larch," "hackmatack," "American larch," "black larch," and "red larch." The wood resembles red pine. The grain is rather coarse. Lumbermen recognize two varieties of tamarack, the red and the white, the distinction being based on the colour of the heartwood, which varies with the soil and climate. The wood is used in shipbuilding, sometimes in the form of knees, and also for spars and masts, and for ties and telegraph poles.

RED PINE.

Red or Norway pine (*Pinus resinosa*) is one of the trees which is found practically only in Canada. It occurs in all provinces east of Manitoba but more than 80 per cent of the cut is in Ontario. In 1915, 122,387,000 feet, board measure, worth $2,206,840 at an average value of $18.03, were produced in Canada. Of this Ontario produced $1,873,955 worth. In 1915 it ranked sixth among the timbers cut in Canada.

A fifty thousand gallon water tank built of red pine, Montreal. Red pine is the best Eastern Canadian wood for this purpose.

The wood has a rather coarse grain, and is somewhat resinous, lying between white pine and pitch pine in this respect. In colour the heartwood is light red and the sapwood yellow, or often almost white.

Red pine was formerly much used in construction work, but now it is replaced by pines from the Southern States and the woods from British Columbia. The species is still used to some extent, however, for structural purposes. The wood was largely used and is still used, both in Canada and England, for masts, spars, piling, and deck plank. It is used specially in car construction, including sills and frames. It is considered to be the best Eastern Canadian wood for paving blocks and for construction of water tanks. (See plate 16.)

PLATE 17

Eastern white pine, timber on the ice waiting for the spring thaw

THE SPRUCES.

The spruces collectively supply more lumber and have a higher total value than any other kind of wood in Canada. In 1915 spruce lumber to the value of almost $24,000,000, was produced, mostly in Quebec, New Brunswick, and Nova Scotia. Of the different species white spruce (*Picea canadensis*) is found in all provinces, red spruce (*Picea rubra*) in Ontario to a small extent, but more commonly in Quebec and the Maritime Provinces, black spruce (*Picea mariana*) in all provinces, Engelmann spruce (*Picea Engelmanni*) in British Columbia and Alberta, and Sitka or tideland spruce (*Picea sitchensis*) in British Columbia. The latter is the largest of all the spruces and formed about one-half of the spruce cut in British Columbia in 1915. The average value of spruce lumber in Canada in 1915 was $15.24 per thousand feet, board measure.

The wood of all the spruces is much the same. None of them produces especially strong or durable timber, but for many purposes, including joists and light structural timber, they are satisfactorily used to a very large extent. Spruce lumber is used for a great variety of manufactured articles, for inside and outside finish, boxes, etc. Enormous amounts are cut in Eastern Canada for pulpwood.

The wood is dull white with no difference between the sapwood and heartwood. Sometimes the wood is hard but more often it is soft, straight-grained, and easily worked. (See plate 18.) The black spruce is apparently the strongest and most durable of the spruces but in many localities does not reach saw-timber size. White spruce is the most common and most important spruce in the Prairie Provinces and eastward, except in the Maritime Provinces, where red spruce is more abundant.

IMPORTANT WOODS NOT STRUCTURAL TIMBERS.

The other coniferous woods of Canada, while sometimes used for light building purposes and to a large extent for finish, cannot be classed as structural timbers. The most important is white pine (*Pinus Strobus*), which ranked second in amount in the production of 1915 and was second in value, being worth $17,465,268. (See plate 17.) The tree occurs in all Canada east of Manitoba, but Ontario cut more than five-sevenths of the total for 1915. In England it is known as "Weymouth" or "yellow" pine. The western white pine (*Pinus monticola*) of British Columbia, yields a very similar wood to the eastern white pine. Both are light, soft, straight-grained, and easily worked. The wood is probably utilized for a greater variety of manufactured articles than any other Canadian species. In buildings it is especially used for all kinds of finish and in general for all purposes where strength and hardness are not of first importance. The lodge-pole or western jack pine (*Pinus Murrayana*), growing in British Columbia and Alberta, produced about $100,000 worth of lumber in 1915. This tree will probably become more important as the country is opened up. The eastern jack pine (*Pinus Banksiana*) yields a much less valuable wood, though almost $100,-000 worth of its lumber was cut in 1915, in the provinces east of British Columbia, nearly all of which was produced in Ontario and Quebec.

True firs do not yield valuable structural timber, being in general soft and weak. Balsam fir was cut to the value of $3,327,839 in 1915. This figure includes the eastern balsam fir (*Abies balsamea*), which occurs throughout Canada except in British Columbia, the mountain or alpine fir (*Abies lasiocarpa*) of British Columbia and Alberta, the amabilis or lovely fir (*Abies amabilis*) of British Columbia, and the western balsam, lowland or grand fir (*Abies grandis*) of British Columbia.

The cedars cannot be classed as structural timbers, though they are sometimes used, especially placed in the ground, because of their resistance to decay. Practically all of the western or British Columbia red cedar (*Thuja plicata*) is manufactured into shingles and siding, and the eastern white cedar (*Thuja occidentalis*) is also largely used for shingles. In 1915 the western red cedar of British Columbia produced nearly $1,000,000 worth of lumber and the white cedar in the eastern provinces over $200,000 worth. *Chamæcyparis nootkatensis*, the yellow cypress of British Columbia, is valuable but not so common as the British Columbia red cedar. None of these woods last mentioned is suitable for heavy structural work, and white pine and red cedar are far too valuable for special purposes to be used in heavy construction.

GRADING.

The purpose of grading rules is to separate structural timbers into classes in such a way that the material in any one class will be of approximately uniform quality.[1] Grading rules must be based on test data and a knowledge of the requirements of the trade and the ability of the producer to meet these requirements.

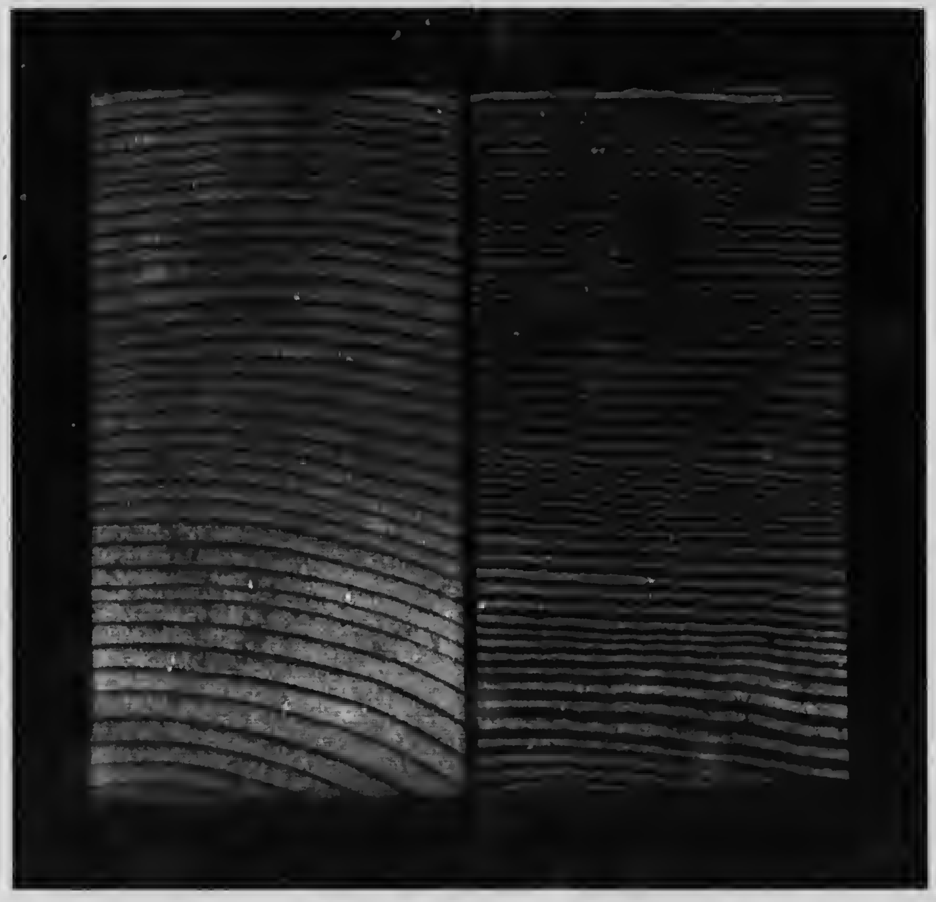
Strength and durability are the most important qualities to be known in the case of the wood of structural timbers. In order to select material properly for a given

[1] "Structural Timber in the United States," by H. S. Betts and W. B. Greeley: Paper presented at International Engineering Congress, San Francisco, 1915.

use a knowledge of the influence of the various physical characteristics of timber on its strength and durability becomes necessary. The characteristics which may be considered in judging the properties of timber are density of wood, direction of grain, moisture condition, proportion of sapwood, and, in addition, defects such as knots, checks, and shakes.

Density.—The strength, hardness, shock-resisting ability, and stiffness of wood vary with the weight in small, clear, straight-grained pieces of the same moisture content. As the weight increases the strength increases. It is, therefore, necessary

PLATE 18.



Photograph of white spruce (left) and Douglas fir wood (right), cross-section, natural size. Note the alternating light and dark bands, the spring wood and summer-wood. The summer-wood in the Douglas fir is much denser than that in the spruce.

to have some means of estimating density by visual inspection, and this may be done with a certain degree of accuracy by determining the proportion of summer-wood. By summer-wood is meant the darker, harder portion in each annual ring, formed during the latter part of the year's growth. (See plate 18.)

Very little is known about the relation between density and durability. In fact, it appears that qualities other than density often affect durability to the greatest

Pine wood, showing cross grain around a large knot.

extent. For example, the essential oils which occur in the cedars cause their wood to be in the class of woods most resistant to fungous action, while the much more dense hemlock is far more subject to decay. As is stated above, there is little established data concerning the resin content of pines being a means of judging their durability.

Direction of Grain.—By grain is commonly meant the annual rings which mark the yearly increase in growth. Logs should be sawed in such a way that the grain runs parallel to the faces of the stick, for if it does not the load which the stick will carry will be considerably reduced. (See plate 19.) If the fibres grow naturally in the tree in a spiral manner the result will be a natural spiral grain which likewise reduces the strength of the timber. Such spiral grain can often be detected by the diagonal direction of fine checks on the flat sawn surface of the stick and can be positively recognized by splitting the wood.

Moisture.—While the effect of moisture on strength is very marked in small clear pieces it is much less in evidence in large structural timbers. This is due to the development of checks and shakes during the process of seasoning the larger material. The durability of green wood is much lower than reasonably well seasoned wood placed under the same conditions. Careful seasoning is, therefore, necessary if timber is expected to last for a considerable time, and in some cases where timber is placed in moist or humid situations preservative treatment is desirable. Since green timber is usually subject to shrinkage and more or less distortion it is well not to use it for permanent structures.

Sapwood.—The proportion of sapwood in a stick of timber does not affect its strength. Sapwood is, however, less durable than heartwood and only a very small proportion of sapwood is allowed in the highest classes of structural timbers. If the material is to be given preservative treatment the presence of sapwood is not detrimental.

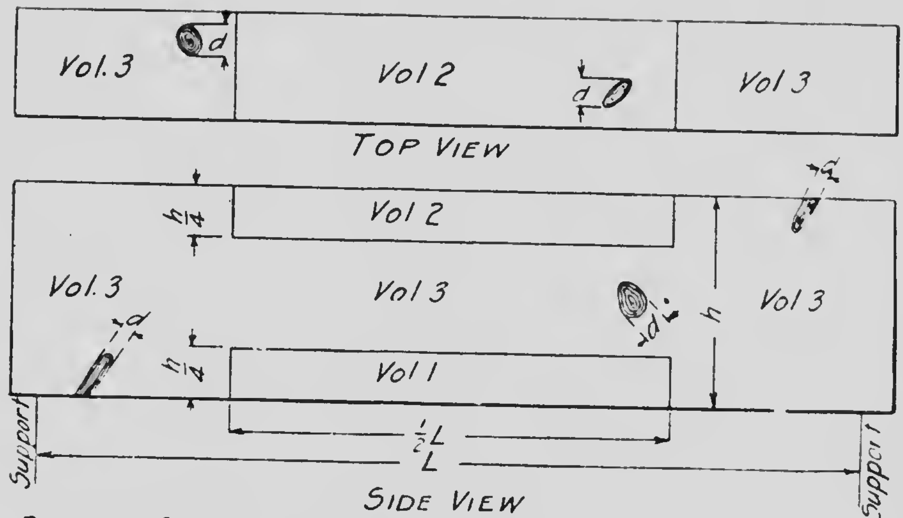
Defects.—Knots, checks and shakes are the most common kind of defects affecting strength. In timber for use as beams the influence of knots is largely a matter of location. Figure 2 shows the United States Forest Service method of dividing a beam into three volumes with reference to the location.

Numerous tests have shown that knots in Volume 1, which occupies the lower quarter of the central half of the beam, have considerably more weakening effect than similar knots occurring in other volumes. Loose or rotten knots are, of course, more harmful than those tightly attached to the surrounding wood. A comparatively small knot situated near enough to the lower edge of a beam to divert the grain is more harmful than a larger knot so placed as to allow the grain to be continuous in passing. In some cases knots near the neutral plane may act as pins and tend to strengthen a beam against failure in longitudinal shear.

Checks are caused by stresses set up in seasoning. Structural timber in large sizes is difficult to season without more or less checking, even under favourable conditions. A shake is a separation between two annual rings, which generally is confined to only part of the ring, but sometimes it is complete. Shakes are ascribed to the bending action of wind on the standing tree. Though present they are frequently not apparent in green timber but become evident later in seasoning Both checks and shakes weaken the ability of beams to resist horizontal shear in proportion as they affect the area of the beam near the neutral axis.

In the case of a stringer, 8 by 16 inches in section, tested in bending over a 15-foot span, failure may occur by tension or tearing apart of the fibres in the lower part of the beam, by compression or crushing in the upper part, or by shearing along the neutral axis. The results of shearing tests on small clear pieces show that, under the conditions given, failure would always occur in tension or compression long before the beam would have reached its maximum shearing stress, provided the shear-resist-

FIGURE 2.



Division of beam into volumes for location of knots
Measurement of knots on horizontal and vertical face of beam
d= diameter of knot

ing area was intact. In tests on commercial material, however, horizontal shear is a common form of failure, due to the fact that the area that resists shear is frequently weakened by checks and shakes. A comparison of the stresses obtained from tests on 8- by 16-inch by 16-foot stringers and small clear pieces, shows that the shear-resisting area is frequently reduced about 50 per cent. due to checks and shakes.

Checks and shakes influence the durability of timber by allowing the collection of moisture and the formation of conditions suitable to the propagation of fungous growth. Knots have little effect on durability one way or the other, except in cases where they become loose and fall out, leaving holes that are apt to collect moisture and produce conditions favourable to decay.

Grading Rules and Specifications for Structural Timber.

At the present time, a large number of different rules and specifications for the grading of timber are in use in the United States. Practically all of the lumber associations in the United States have adopted rules for the purpose of classifying the lumber manufactured by their members. The railroads also have specifications for the selection of their timber, and a number of engineering societies have from time to time brought out timber specifications or grading rules. Some lumber associations in Western Canada have adopted specific grading rules, and general rules for grading lumber are given in the annual report for 1912 of the Canadian Lumbermen's Association, but neither these nor any other rules have been adopted by the latter association.

The most efficient grading rule is one that will pass the largest amount of material suitable for the purpose intended and throw out the largest amount of material not suited for such a purpose. Many of the present grading rules are either very general and loose, or else so rigidly drawn as to exclude timbers of high strength. The following are examples of grading specifications, some of which cover only one grade, while others have several grades:—

COMMERCIAL SPECIFICATIONS.

Specification A.

Specification A is used by one of the leading trans-continental railway systems.

All timber must be of the best description of the kind required. It must be sawed square and to proper dimensions. It must be free from all loose, large or unsound knots, sap, sun cracks, shakes, wanes, or other imperfections or defects which would impair its strength or durability.

Specification B.

Specificatiton B is used by the Isthmian Canal Commission.

Stringers. Douglas fir shall show not less than 85 per cent heart on any face and not less than 70 per cent on any edge; it shall show not less than an average of twelve annual rings to the inch. Sound knots less than 3 inches in diameter shall be permitted in the vertical faces of the stringer at points not less than one-fourth the depth from the edge of the piece.

Specification C.

Specification C is the standard adopted by the Pacific Coast Lumber Manufacturers' Association (now the West Coast Lumber Manufacturers' Association) in 1911. But very slight changes have been made in this set of grading rules since 1899:—

"Clears" shall be sound lumber well sawed, one side and two edges free from knots and other defects impairing its use for the probable purpose intended. Will allow in dimensions larger than 6 inches by 10 inches pitch pockets when not extending through the piece; light-coloured sap on corners not exceeding 3 inches on face and edge, knots 2 inches and less in diameter, according to size of piece, when on one face and one-half of each corresponding edge, leaving one face and upper half of each edge clear.

"Selects" shall be sound, strong lumber, well sawed. Will allow in sizes over 6 inches, knots not to exceed 2 inches in diameter, varying according to the size of the piece; sap on corner not to exceed 2 inches on both face and edge, pitch pockets not to exceed 6 inches in length. Defects in all cases to be considered in connection with the size of the piece and its general quality.

"Merchantable." This grade shall consist of sound, strong lumber, free from shakes, large, loose, or rotten knots and defects that materially impair its strength, well manufactured, and suitable for good, substantial constructional purposes. Will allow slight variations in sawing, sound knots, pitch pockets, and sap on corners, one-third the width and one-half the thickness or its equivalent. Defects in all cases to be considered in connection with the size of the piece and its general quality. In timber 10 inches by 10 inches and over, sap shall not be considered a defect. Discolorations through exposure to elements, other than black sap, shall not be deemed a defect excluding lumber from this grade, if otherwise conforming to merchantable grade.

"Common." This grade shall consist of lumber having knots, sap, and other defects which exclude it from grading as merchantable, but of a quality suitable for rough kinds of work.

Specification D.[1]

Proposed specifications for selected structural Douglas fir bridge and trestle timbers; American Society for Testing Materials.

[1] The proposed specifications are of a tentative nature and subject to change; they are not as yet accepted by the American Society for Testing Materials.

I. DEFINITIONS.

1. The following definitions are used in connection with these specifications:—

(a) *Annual Ring.* Each annual ring is composed of two distinct types of wood structure, namely, the porous, light-coloured and light-weight spring-wood formed during the first part of the growing season, and the hard, dense, and darker-coloured summer-wood formed during the latter part of the growing season.

(b) *Summer-wood.* Summer-wood is the hard, dense portion of the annual ring. It is darker in colour than the more porous spring-wood.

(c) *Sound and Tight Knot.* A sound and tight knot is one which is solid across its face and which is as hard as the wood surrounding it; and is so fixed by growth or position that it will retain its place in the piece.

(d) *Encased Knot.* An encased knot is one whose growth rings are not intergrown and homogeneous with the growth rings of the piece it is in. The encasement may be partial or complete; if intergrown partially or so fixed by growth or position that it will retain its place in the piece, it shall be considered a sound and tight knot.

(e) *Loose Knot.* A loose knot is one not firmly held in place by growth or position.

(f) *Rotten Knot.* A rotten knot is one not as hard as the wood it is in.

(g) *Measurement of Knots—*

In beams, the diameter of a knot on the narrow or horizontal face shall be taken as its projection on a line perpendicular to the edge of the timber. On the wide or vertical face, the smallest dimension of a knot is to be taken as its diameter.

In columns, the diameter of a knot on any face shall be taken as its projection on a line perpendicular to the edge of the timber.

(h) *Diagonal Grain* (including cross and spiral grain). Diagonal grain is grain not parallel with all the edges of the piece.

(i) *Dense and Sound Douglas Fir.* Under this heading two classes of timber are designated: (1) dense Douglas fir and (2) sound Douglas fir. It is understood that these two terms are descriptive of the quality of the clear wood.

(j) *Dense Douglas Fir.* Dense Douglas fir shall show on either one end or the other an average of at least six annual rings per inch or eighteen rings in 3 inches and at least 33⅓ per cent summer-wood, as measured over the third, fourth, and fifth inches on a radial line from the pith, for girders not exceeding 20 inches in height, and for columns 16 inches square or less. For larger timbers the inspection shall be made over the central three inches on the longest radial line from the pith to the corner of the piece. Wide-ring material excluded by the above will be accepted provided the amount of summer-wood as above measured shall be at least 50 per cent.

In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over three inches on an approximate radial line beginning at the edge nearest the pith.

The radial line chosen shall be representative. In case of disagreement between purchaser and seller as to what is a representative radial line, the average summer-wood and number of rings shall be the average of the two radial lines chosen.

(k) *Sound Douglas Fir.* Sound Douglas fir shall include pieces of Douglas fir without any ring or summer-wood requirement.

II. GENERAL REQUIREMENTS.

2. (a) The timber shall be only "Dense Douglas [illegible]" as defined in section 1 (j).

(b) The timber shall be well manufactured, square edge and sawed standard size; solid and free from defects such as ring-shakes and injurious diagonal grain, loose or rotten knots, knots in groups, decay, pitch pockets over 6 inches long or ⅜ inch wide, or other defects that will materially impair its strength.

(c) Occasional variation in sawing, not to exceed ¼ inch scant at the time of manufacture, will be allowed.

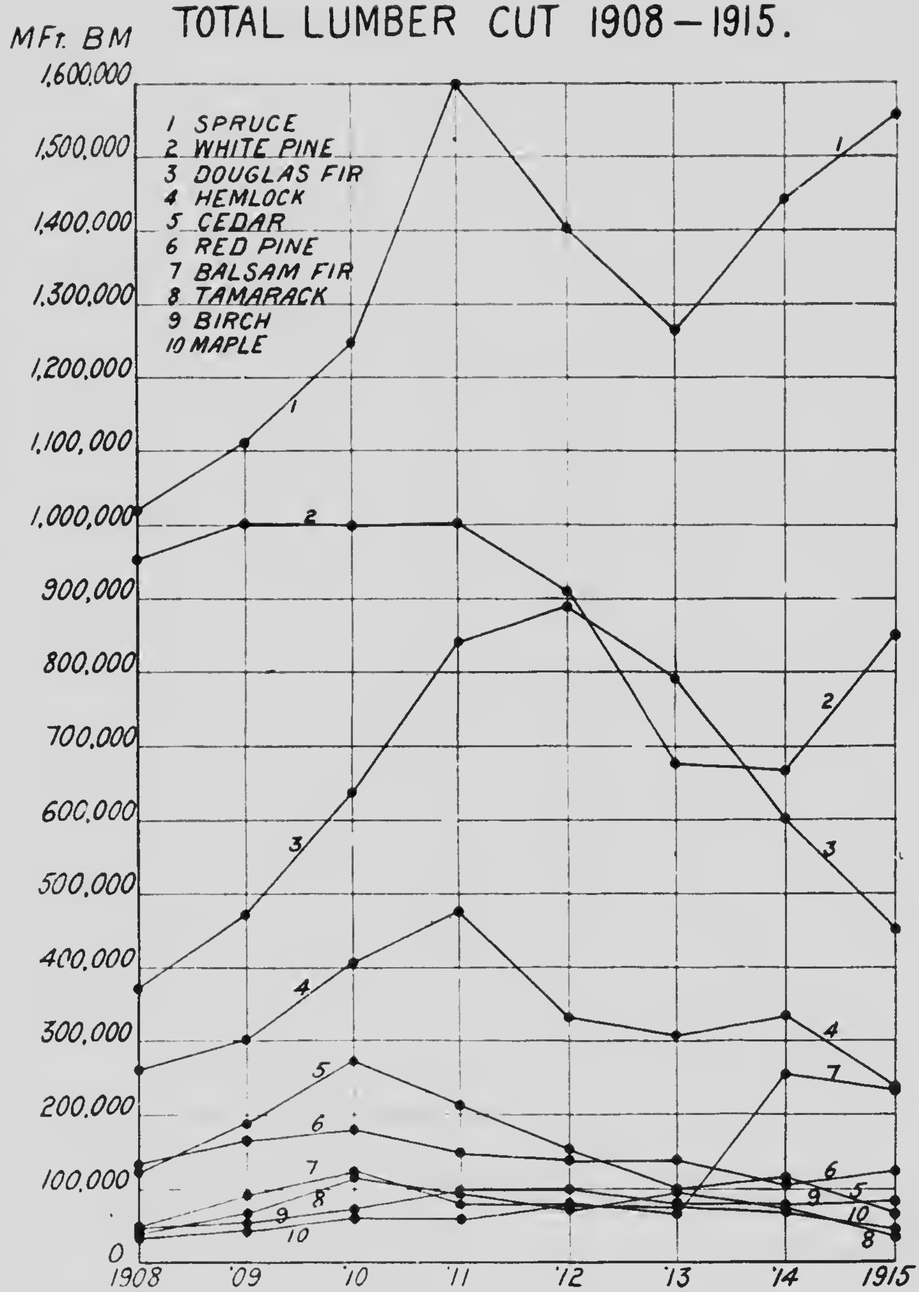


Fig. 3.—Curves showing total lumber production of the 10 most important Canadian woods for years 1908 to 1915. The number of thousand feet, board measure, are indicated on the left hand side and the years at the bottom of the diagram.

(d) When timbers 4 by 4 inches and larger are ordered sized, they shall be ½ inch less than rough size, either S1S1E or S4S, unless otherwise specified.

III. STRINGERS, GIRDERS AND DEEP JOISTS.

3. The timber shall show not less than 85 per cent of heart on each of the four sides, measured across the sides anywhere in the length of the piece. It shall not have in volumes 1 and 2 (Fig. 2) knots greater in diameter than one-fourth the width of the face in which they occur with a maximum of 1½ inches in diameter. It shall not have in volume 3 (Fig. 2) knots larger than one-third the width of the face in which they occur, with a maximum of 3 inches in diameter. Knots within the centre half of the span shall not exceed in the ag 'egate the width of the face in which they occur. Diagonal grain in volumes 1 or 2 with a slope greater than 1 in 20 will not be permitted. When stringers are of two-span length they shall be considered as two separate pieces and the above restrictions applied to each half. The inspector shall place his stamp on the edge of the stringer to be placed "up" in service.

IV. CAPS AND SILLS.

4. The timber shall show 85 per cent of heart on each of the four sides, measured across the sides anywhere in the length of the piece, and shall be free from knots larger than one-fourth the width of the face in which they occur, with a maximum of 3 inches in diameter. Knots shall not be in groups.

V. POSTS.

5. The timber shall show not less than 85 per cent of heart on each of the four sides, measured across the face anywhere in the length of the piece, and shall be free from knots larger than one-fourth the width of the face in which they occur, with a maximum of 3 inches in diameter. Knots shall not be 'n groups.

VI. LONGITUDINAL STRUTS OR GIRTS.

6. The timber shall show all heart on one face; the other face and two sides shall show not less than 85 per cent of heart measured across the face or side anywhere in the length of the piece, and shall be free from knots over 2 inches in diameter.

VII. LONGITUDINAL X-BRACES, SASH BRACES AND SWAY BRACES.

7. The timber shall show not less than 85 per cent of heart on two faces and shall be free from knots larger than one-third the width of the face in which they occur, with a maximum of 2 inches in diameter.

VIII. BRANDING.

8. The inspector shall brand each timber which conforms to the above requirements, "Selected structural Douglas fir."

Acknowledgment is hereby made to the British Columbia Forest Branch for use of photographs for plates 1, 2, 3, 5, 8, 9, 15; to the Toronto Harbour Commissioners for photographs for plates 11, 12, 13; and to the above and the Department of Public Works, the secretary of the Canadian Lumbermen's Association, the British Columbia Lumber Commissioner at Toronto, and to many lumber firms and individuals for assistance and courtesy extended.

TABLE 2.—TOTAL LUMBER CUT BY PROVINCES.

Province.	Rank.			Quantity, M. Ft., B. M.			Value at Mill.			Average value per M. Ft., B.M. 1915.
	1911	1913	1915	1911.	1913	1915	1911.	1913.	1915.	
							$	$	$	$
Quebec	3	3	1	756,508	630,346	1,078,787	10,730,844	10,618,528	17,784,415	16 49
Ontario	1	2	2	1,716,819	1,101,066	1,035,341	30,584,721	25,772,617	19,663,950	18 99
British Columbia	2	1	3	1,341,912	1,173,617	669,816	19,233,681	16,428,218	8,414,227	12 56
New Brunswick	4	4	4	467,500	399,247	633,518	6,307,245	5,758,[illegible]49	9,902,202	15 63
Nova Scotia	5	5	5	388,114	247,722	294,475	5,034,785	3,66[illegible],[illegible]64	4,366,165	14 83
Saskatchewan	6	6	6	134,745	111,800	62,864	2,266,435	1,908,482	880,353	14 00
Manitoba	7	7	7	53,745	71,961	12,357	769,800	946,458	549,430	12 97
Alberta	8	8	8	51,084	44,462	17,975	801,153	608,902	244,487	13 60
Pr. Edward Island	9	9	9	7,715	6,391	7,513	102,278	85,120	114,577	15 19
Total, all Provinces				4,918,202	3,816,642	3,812,676	75,830,954	65,796,438	61,919,806	16 11

NOTE. This table includes all kinds of wood and all classes of lumber. For more complete data see Annual Forestry Branch Bulletins entitled "Forest Products of Canada".

TABLE 3.—LUMBER CUT BY KINDS OF WOOD, 1911, 1913, 1915.

Species.	Quantity, M. Ft., B. M.			Value at Mill.			Average value per M. Ft., B. M.		
	1911.	1913	1915.	1911.	1913.	1915.	1911.	1913.	1915.
				$	$	$	$	$	$
Spruce	1,600,[illegible]51	1,274,215	1,564,113	21,842,657	19,126,990	23,843,548	13 65	15 01	15 24
White Pine	1,038,542	678,330	849,196	20,786,147	18,502,041	17,584,149	20 01	27 28	20 71
Douglas Fir	845,936	793,143	453,534	11,794,252	10,898,978	5,333,573	13 94	13 74	11 76
Hemlock	176,239	306,312	238,992	6,025,143	4,505,767	3,271,612	12 65	14 71	13 69
Balsam Fir	79,717	64,957	233,521	969,315	845,955	3,327,839	12 16	13 02	11 25
Red Pine	150,806	144,320	122,387	2,665,985	2,688,653	2,206,810	17 68	18 63	18 03
Cedar	214,624	101,053	67,366	3,189,130	1,487,633	1,172,279	14 86	14 72	17 40
Tamarack	94,366	96,325	36,192	1,316,609	1,327,672	491,687	13 95	13 77	13 59
Yellow Pine	80,393	58,939	35,166	1,223,963	874,011	457,758	15 22	14 83	13 02
Jack Pine	47,007	35,404	31,233	648,747	508,840	481,323	13 80	14 37	15 39

These 10 woods comprise more than 94 per cent of *all* lumber cut in Canada. The total production in 1915 was 3,812,676 M. Ft., B.M., valued at mills at $61,919,806. In this table several kinds of wood may be included under the names as given, the various species being listed in the text. The two most important hardwoods, birch and maple, produced respectively 85,733 and 47,418 M. Ft., B. M., in 1915.

TABLE 4.—AVERAGE STRENGTH VALUES,[1] GREEN STRUCTURAL TIMBERS WITH ORDINARY DEFECTS AND SMALL SPECIMENS OF GREEN MATERIAL WITHOUT DEFECTS.

Species.	Bending.					Compression parallel to grain.	Compression perpendicular to grain.	Shear.
—	Weight per cubic foot, oven dry.	Rings per inch.	Fibre stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.	Crushing strength at maximum load per square inch.	Crushing strength at elastic limit per square inch.	Shearing strength per square inch.
	Lbs.		Lbs.	Lbs.	1,000 Lbs.	Lbs.	Lbs.	Lbs.
Douglas Fir:								
Structural sizes	28·0	11·0	3,968	5,983	1,517	3,495	570	
Small specimens			5,227	8,280	1,597	4,030		765
Longleaf Pine:								
Structural sizes	35·0	13·8	3,734	6,140	1,463	4,800	568	
Small specimens			4,950	9,070	1,540	4,400		973
Loblolly Pine:								
Structural sizes	31·0	5·9	3,040	5,084	1,387	[illegible]	500	
Small specimens			4,100	7,870	1,440	3,240		630
Shortleaf Pine:								
Structural sizes	30·0	12·1	3,237	5,548	1,473	3,435	351	
Small specimens			4,350	7,710	1,395	3,570	400	704
Western Hemlock:								
Structural sizes	27·0	15·6	3,516	5,296	1,445	3,355	434	
Small specimens			4,406	7,294	1,428	3,392		630
Western Larch:								
Structural sizes	2[illegible]·0	24·3	3,324	4,948	1,301	3,510	456	
Small specimens			4,274	7,251	1,310	3,696		700
Tamarack:								
Structural sizes	30·0	14·0	2,813	4,556	1,220	3,230		
Small specimens			3,875	6,820	1,141	3,190		668
Red Pine:								
Structural sizes	25·0	13·7	2,492	3,864	1,133	2,555		
Small specimens			2,808	5,173	960	2,504		589
Black Spruce: [2]								
Small specimens	26·0	17·9	3,290	6,040	1,385	2,710	262	774
Eastern Hemlock:								
Small specimens	28·0	20·5	4,155	6,685	1,124	3,270	497	877
Western Yellow Pine:								
Structural sizes	30·8	15·6	2,769	4,560	1,243	2,830	299	
Small specimens	25·6	14·9	3,156	5,831	1,178	2,896		
Red Spruce:								
Structural sizes	25·5	21·9	2,394	3,566	1,180			
Small specimens		21·3	3,627	5,900	1,157	2,750	310	758
White Spruce:								
Structural sizes	21·3	9·3	2,239	3,288	1,081			
Small specimens		10·2	3,090	5,185	998	2,370	270	651
Black Hemlock:								
Small Specimens	3[illegible]·0	23·0	3,490	6,030	936	2,890	399	884
Lodgepole Pine:								
Small specimens	26·0	30·0	2,750	5,170	972	2,400	332	714
White Pine:								
Small specimens	24·0	16·0	3,410	5,310	1,073	2,720	314	644
Western White Pine:								
Small specimens	26·0	28·0	3,520	5,700	1,329	3,070	303	712
Engelmann Spruce:								
Small specimens	21·0	11·0	2,180	3,850	798	1,800	279	569
Amabilis Fir:								
Small specimens	25·0	7·0	4,060	6,570	1,323	3,040	334	578
Grand Fir:								
Small specimens	26·0	29·0	3,560	6,090	1,311	3,030	316	735
Western Red Cedar:								
Small specimens	20·0	21·0	2,890	4,750	886	2,630	278	698

[1] U. S. Forest Service Bulletin 108.
[2] Forest Products Laboratories of Canada figures.

TABLE 5.—SHOWING, IN DESCENDING SCALE,[1] THE COMPARATIVE VALUE[1] OF CANADIAN WOODS BASED ON:—

Cross bending strength (Small, clear, green specimens).		Cross bending strength, (Green structural sizes).		Available resources (native woods only) estimated.	Actual lumber production.
Modulus of rupture.	Modulus of elasticity.	Modulus of rupture.	Modulus of elasticity.		1914
Longleaf pine[3]	Douglas fir . .	Longleaf pine[3] . .	Douglas fir	Douglas fir.	Spruce.
Douglas fir	Longleaf pine[3].	Douglas fir. . .	Longleaf pine[3].	Eastern white pine.	Eastern white pine.
Loblolly pine[3]	Loblolly pine[3] . .	Shortleaf pine[3].	Shortleaf pine[3].	White spruce . . .	Douglas fir.
Shortleaf pine[3].	Western hemlock.	Western hemlock.	Western hemlock.	Other spruces . .	Eastern hemlock
Western hemlock.	Shortleaf pine[3].	Loblolly pine[3] . .	Loblolly pine[3]	Western hemlock.	Red pine.
Western larch .	Black spruce[2]. .	Western larch	Western larch .	Eastern hemlock	Western red cedar.
Tamarack . . .	Western white pine.	Western yellow pine.	Western yellow pine.	Western yellow pine.	Western larch.
Eastern hemlock	Amabilis fir. . . .	Tamarack . . .	Tamarack . . .	Western larch	Western yellow pine.
Amabilis fir. .	Grand fir.	Red pine . . .	Red spruce . . .	Red pine	Western hemlock.
Grand fir.	Western larch	Red spruce.	Norway pine. . .	Western red cedar.	Western white pine.
Black spruce[2]. .	Western yellow pine.	White spruce. . . .	White spruce. .	Western white pine.	Tamarack.
Black hemlock	Red spruce	. . . .	. . . .	Tamarack.	
Red spruce. . .	Tamarack.				
Western yellow pine.	Eastern hemlock				
Western white pine.	White pine.				
White pine. . .	White spruce.				
White spruce. .	Lodgepole pine.				
Lodgepole pine. .	Red pine.				
Red pine	Black hemlock.				
Western red cedar.	Western red cedar.				
Engelmann spruce.	Engelmann spruce.				

[1] This refers to value in constructional work, not for manufactured articles.
[2] Forest Products Laboratories of Canada figures.
[3] Imported, not native, woods; here listed for comparison only.