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AN ANALYSIS OF MOISTURE CONTENT VARIATION IN EASTERN SPRUCE AND BALSAM FIR IN MAINE

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LIFE SCIENCES AND AGRICULTURE EXPERIMENT STATION
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MOISTURE CONTENT VARIATION IN EASTERN SPRUCE AND BALSAM FIR IN MAINE

JAMES E. SHOTTAFER[1] AND ALLEN M. BRACKLEY[2]

INTRODUCTION

It is well-known that many of the physical properties of wood vary with the amount of moisture present in it, both in the living tree and in wood in service as a material. The amount of water present in wood can have a direct effect on the weight, strength, physical behavior, and processing characteristics that must be considered in its utilization. Despite the acknowledged importance of moisture content in the conversion of green wood, only limited attempts have been made to determine standard or representative values for it in the various commercial tree species. Such values have proved difficult to define as a species characteristic, because moisture content is subject to a host of factors that can and do cause it to fluctuate widely, both within a species and among species. If the additional variations introduced by conditions of transportation, storage, and even systems of measurement are also considered, the difficulties in establishing representative values for the various species of wood become evident.

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Concern for more specific information on the moisture content of eastern spruce and balsam fir after harvesting has developed recently in Maine for a number of reasons. In 1977 the legislature of the State enacted what is currently known as the "Maine Weights and Measures Law", which requires the development of standards for the measuring and scaling of wood in commerce. Since such standards require some provision for the scaling of wood by weight, the subject has become a point of immediate concern to those in the State who buy and sell green wood. Moisture content is the principal factor that may cause the weight of a specific quantity of wood to vary.

Almost all of the more common primary conversion processes involving green wood are affected by its moisture content and most of them also involve the drying or partial drying of the material. To those responsible for the planning and control of such processes, a knowledge of the initial moisture content of the wood is particularly useful. Over the years the pulping operations and sawmills, which were the primary converters of the spruce and fir resource of Maine, developed some general knowledge of the amount of water present in their raw material. As the use of the resource has become more diverse, however, more specific information has often been needed. The more modern methods of lumber and plywood production and particle board processing frequently require more exacting estimates of the moisture content of the raw material. This problem has been further compounded by the recent depredations of the spruce budworm in the State. Timber killed by budworm is assumed to have some tendency to dry out, so that a mixture of salvage and conventional round wood may exhibit even more variation than is typical for the material. Again, this will be directly reflected in the weight of the green wood and in the difficulty in controlling drying processes, especially where mixtures of species are involved.

This study was undertaken as an attempt to develop some estimate of the characteristic moisture content of green eastern spruce (Picea spp.) and balsam fir (Abies balsamea (L.) Mill.), employing the methods prescribed under the Maine Weights and Measures Law. Certain procedural factors and conditions of growth were also considered, to evaluate their effect on the moisture content of the wood at the time of harvesting, or shortly after cutting.

BACKGROUND OF THE STUDY

The weight of wood is commonly expressed as density or weight per unit volume, so that the premise that underlies the concept of scaling or measuring wood by weight is that given the weight, the volume may be estimated. The three primary components of this weight are the actual amount of the wood substance present, the moisture content of the wood, and whatever extractives may be included.

The effect of extractives on the weight of most commercial wood species is negligible. Since the specific gravity of the actual cell wall substance is about 1.50 and varies little with species, the variation in weight related to the wood substance present is primarily a function of the anatomical structure of the material (11, 19, 20). The effect of wood substance causes wide variations in weight, or specific gravity, among wood species and average specific gravity is commonly accepted as a species characteristic. A coefficient of variation of about 10 percent is considered typical of specific gravity or density within a species.

If the variations in weight assignable to internal structure in wood are accepted as a species characteristic, the remaining factor which influences the weight of wood is the amount of water present in the material. The fact that the moisture content of wood is, itself, subject to considerable variation must then be considered.

Variation in Moisture Content

While average moisture content values for wood in the green condition and in trees are available, it is generally acknowledged that a potentially wide range of values may be encountered within most species. Moisture content in trees or very green wood may range from slightly less than 30 percent to more than 200 percent of the actual weight of the wood substance. There have been notable differences observed within individual trees between heartwood and sapwood and at different points in the height of the tree (11, 14, 19). Both Wangaard (21) and Kollman (11), as well as the Wood Handbook (20), indicate moisture content values determined for sapwood are distinctly higher than those of comparable heartwood. Brown (2) reported that the moisture content of sapwood was 1/2 to 2/3 of green weight in softwoods, while the heartwood moisture content was 1/4 to 1/2 of total weight. In many conifers, moisture content has also been found to increase with height in the tree (11, 14, 19). Both Kollmann (11) and Wangaard (21) note that the amount of water contained in softwoods appears to change very little with the seasons of the year.

When the tree is cut, the wood immediately begins to dry, although the intitial rate of drying may be quite slow (17). The rate at which the material dries will be affected by a host of factors, including the initial moisture content of the wood in the tree and the anatomical structure of the wood. The conditions of relative humidity and temperature to which the cut wood is exposed are the principal determinants of the rate at which it will dry. Due to the fact that moisture movement in wood is 12 to 15 times faster along the grain than across it, however, drying at the cut surfaces or cross section of the stem, can be quite rapid under certain conditions.

The precise mechanisms involved in the movement of moisture in wood are very complex and beyond the scope of this report. Those wishing to pursue the subject should consult standard works on the subject, such as Siau (15), Skaar (16), and Stamm (17).

Variations in Moisture Content Determination

Beyond the inherent range in water content that may be observed in green wood, the stated moisture content of wood may be subject to some variability as a matter of definition. There is more than one recognized method for measuring and calculating the moisture content of a material and this also contributes to the range in values that are published and in current use.

The American Society for Testing and Materials (ASTM) recognizes no less than 21 definitions for expressing the moisture present in material. As has been pointed out by Galligan (6), a strict definition of the term "moisture content" is the amount of water in a material, expressed as a percentage of the total mass of the material. The amount of water in a material expressed as a percentage of the dry or water-free mass is termed moisture regain. For some time, however. wood scientists have employed the terms moisture content oven dry basis, or simply "oven dry" and moisture content green basis or "green", as a convention.

Kollmann (11) discusses these two methods of calculating moisture content, where the values are expressed as:

$$U = \frac{Wu - Wo}{Wo} \qquad X \quad \frac{Wu - Wo}{Wu}$$

Where: U = weight of water contained in wood expressed as a ratio to the weight of the wood oven dry (percent).

X = weight of water contained in the wood expressed as a ratio to the weight of the wood green (percent).

Wu = weight of wood with a moisture content u (original weight).

Wo weight of wood oven dry.

Kollmann notes that moisture content green basis, commonly used by the pulp industry, can be converted to moisture content dry basis, and vice versa, using the formula:

$$U = \frac{100\ X}{100\ -X} \qquad \text{or} \qquad X = \frac{100\ U}{100\ +U}$$

With the exception of the pulp industry, moisture content based on oven dry (OD) weight is the most widely used measure in wood research and the various industries converting wood. Most of the important changes in the physical and mechanical properties of wood, as it dries, occur below the fiber saturation point (FSP) in the common commercial wood species. This typically ranges from 24 to 30 percent moisture content, on the basis of oven dry weight. The generally accepted methods for determining moisture content on an OD weight basis are described in ASTM Standard D 2016-74 (1). The pulp industry, which is more interested in the amount of water present in wood than its effect on wood structure, is concerned with moisture content green basis. This is reflected in the procedures prescribed in TAPPI Standard T 1205-75, (18) of the Technical Association of Pulp and Paper Industries (TAPPI).

It is particularly important, therefore, that in the measuring, calculation, and discussion of moisture content and its effects on wood, the basis of the determination be clearly understood.

Moisture Content and Wood Measurement Regulations

Section 2363, as amended, of Title 10, the Maine Weights and Measurements Law, requires that following the appropriate public hearings, the State Sealer of Weights and Measures shall establish procedures and regulations for the measurement of wood purchased in the State. The required procedures were promulgated as Chapter 305 of the Department of Agriculture's Inspection Regulations (13) entitled "Wood-Standards for Measurement" The sections of this regulation that are pertinent to this investigation are reproduced in the Appendix of this report; however. a few are particularly relevant. Section 3 of the regulation addresses itself specifically to the subject of weight scaling.

Section 3D3 entitled "Selection of Samples", states in paragraph a:

"A minimum of ten, one-inch discs (known further as 'the sample') will be cut from the stems or pieces of stems from points agreed to by the buyer and seller "

Paragraph c, with respect to loads when that agreement of the buyer and seller cannot be obtained states:

"The State Sealer shall make his selection of sample points on a random basis, first selecting a minimum of ten stems and then a specific sampling point on each stem. In cases where the removal of a disc would ruin a log or bolt the sample point will be moved "

Section 3D4 states in paragraph a, on moisture content determination, that it shall be computed on the basis of oven dry weight.

Section 3D5 states in paragraph a:

"If the moisture content of the original sample is found to be below the lower moisture content limit, then he will compute a weight adjustment to increase the weight of that load to what it would have been at the lower limit of moisture content. If the moisture content is found to be above the upper limit, then a deduction in weight will be computed to bring the moisture content down to that upper limit."

In paragraph b:

"If the moisture content is found to be between the two limits of range, then it will be declared green and no adjustment made."

In paragraph c:

"The upper and lower moisture content limits will be determined by the State Sealer after sampling the area where the wood in dispute was cut."

It is evident that if the Regulation is to be employed as written, a certain amount of variation in moisture content may be expected, and apparently must be considered inherent. Differences related to sampling and measurement procedures are evidently not identified as such. From these Sections of the Regulation, however, it also appears that some knowledge is presumed of the variation of moisture content both within the tree or green log, and with geographic location. It is of particular importance when the moisture content of the material is at issue in a dispute over the weight of purchased wood.

Moisture Content in Eastern Spruce and Balsam Fir

The moisture content of balsam fir and the three species of spruce known collectively as eastern spruce, is of particular interest because of the importance of these species as commercial timbers in Maine. Together, eastern spruce and balsam fir currently account for over 50 percent of the volume of timber cut in the State. About 37 percent of the material cut is harvested for pulpwood, and is utilized by the paper industry (4). Fir and spruce are often grouped together for marketing purposes because the conversion characteristics are quite similar. The species that comprise the eastern spruces, white (Picea glauca (Moench) Voss), red (Picea rubens Sarg.) and black (Picea mariana (Mill.) B.S.P.), cannot be separated on the basis of the characteristics of their wood (14). Balsam fir (Abies balsamea (L.) Mill.) can be identified from its wood structure, but is harvested and mixed with the spruces.

Specific information regarding the moisture content of spruce and fir harvested in Maine is extremely limited. In discussing differences found in the moisture content of heartwood and sapwood in spruce and fir by Gaumann in 1928, Kollmann (11) relates:

> "The variations in individual trees may be considerable while changes with season are, as a rule, relatively small and their causes not quite clear. In spruce heartwood, Gaumann (1928) found a nearly constant moisture content of between 33.4 and 34.9% at a height of 6 M above the ground, over the entire year The sapwood exhibited remarkable variations from stem to stem but the lowest moisture content values (on the average 154.1± 5.7%) appeared during the winter months (December, January, February) in contrast to the remaining nine months (187.1± 5.2%). Fir heartwood contained an average of 45% moisture content from June until January. From

January on the moisture content decreased and reached a minimum in April; subsequently it reached the normal state in June. In fir sapwood the conditions are more complicated; the moisture content amounted to a maximum of 211% in April followed by a low range between 170% and 186% during the early summer months. Following was a second peak higher than 200% in August and September and then a continuous decrease to a minimum of 134% in March."

The particular species of spruce and fir observed by Gaumann and their origin were not reported.

Some estimate of green moisture content (MC) in eastern spruce and balsam fir can be derived from data collected by Hardy and Weiland (8) at Old Town, Maine. The information is based on 463 stem discs, taken from loads of four-foot pulpwood. The green material was designated "fresh and non-fresh"

Fresh Wood	Eastern Spruce	Balsam Fir
MC green basis (percent)	46.0	56.5
MC OD basis (percent)	85.2	129.7
Non-Fresh Wood		
MC green basis (percent)	44.0	50.7
MC OD basis (percent)	78.9	102.8

In a study of a single tree each of spruce and fir, Young (22) reported data from which green moisture content estimates may be calculated:

Moisture Content (percent)	Red Spruce	Balsam Fir
Green Basis	46.6	64.2
Oven Dry Basis	87.1	178.3

Dunfield et al. (3) reported moisture content values for spruce and fir trees in a study conducted in Eastern Canada.

Species	Oven Dry Moisture Content
Black Spruce	49 Percent
White Spruce	75 Percent
Balsam Fir	123 Percent

In a study of specific gravity variation in conifers in Eastern Canada, Kennedy et al. (10) determined moisture content values from samples of over 1000 eastern spruce and balsam fir trees. The moisture determinations reported in this study were based on oven dry weight, following ASTM standards, but did not include any analysis of the moisture content information.

Species	Oven Dry Moisture Content
Black Spruce	53 Percent
Red Spruce	59 Percent
White Spruce	71 Percent
Balsam Fir	80 Percent

The United States Forest Products Laboratory lists the following values for spruce and fir (OD basis) in the Wood Handbook (19).

Species	MC Sapwood	MC Heartwood	MC Mixed
Eastern Spruce	128 Percent	34 Percent	---
Balsam Fir	---	---	117 Percent

The effect of spruce budworm attack on the moisture content of standing trees has not been reported, although a considerable literature is developing related to the problems of utilizing budworm killed timber. A summary of a number of these studies has been prepared by Field and Shottafer (5). From research conducted on other species damaged by insects, and the reported observations of those involved in the harvesting of budworm killed material, it is reasonable to assume that some moisture loss must be expected in killed spruce and fir that remains standing. Present published information on the moisture content of spruce and fir killed by budworm must be considered too fragmentary to be representative.

Purpose and Scope of the Study

Following the implementation of the Wood Measurement Regulations of the Maine Weights and Measures Law, a number of moisture content tests of green wood were conducted by the School of Forest Resources' Forest Products Laboratory at the University of Maine, Orono. These samples, consisting of 20 to 30 stem discs cut from recently harvested trees, were submitted to the Laboratory by a variety of private firms and individuals, and the Maine Department of Agriculture's Division of Inspections. These disc specimens were evaluated at the Laboratory using standard procedures. When it became evident that a large number of test samples from a variety of locations could be expected, it was decided to attempt a more comprehensive evaluation of the green moisture content of spruce and fir.

In reviewing these intitial tests it was established that the Department of Inspections and at least one private firm were employing essentially the same field collection procedures. These procedures are listed in the Appendix. While a number of persons were involved in the collection of the samples, all the moisture content evaluation and data analysis were conducted by the authors at the School of Forest Resources. Based on the results of the preliminary tests, the following specific objectives appeared feasible, and certain constraints on the investigation became evident:

1. The study would be conducted in the context of the procedures prescribed by the Maine Weights and Measures Law and the associated Wood Measurement Regulations (13).
2. The effect of several specific factors on green moisture content would tentatively be evaluated:
    a. tree species
    b. sample position in the tree
    c. geographic location
    d. severity of spruce budworm damage
    e. season of the year
3. No attempt was made to determine the effect of specific conditions of growth and the samples were selected from commercially harvested trees cut by conventional methods.

It was evident at the beginning of the study that some variation in the moisture content values determined would be introduced by the practical limitations of the collection procedure. It was necessary to consider such variation, together with differences encountered in growth conditions and cutting circumstances, as part of the inherent variability observed in the range of the moisture content values. It was also recognized that the moisture content values determined could not be considered as necessarily representative of eastern spruce and balsam fir throughout their entire range, or even within the State of Maine.

CONDUCT OF STUDY

Collection of Moisture Content Samples

For a period of approximately 18 months, samples were taken from freshly-cut timber at several locations in the State of Maine. The procedures followed were in general accordance with ASTM D2016-74, except that it was not always possible to take the sample from the log within two hours of the time the tree was cut. Also, since field staff of the Division of Inspections, the Maine Bureau of Forestry, and the private firm were involved, it was expected that some procedural errors due to communication might be encountered. The complete instructions for sample collection and recording of field data appear in the Appendix, but the date, location, position of the sample in the tree, species, and degree of budworm damage were of particular interest. A disc sample was taken from each log or stem within 6 feet of the butt, at the mid point, and near the top at a point where the log diameter was about 4 inches. If the disc was large it was halved or quartered as described in ASTM Standard D2016-74, to reduce the size, but maintain the material proportions. The sample was tightly wrapped in aluminum foil after numbering for identification, and placed in a double plastic bag. Between five and ten logs of each species were sampled when available, and the sample group, packed in foil and plastic, was delivered to the Forest Products Laboratory at the School of Forest Resources.

Determination of Moisture Content

The sample discs were evaluated by groups for moisture content, as specified by ASTM Standard D2016-74, Method A, utilizing a forced air drying oven at 103°± 2°C. Drying periods were typically 24 to 26 hours. Green weight, a check weight, and final or oven dry weight were recorded. The moisture content of the samples on a green basis and on oven dry basis was determined, and the mean ($\bar{x}$), standard deviation (s), and coefficient of variation for each sample group were calculated by species. The species identification of a number of samples was verified, and at least one specific gravity evaluation of each species was made for each group. Any observations made during the evaluation of the samples relevant to their condition or behavior were recorded. Because of the basic premise of the investigation, that the moisture content of freshly cut logs would be evaluated following the Wood Measurement Regulation, the samples were weighed and dried with the bark on.

Analytical Procedures

As had been anticipated, all of the samples collected were not acceptable for the general analysis. At the time the initial analysis of the data was begun, 13 sample groups submitted by the Division of Inspections, and 5 groups submitted by the private firm cooperating in the study, were available. These groups provided the moisture content values that were the basis of the analysis.

All statistical analyses were conducted using programs available in SPSS (Statistical Package for the Social Science), available at the University of Maine Computer Center. Subprograms ANOVA (Analysis of Variance) and ONEWAY were utilized as required, depending on the statistical design necessary to test the specific hypothesis in question. LSD (least significant difference) tests were employed to evaluate posterior contrast of group means. The LSD test proved useful in the analysis, since it is considered exact for the type of unequal group sizes encountered in the data (9, 12). In discussion of the results of the analyses, differences at the 5 percent significance level were termed significant, and at the 1 percent level, highly significant.

For purposes of analysis, the calender year was divided into three seasons: Winter (January, February, March, April), Summer (May, June, July, August) and Fall (September, October, November. December). The eight geographic locations designated in the analysis were townships, or areas involving neighboring townships: Glenwood [1] T75 WELS [2] Stratton area [3] Wesley [4] Medford [5] Mattamiscontis area [6] T13R7 WELS [7] and T6R14 WELS [8]. The approximate locations of these areas in the State are shown in Figure 1.

Following a review of the data, it was decided to conduct the analysis using the moisture content values of the samples calculated on a green weight basis. Since both moisture content on an OD basis and moisture content on a green basis are derived from an identical weight difference, the absolute values of green moisture content are smaller than the corresponding OD basis values. The magnitude of both the variance (s^2) and coefficient of variation (C) for the green basis

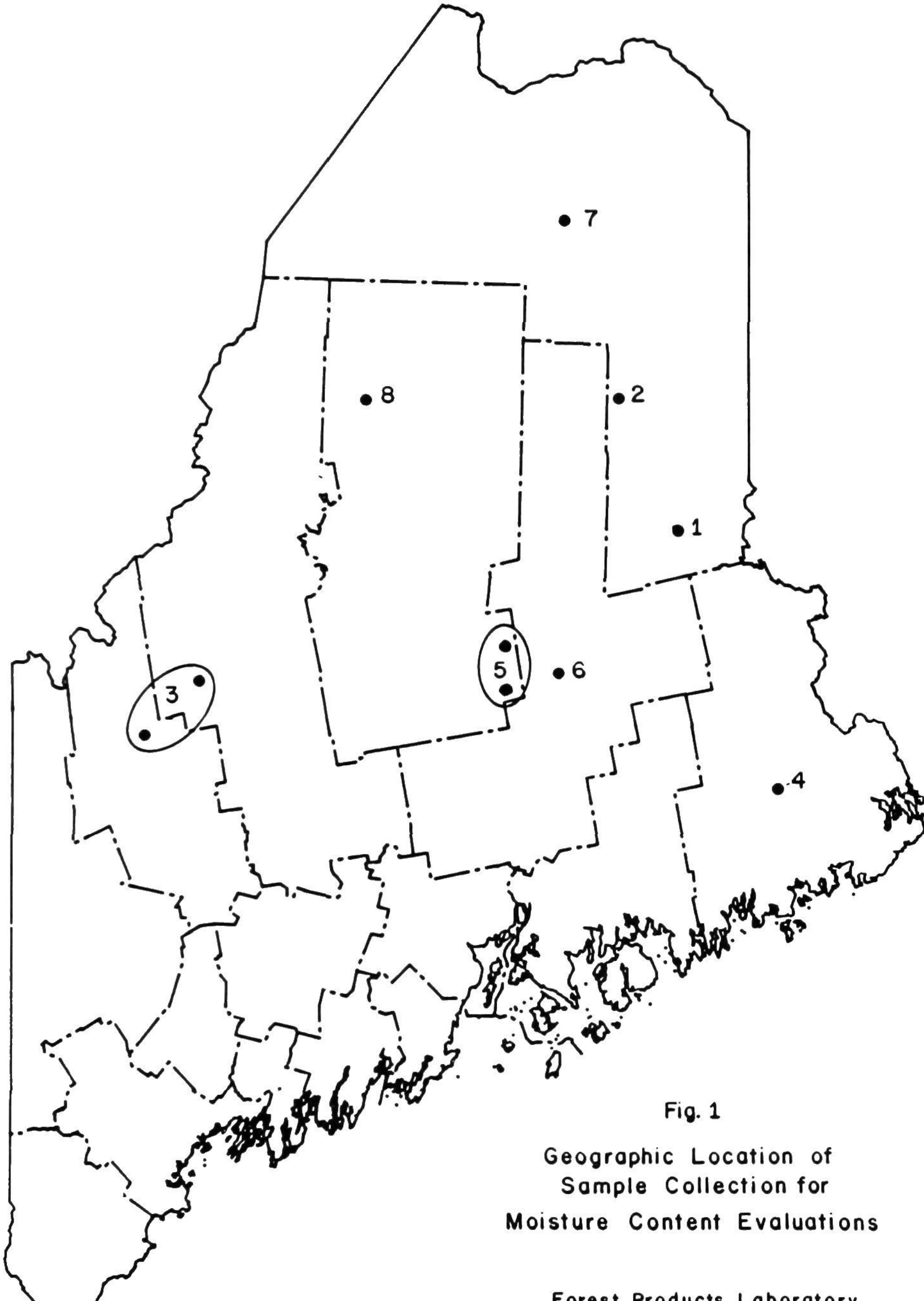

Fig. 1

Geographic Location of Sample Collection for Moisture Content Evaluations

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values is also smaller than the OD weight basis values. The direct effect of this relationship is that when conducting an ANOVA procedure, higher F values, therefore greater sensitivity, are provided by the use of the green basis data. From a more immediate standpoint, all of the moisture content tests related to the Maine Wood Measurement Regulation that had been conducted by the Forest Products Laboratory at the School of Forest Resources at the time of the analysis, involved the evaluation of pulpwood. As noted before, the pulp industry commonly utilizes moisture content values calculated on the basis of green sample weight.

RESULTS OF THE STUDY

The moisture content values determined in the laboratory phase of the investigation are summarized in Table 1 for the entire study, and by location in Table 2. Some comparisons with the reported results of other research appear in Table 3.

Over the period during which the disc samples were delivered to the laboratory for evaluation, a number of persons and organizations were involved in the collection of samples for the State. Of the 23 sample groups of spruce and fir collected, however, only one, sample group number 15, proved unusable because of errors in field procedures. All the 5 sample groups received from the private firm involved proved acceptable.

An initial concern was the possibility of moisture loss from the samples during the period they were in transit from the field to the laboratory. No marked evidence of condensation was noted however, on either the plastic bags or the foil in which the individual samples were wrapped. Only a few samples showed evidence of bark loss, although the bark on many loosened during the drying procedure. In a few instances it was necessary to clean dirt, small stones, etc. from the samples before weighing.

DISCUSSION AND ANALYSIS OF THE RESULTS

In order to utilize the available data as completely as possible, it was necessary to analyze the results in two sequential stages.

Table 1. Moisture Content Values Determined for Eastern Spruce and Balsam Fir Logs in Maine

Species	Number of Trees	Value	Moisture Content (percent) Green Weight Basis	Moisture Content (percent) Oven Dry Basis
Eastern Spruce	75	Average ($\bar{x}$)	47.73	96.45
		Std. dev. (s)	7.58	24.06
		Std. Error ($s_{\bar{x}}$)	0.88	2.78
		Coeff. of Var.[1]	15.0	24.9
Balsam Fir	181	Average ($\bar{x}$)	53.13	118.23
		Std. Dev. (s)	5.61	24.42
		Std. Error ($s_{\bar{x}}$)	0.42	1.82
		Coeff. of Var.[1]	10.6	20.1

[1]Coefficient of variation (C) values in percent

Table 2. Moisture Content Values for Eastern Spruce and Balsam Fir Logs at Different Locations and Seasons[1]

		Average Moisture Content (percent)					
		Green Weight Basis			Oven Dry Weight Basis		
Location	Species	Winter	Summer	Fall	Winter	Summer	Fall
Glenwood [1]	Fir	53.8	52.5	--	102.2	115.7	--
	Spruce	49.1	50.0	--	98.5	103.8	--
T7R5WELS [2]	Fir	52.0	48.2	54.7	111.6	95.0	123.3
	Spruce	49.1	50.1	52.8	99.6	103.7	115.0
Stratton Area [3]	Fir	54.0	54.2	--	121.2	121.9	--
	Spruce	46.9	42.5	--	91.7	80.4	--
Wesley [4]	Fir	59.2	56.0	--	146.7	129.9	--
	Spruce	50.0	50.8	--	101.0	106.7	--
Medford [5]	Fir	--	--	52.3	--	--	115.1
	Spruce	--	--	--	--	--	--
Mattamiscontis [6]	Fir	54.4	--	--	123.4	--	--
	Spruce	43.5	--	--	82.8	--	--
T13R7WELS [7]	Fir	--	--	56.4	--	--	132.4
	Spruce	--	--	53.6	--	--	116.6
T6R14WELS [8]	Fir	--	48.5	49.7	--	100.0	105.0
	Spruce	--	42.6	37.1	--	78.6	66.2

[1]Seasons: Winter (Jan., Feb., Mar., Apr.); Summer (May, June, July, Aug.); Fall (Sept., Oct., Nov., Dec.)

Average values based on two [2] disc samples per tree.

Table 3. Summary of Moisture Content Values from Various Studies of Eastern Spruce and Balsam Fir.

	Average Moisture Content (percent)					
	Green Weight Basis		Oven Dry Weight Basis		Number of Samples	
Data Source	Spruce	Fir	Spruce	Fir	Spruce	Fir
Wood Handbook (7)	--	53.9	--	117.0	--	unknown
Dunfield (3)						
Black spruce	33.0	55.2	49.0	123.0	unknown	unknown
White spruce	42.9	--	75.0	--	unknown	--
Hardy & Weiland (8)[1]						
Fresh cut	46.0	56.5	85.2	129.7	X	Y
Non-fresh	44.0	50.7	78.9	102.8	Z	W
Young (22)	46.6	64.2	87.1	178.3	1 tree	1 tree
Kennedy *et al.* (10)[2]						
Red spruce	--	--	59.0	80	382	571
White spruce	--	--	71.0	--	204	--
Black spruce	--	--	53.0	--	318	--
Present study						
State data	49.0	53.8	96.2	120.3	61 trees	65 trees
Private data	42.5	52.8	73.9	117.1	14 trees	116 trees

[1]X+Z=272 disc samples; Y+W=361 disc samples

[2]Mixed specimens from green logs and lumber

Analysis of the Effect of Species and Sample Position

In this phase of the analysis only results from the samples collected by the State were included. The average values of this data set are summarized below for spruce and fir at various positions in the tree. Also included was a dummy value, the average of the butt and top sample values for each log involved.

	Butt	Midpoint	Top	Dummy
Balsam fir	51.0	55.2	57.3	54.1
Eastern spruce	44.4	47.6	53.3	48.9

Based on an analysis of variance, the difference between the average values for spruce and fir, 48.6 and 54.4 percent, respectively, was highly significant. A significant difference was also evident among the average values for sample position in the tree. Based on the results of a multiple range test using the LSD procedure, it was determined that there was a significant difference between the moisture content of samples from the butt, midpoint, and top sections of the logs. There was no difference evident between the values from the midpoint samples, and the average (dummy) values of only the top and butt sections.

A reasonable assumption, based on the results of the initial analysis, is that a basic difference does exist in the green moisture content of the eastern spruce and balsam fir logs included in the investigation. It is also evident that a reasonable estimate of the moisture content of these logs may be obtained by the collection of a sample from the midsection of a log, or by averaging the values provided by samples from the butt and top sections of the log. Accordingly, all of the subsequent analyses were conducted on the basis that the moisture content of the species must be considered separately. Also, the fact that a useful estimate of log (or tree) moisture content could be determined using only butt and top samples, indicated that those logs where a midpoint sample was missing could be included in the analyses.

Analysis of the Effect of Season, Geographic Location, and Degree of Budworm Damage

The data available from both the State samples and those of the private firm involved in the study were combined in this portion of the analysis, but the two species were examined separately or treated as a variable.

The differences evident in the moisture content of samples collected at the various locations proved to be highly significant in the case of both spruce and balsam fir. The posterior contrast (LSD) test also indicated a different distribution of moisture content values for different locations.

Location	Rank Fir	Rank Spruce
TGR14 WELS	1	1
T7R5 WELS	2	5
Medford	3	--
Glenwood	4	4
Stratton	5	3
Mattamiscontis	6	2
T13R7 WELS	7	--
Wesley	8	6

It would appear that the moisture values of the tree length logs sampled at these locations are indeed different, but the cause of these differences is not certain.

An analysis of variance was conducted using the combined species data sets, and considering location, species, and season of the year as dependent variables. Again, the effect of location and species on the moisture content of the tree stems sampled was highly significant. There was no significant difference, however, between sample groups collected at different seasons of the year

In examining the effect of spruce budworm attack on the moisture content of the tree length logs sampled, the data were again divided into spruce and fir subsets. Since no data were made available from trees exibiting light budworm damage, only values from material which had shown medium or severe foliage damage were evaluated. This analysis proved inconclusive, since the number of samples from some groups was inadequate, and the actual difference, about 3 percent, was quite small. The two data sets were combined, and again examined by analysis of variance, and in this case the difference in samples showing heavy and medium levels of budworm damage was significant. A further analysis was conducted to evaluate the effect of budworm damage on moisture content, using values based on the oven dry weight of the samples. Again, the difference in moisture content between samples from stems with a medium level of budworm damage, and those exhibiting severe budworm damage was significant.

It is apparent from the results of the analysis that a number of factors can influence the moisture content of eastern spruce and balsam fir tree length logs. As previously noted, there was some concern that certain aspects of the sample collection procedure might contribute to the variability encountered in data. If such additional variability was introduced, it would tend to obscure differences, rather than delineate them. The coefficient of variation (C) values shown in Table 1 do not indicate a particularly large amount of variation in the data, given the circumstances of the study. In agreement with the literature (11, 14, 17), the results indicate an increase of moisture content from the butt to the top of the stem in the trees sampled. The fact that different moisture content values were characteristic of the species evaluated, and that moisture content varied both within and between species at different locations, is also in accordance with the generally accepted results of other studies.

The lack of any discernable differences in the moisture content of samples collected at different seasons of the year is more difficult to interpret. A certain lack of agreement in the literature does not help to clarify these results. Wangaard (21) and Kollmann (11) indicate that little seasonal variation may be expected in the moisture content of the wood in softwoods. In contrast, Gibbs (7) reported considerable variation in some species with the seasons. Both Gibbs and Skaar (16) do indicate that the variation in softwoods appears less defined than in hardwoods. In any event, all of the investigations cited indicate that seasonal changes in moisture content are highly variable among species. In addition, many of the studies which investigated the moisture present in living trees frequently included twigs, branches, and top material.

Since the sample collection procedure was not specific as to how long after the tree was cut the end samples might be taken, some drying of these samples remains a possibility. This would especially be the case if the samples were taken directly from the ends of the tree length stems. If samples with higher initial moisture content were permitted to lose moisture before collection, differences with samples with lower initial moisture content could be confounded. In any event, some refinement of the sample collection procedure appears advisable. Wood with exposed end grain unquestionably responds to humidity conditions which favor drying; however, the fact remains that the results of the study may accurately reflect the condition of the material that would commonly be subject to the Maine Weights and Measures Law.

IN CONCLUSION

A moisture content sampling system that is to produce consistent results must recognize the fact that the moisture content of freshly cut green wood may be different for different species. In the case of eastern spruce and balsam fir, there is a basic difference in moisture content, and any attempt to determine the moisture content of mixed lots (such as truck loads) of these species should be statistically weighted by species volume. Material from different locations must be considered separately, and the sampling system should be refined in some respects.

Some limit should be placed on how long after a tree is harvested a moisture content sample may be taken. Samples taken from the butt and top of a spruce or fir tree stem and averaged appear to accurately reflect the moisture content of the tree length log, but some restrictions on how the samples are collected are necessary. Samples should be taken several inches from the exposed end of the stem or log, and the determination of moisture content made as soon as practical after the sample is cut. The sample species must be correctly identified, and the sample must be carefully protected from moisture loss.

The differences in moisture content of material obtained at different geographic locations should be investigated and an attempt made to identify the causes of such variation. The effects of spruce budworm damage on the moisture content of harvested trees should be examined further, since, while the differences determined in this study appear real, their actual magnitude was relatively small. Further research is indicated to determine the rate of moisture loss from freshly harvested material, especially during different seasons of the year.

Literature Cited

1. American Society for Testing and Materials. 1981. Annual Book of Standards. Part 16. Philadelphia.
2. Brown, N.C. and J.S. Bethel. 1958. Lumber. 2nd ed. J. Wiley & Sons, Inc., New York.
3. Dunfield, J.D., C.R. Silversides, and T.B. Tsay. 1974. Engineering Characteristics of Trees-Dimensions and Weights of Trees East of the Canadian Rocky Mountains. Forest Management Institute Information Report FMR-X-60. Ottawa, Canada.
4. Field, D.B. 1980. The Economic Importance of Maine's Spruce-Fir Resource. CFRU Res. Bulletin 2. School of Forest Resources. Misc. Report 227. Life Sciences and Agriculture Experiment Station. University of Maine, Orono.
5. Field, D.B. and J.E. Shottafer. 1979. Utilizing Spruce Budworm Damaged Timber in Maine-A Problem Analysis. CFRU Report 3. School of Forest Resources. Life Sciences and Agriculture Experiment Station. University of Maine, Orono.
6. Galligan, WL. 1976. SWST Newsletter. March. Society of Wood Science and Technology. Madison.
7. Gibbs, R.D. 1957. Patterns in the Seasonal Water Content of Trees. In: The Physiology of Forest Trees, ed. K.V. Thimann. Ronald Press, New York.
8. Hardy, S.S., and G.W. Weiland III. 1964. Weight as a Basis for the Purchase of Pulpwood in Maine. Tech. Bulletin No. 14. Life Sciences and Agriculture Experiment Station, University of Maine, Orono.
9. Hie, N.H., C.H. Hall, J.G. Jenkins, K. Steinbrenner, and D. Bent. 1975. SPSS-Statistical Package for the Social Sciences. 2nd ed. McGraw Hill Co., New York.
10. Kennedy, Elma I., A.T. Jessome, and F.J. Petro. 1968. Specific Gravity Survey of Eastern Canadian Woods. Dept. Publication 1221, Department of Forestry and Rural Development. Ottawa, Canada.
11. Kollmann, F.P. and W.A. Cote. 1968. Principals of Wood Science and Technology. Vol. I. Springer-Verlag. New York.
12. Li, J.C.R. 1964. Statistical Inference. Vol. I. Edwards Brothers Inc., Ann Arbor.
13. Maine Department of Agriculture. 1980. Rules and Regulations, Division of Inspections; Chapter 305, Wood Measurement. Augusta.
14. Panshin, A.J. and C. deZeeuw. 1980. Textbook of Wood Technology. 4th ed. McGraw Hill, New York.
15. Siau, J.F 1971. Flow in Wood. Syracuse University Press, Syracuse.
16. Skaar, C. 1972. Water in Wood. Syracuse University Press, Syracuse.
17. Stamm, A.J. 1964. Wood and Cellulose Science. Ronald Press, New York.

18. TAPPI Standard T1205-75. 1975. Preparation of Wood for Chemical Analysis. Technical Association of The Pulp and Paper Industry. Atlanta.

19. United States Forest Service. 1955. The Wood Handbook. U.S.D.A. Forest Products Laboratory. Agriculture Handbook No. 72. Washington, D.C.

20. United States Forest Service. 1974. The Wood Handbook. U.S.D.A. Forest Products Laboratory. Agriculture Handbook No. 72. Washington, D.C.

21. Wangaard, F.F. 1950. The Mechanical Properties of Wood. Wiley & Sons, New York.

22. Young, H.E. and A.J. Chase. 1965. Fiber Weight and Pulping Characteristics of Logging Residues of Seven Tree Species in Maine. Tech. Bulletin No. 17. Life Sciences and Agriculture Experiment Station, University of Maine, Orono.

APPENDIX

SAMPLE COLLECTION PROCEDURES

The procedures for the collection of moisture content samples from wood subject to the Maine Weights and Measures Law, are reproduced below. These procedures were prescribed by the Maine Department of Agriculture, Bureau of Weights and Measures, relevant to Chapter 305 of the Department's inspection regulations on wood measurement.

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1. Measure butt
2. Cut 1" disc
3. Sample
   a. On butt or 4'
   b. Mid 10' 20'
   c. Back from top to 4" dia.
4. Cut wedge or half
   a. Avoid pitch pockets and knots
   b. Have bark on sample
5. Mark sample on wood with magic marker

   Example 1B, 1M, 1T, etc.
6. Wrap sample in aluminum foil, squeeze air out as much as possible without ripping foil.
7. Mark foil with number on wood
8. Put in a garbage bag
9. Repeat for each of 5 spruce and 5 fir
10. When all samples taken, squeeze air out of garbage bag and tie, put in another bag and do same.

Chapter 305 of the Maine Department of Agriculture's Inspection Regulations, entitled "Wood-Standards for Measurement", are described below. Sections not relevant to moisture content evaluation are not detailed. Effective August, 1981.

Chapter 305 WOOD MEASUREMENT

SUMMARY: Provides a mechanism for appeal to the State Sealer, weighing method, determination of moisture content, testing accuracy of butt scale tables, methods to be used for board foot and cord measure, methods to be used to determine defects in the absence of written specifications. Also requires that written measurement specifications be furnished or made available by the buyer to the seller.

1. Intent of Regulations

A. It is the understanding of the State Sealer that the sale of wood is accomplished in Maine by various methods, including weighing, cubic foot measurement, butt measurement of tree length stems, board foot measurement, cord measurement and by the piece.

B. It is the intent of the State Sealer that these regulations govern such sales at all levels of transfer where wood is measured and/or payment determined based on the measurement thereof. These regulations shall be liberally construed in order to effectuate this purpose.

2. General

Not germane

3. Weight Scale

A. Single Draft Weighing Method — Not germane

B. Weight of Load — Not germane

C. Payment — Not germane

D. Settlement of Dispute on Green Wood

In cases where a dispute arises over whether wood is green and the scale is to be completed, the following procedure will be used:

1. Declaration of Wood Not Green

a. The seller or his designated representative must declare to the buyer or his agent his opinion that the wood in the load is not green. This declaration must be made prior to the unloading of the wood at the purchase yard, as required in Section 2F

b. In the case of production cutters who will be paid on the basis of the weight when delivered to the weighing site; they must declare to their employer or his agent their opinion that the wood is not green before the wood is loaded onto the trucks for transportation to the weighing site, as required in Section 2F. Samples for moisture test will be taken after the wood has been weighed at the weighing site.

2. Weigh In at Mill or Yard

Upon arrival at the buyer's scale the load will be weighed and the weight recorded on the scale slip.

3. Selection of Samples

a. A minimum of ten, one inch discs (known further as "the sample") will be cut from stems or pieces of stems from points agreed to the buyer and seller The truck is then reweighed for the tare weight.

b. If no agreement can be reached as to the amount or location of where the sample will be taken, then the truck will be unloaded but the entire load will be kept intact and separate from the rest of the wood in the yard. The load will be clearly labeled to be in dispute with the name of buyer, seller or producer, scale slip number, and date of arrival. The truck will be weighed out for the tare weight and a copy of the scale slip will be retained on file in the scale house. The State Sealer will be notified of the disputed load as provided for in Section 2F

c. The State Sealer shall make his selection of sample points on a random basis, first selecting a minimum of ten stems and then a specific sampling point on each stem. In cases where the removal of a disc would ruin a log or bolt for processing purposes (as in saw logs bought on weight), the sample point will be moved to the nearest end of the shortest standard length given for that product in the buyer's specifications.

d. The samples will immediately be placed in a moisture proof bag and sealed after excluding excess air from the bag. A copy of the completed weight slip will be attached. Also attached to the bag will be a tag with the following information: Date sample taken, weight slip number, species of trees in the load, gross weight, tare weight, seller's name, cutter's name if applicable, buyer's name, trucker's name if different from seller and buyer, point of delivery, names and signature of parties selecting and taking the sample discs. All parties need not be present, but those present must sign the tag. All bagged samples will be stored in a cool, shaded place until they are tested.

4. Moisture Content Determination

a. The State Sealer will determine the weight of the sample taken and the oven dry weight of the sample. He will then compute the average percent moisture content on the oven dry basis.

$$\text{M.C.\%} = \frac{\text{Wgt. of wood with moisture - Wgt. of wood oven dried x 100}}{\text{Wgt. of wood oven dried.}}$$

5. Adjustments in Weight Based on Average Moisture Content

a. If the moisture content of the original samples is found to be below the lower moisture content limit, then he will compute a weight adjustment to increase the weight of that load to what it would have been at the lower limit of moisture content. If the moisture content is found to be above the upper limit, then a deduction in weight will be computed to bring the moisture content down to that upper limit.

b. If the moisture content is found to be between the two limits of the range, then it will be declared green and no adjustment made.

c. The upper and lower moisture content limits will be determined by the State Sealer after sampling the area where the wood in dispute was cut.

6. Cost of Sampling For Moisture Content

The cost of conducting moisture tests will be paid one-half by the buyer and one-half by the seller. Such tests will be conducted by a testing agency approved by the State Sealer.

4. <u>Butt Scale</u> — Not germane

5. <u>Log Scale Procedure</u> — Not germane

6. <u>Cord Scale</u> — Not germane

Table 4. Moisture Content Values for Eastern Spruce and Balsam Fir Sample Groups Collected at Various Locations in Maine

			Moisture Content (Percent)			
			Green Weight Basis		Oven Dry Basis	
Location	Season	Species	Mean	Std.Dev.	Mean	Std.Dev.
Glenwood	Summer	Fir	52.6	2.73	115.9	12.51
		Spruce	48.1	6.74	96.5	25.43
T7R5	Summer	Fir	47.9	3.75	96.6	12.28
		Spruce	48.9	4.27	98.4	16.65
Stratton	Summer	Fir	53.3	6.14	119.2	28.73
		Spruce	38.9	7.53	65.3	20.41
Wesley	Summer	Fir	55.3	3.95	126.3	19.98
		Spruce	50.1	2.12	101.7	8.55
Glenwood	Summer	Fir	53.0	1.88	116.1	9.86
		Spruce	51.6	4.54	109.6	21.23
Stratton	Summer	Fir	55.0	3.44	124.0	17.81
		Spruce	41.8	12.94	78.9	33.84
T7R5	Summer	Fir	53.9	3.76	118.9	16.63
		Spruce	48.6	2.79	96.7	10.77
Wesley	Summer	Fir	58.0	3.74	139.8	20.37
		Spruce	52.9	5.17	118.8	24.00
T7R5	Fall	Fir	55.9	2.37	129.2	12.48
		Spruce	51.7	3.41	109.5	13.88
Wesley	Winter	Fir	58.9	3.15	145.2	19.25
		Spruce	50.0	3.27	101.8	13.92
T7R5	Winter	Fir	51.4	2.61	109.1	11.39
		Spruce	48.9	2.17	97.9	9.22
Glenwood	Winter	Fir	53.7	3.29	120.1	16.09
		Spruce	49.1	1.28	98.5	5.56
Stratton	Winter	Fir	54.9	3.97	121.2	18.75
		Spruce	46.9	6.81	91.7	27.32
Medford	Fall	Fir	52.3	5.96	115.1	27.6
		Spruce	--	--	--	--
T13R7	Fall	Fir	56.4	3.19	132.4	17.42
		Spruce	53.6	0	116.6	0
Mattamis-contis	Winter	Fir	54.4	4.52	123.4	22.58
		Spruce	43.5	11.33	82.8	33.39
T6R14	Fall	Fir	49.0	7.54	102.3	28.36
		Spruce	40.5	11.72	73.9	29.73

			Moisture Content (Percent)			
			Green Weight Basis		Oven Dry Basis	
Location	Season	Species	Mean	Std.Dev.	Mean	Std.Dev.
Wesley	Summer	Fir	55.4	4.86	127.1	23.69
		Spruce	44.9	4.94	83.0	16.80
T7R5	Summer	Fir	50.8	3.62	106.7	14.15
		Spruce	45.8	3.53	85.8	11.71
Stratton	Summer	Fir	51.8	2.32	111.1	11.67
		Spruce	52.2	2.77	111.4	13.68
Glenwood	Summer	Fir	47.5	6.23	94.5	22.50
		Spruce	42.6	6.42	77.8	22.10
Unknown	Summer	Fir	57.1	3.65	135.2	19.70
		Spruce	47.2	5.07	91.2	20.40
T7R5	Summer	Fir	45.0	4.96	85.3	17.14
		Spruce	53.0	6.02	118.0	26.83
Stratton	Fall	Fir	55.6	3.83	128.6	17.75
		Spruce	51.6	3.18	108.2	13.04
T7R5	Fall	Fir	54.5	2.06	122.4	10.18
		Spruce	47.1	2.54	90.7	9.19
Glenwood	Fall	Fir	51.8	1.90	112.1	6.10
		Spruce	45.9	7.87	90.5	25.60

NOTE: Average values include midpoint values where available. Only values through T6R14 WELS (Fall) included in general analysis. Seasons designated as Winter (Jan., Feb., Mar., April.) Summer (May, June, July, Aug.) Fall (Sept., Oct., Nov., Dec).