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Title A QUANTITATIVE ANALYSIS OF LOG VOLUME CONCEPTS AND PRODUCT DERIVATIVES

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One of the most important challenges facing foresters is the development of a raw material measurement system designed to give a complete inventory of log volume and to assist in planning the complete management of log production. This paper introduces a concept of production analysis in terms of solid fiber content. The basis for the development of this concept is the measurement of logs and log production in terms of cubic feet. Total raw material accountability is maintained throughout the manufacturing process.

A mill study was undertaken to compare the results of this type of analysis with results obtained by traditional analytical methods. It was found that raw material management by this analysis can be useful in measuring the effectiveness of a production design. This analysis has further usefulness in projecting the results of proposed changes in production design. The mill study was undertaken with

the log input, primary lumber products, and sawmill residuals measured in terms of cubic feet of wood fiber. This study is referred to as treatment A in this paper. The mill study data were used to project two changes in sawing practices, treatments B and C, and the expected results are presented. The 471 logs in the study had a volume of 172,850 board feet gross, and 143,490 board feet net, Scribner scale. The logs had a volume of 24,574 cubic feet on the basis of Smalian's cubic foot rule. The volumes in the study were assigned dollar values on the basis of grade and projected on the basis of an annual cut of 30 million board feet, assuming the same variables encountered in the test material. By using the values assigned to the products in Treatment A, the total value of products was $2,802,481, based on the assumed 30 million board feet cutting schedule. The yearly product value for Treatment B was $175,769 more than Treatment A, and the yearly product value for Treatment C was $302,632 more than Treatment A. It is emphasized that any comparison of other situations with those defined in this paper must be carefully qualified.

A review of present and past log measurement systems includes a discussion of the British Hoppus Foot, and the <u>shaku</u> and <u>koku</u> units of measure used in Japan. Various cubic foot rules discussed include Newton's formula, Huber, Smalian, Rapraeger and Sorensen. The more common board foot rules include Scribner, Scribner Decimal C, Spaulding, British Columbia rule, International 1/4-inch and 1/8-inch rules, Brereton, and Doyle log rules. Measurement by displacement and weight is discussed. Efforts in comparing the economics of different measurement methods are reported.

The development of log residual products during manufacture is discussed. These present both problems in terms of disposal and opportunities for additional economic development.

A concerted effort is needed to design mensurational techniques that will act as incentives toward the most complete and profitable utilization of our forest resource. Toward this end it is suggested that those in the field of forest mensuration coordinate their efforts with the research and utilization fields toward a complete understanding of the complex problem of wood measurement.

This paper concludes that cubic analysis of log input and production outflow can better serve the needs of the forest products industry.

A QUANTITATIVE ANALYSIS OF LOG VOLUME CONCEPTS AND PRODUCT DERIVATIVES

by

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A QUANTITATIVE ANALYSIS OF LOG VOLUME CONCEPTS AND PRODUCT DERIVATIVES

INTRODUCTION

Foresters have long been faced with a challenge in the field of log measurement. As a commodity, logs are measured by a variety of methods or rules which can provide several different volumes for the same log, depending on the measurement system used. This situation is supported by a buyer-seller relationship which accepts the volumes and values involved in log transactions. A specific log rule is in general use in a particular area largely as a result of custom. Log rule characteristics are such that only with difficulty can two measurement systems be successfully compared. Sawmill, plywood and other log production items have no precise standard relationship with the raw material volumes involved.

A board foot log rule is a table, derived from a formula or diagrams, showing the estimated or calculated amount of lumber which can be sawed from logs of given length and diameter, assuming certain deductions for kerf, slab, and so forth. Of the more than 100 board foot rules devised, only a few are in wide usage today

(Belyea, 1953). It is difficult to use with confidence any log input data on the basis of a specific log scale to measure the degree of efficiency in a milling situation.

On the basis of solid fiber content of logs, little more than half of this volume is converted to primary products. One of the most important challenges facing foresters is the development of a raw material measurement system designed to give a complete inventory of log volume and to assist in planning the complete management of log manufacture.

In addition to log measure being less than exact, product measure can be deceiving. For example, one thousand board feet (1 MBF) of lumber 2" x 4" sawn full rough contains 83. 33 cubic feet of fiber, while the same amount of lumber sawn 1/8-inch scant contains 75. 68 cubic feet, and dressed to finished size contains 61. 36 cubic feet. These figures suggest substantial variations in volumes of material to be considered in a manufacturing situation.

PURPOSE

The primary purpose of this paper is to present a system of analysis whereby log volumes and log product volumes are examined on the same basis, in terms of cubic content. A method of sawmill production analysis illustrates the consequences of this type of analysis over traditional analytical methods. The purpose of the mill study was to provide data with the log input, primary lumber products, and sawmill residuals measured in terms of cubic feet of wood fiber. This study is referred to as treatment A in this paper. The mill study data were used to project two changes in sawing practices. These are referred to as treatments B and C and the projected manufacturing results are presented. The projected changes involve a thinner saw kerf in proposed treatments B and C, over the treatment A saw kerf at the edger operation. Treatment A sawing practices have all lumber full sawn to nominal dimensions, while treatments B and C project dimension lumber production as being sawn scant by 1/8-inch and 1/4-inch respectively. The solid fiber content type of analysis is submitted as an effective method in measuring the output in a given milling situation. It has real value in projecting economic results that can be expected by making certain changes in manufacturing methods.

While a sawmill production study provided the information used to develop solid content analysis, other wood using industries can find significant value in this type of appraisal. Grantham and Atherton (1959) present plywood mill study data and discuss their findings in terms of solid fiber content. They find that little more than half of the solid log content ends up as finished plywood. The remainder of the log finds its way into panel trim, sanding and compression, cores, spur trim, roundup clippings, and shrinkage.

Wood residuals are no small item in the forest industry today. Their value is measured in terms of useful raw material such as chips for pulp and shavings for hardboard manufacture. Entire new industries have been developed to utilize residual wood fiber. Additional opportunities exist for closer utilization of this material. Wood residuals pose certain problems in the fields of waste disposal and water and air pollution. Solid wood analysis can better identify the material and help in planning the optimum utilization of all components of the log.

This paper first examines the considerable volume of literature that is available on the subject of log measurement. The historical development is followed and the various types of log measure in use throughout the world are noted. The more important board foot rules and the cubic foot formulas are discussed in detail.

The applications of various log measurement systems are discussed and attention is directed toward the experience British Columbia is having in using both board foot and cubic foot measure. The progress in translating values from a board foot basis to a cubic foot basis are reported, along with the problems encountered. The consideration of defect and its effect on log value is discussed. Mention is made of the constant changes in utilization standards and the failure of certain log measurement standards to meet the demands of these changes. The significant item of wood residuals is presented, both as a challenge to develop additional values and as a problem of disposal. The increasing practice of log measurement by weight is mentioned. The future demands for log and product development on the field of mensuration is reported by several authors. A mill study completes the thesis narrative with the emphasis on solid content analysis. Total raw material accountability follows the log through manufacture to its various components. Certain operational changes are proposed and the economic consequences are developed. The summary emphasizes the value of using solid content analysis and calls for a coordinated effort directed toward the most complete and profitable utilization of our forest resource.

LOG MEASUREMENT---REVIEW OF LITERATURE

A great deal has been reported in forestry literature about the various log measurement systems developed over the years to the present time. Some of the more widely used systems are described and their actual relationship to solid content is discussed. Some of the analysis that has been directed toward log measurement in the past is presented to provide a background for the subject.

Different Types of Log Measurement

The log rules to be discussed in this paper include the Hoppus Foot, for many years used extensively in the British area of influence. The shaku and koku are two units of log measure used in Japan. The metric system of cubic measure is used in Columbia, Korea, Taiwan, Philippines, and in a number of other countries. The more common board foot rules include the Scribner and Scribner Decimal C, Spaulding, British Columbia rule, International 1/4-inch and 1/8-inch rules, the Brereton rule, and the Doyle log rule. These board foot rules are generally limited in use to North America. Various cubic foot rules include Newton's formula, Huber, Smalian, Rapraeger and Sorensen. British Columbia, Western Australia, New Zealand, East Pakistan, and the United States use the cubic foot for log volume measurement.

The Hoppus, or Quarter Girth system, was first published in 1674 by Edward Hoppus (Laver, 1951). Its use is limited exclusively to round logs and provides a measure 1.2732 times as large as the cubic foot. The system treats round logs as if they were square sectioned logs of approximately 3/14 less volume. Hoppus Foot volume is found by squaring 1/4 of the log circumference in inches and multiplying by length in feet, dividing the result by 144. There is a trend away from the use of the Hoppus system. Walker (1964) reported at the 7th Commonwealth Forestry Conference that all governments represented were urged to use "true" volumes rather than Hoppus. At this conference, tables were provided giving cubic foot volumes for logs with diameter measurements taken at the middle of the log and log lengths from 4 to 32 feet. This measurement system corresponds to the Huber cubic foot formula.

The principal units for scaling logs in Japan are reported by Zumwalt (1946). The shaku is a linear measure equivalent to 0.303 meters or 0.994 feet, and the koku is a volume measure equal to 10 cubic shaku, or 0.28 cubic meters, or 9.82 cubic feet. Logs are scaled in a manner similar to that used in the west. Volume in koku is found by squaring the small end diameter in shaku measure, multiplying by log length in shaku measure and dividing the result by 10. A conversion factor of 10 is used to convert *koku* to cubic feet, which is more convenient than using the true value of 9.82 cubic feet per *koku*.

The metric system is mentioned here since periodically efforts are made to convert the English system of feet and pounds to meters and grams. The same volume considerations with the use of a particular cubic foot formula would apply for either the metric or English systems.

The Scribner and Scribner Decimal C log rules are the most common board foot rules in use (Dilworth, 1965). The Scribner Decimal C is merely Scribner scale to the nearest 10 board feet with the last digit dropped. This diagram rule assumes 1/4-inch kerf and full-sawn 1-inch board production. The rule treats the log as a cylinder and has no definite slab allowance. This rule, as with other board foot rules, does not provide for the variables inherent in logs as well as in log manufacture. For those interested in complete raw material accountability, the Scribner diagram does not measure all the wood fiber. It is not consistent in the percentage of wood that it does measure. A greater percentage of the cubic content of small logs is developed in the form of slabs and kerf than with large logs, all other things being equal. It is unlikely there is a mill today producing the order file as diagramed in the Scribner rule, or for that matter, any board foot rule. The ratio of board feet per cubic foot in the various board foot log rules varies from less than 4 for small logs, to more than 8 for large logs.

The Spaulding log rule is sometimes called the Columbia River log rule. It is a diagram rule and closely approximates log volumes of the Scribner rule. The Spaulding rule is built around 1-inch lumber cut with 11/32-inch saw kerf instead of the 1/4-inch saw kerf with the Scribner rule.

The British Columbia log rule preceded the Smalian Cubic foot rule as the legal log rule for British Columbia. It is still used where board foot volume is desired in British Columbia. It is a formula rule that assumes 3/8-inch saw kerf and gives a smaller scale than the Scribner or Spaulding rules for the same log.

The International 1/4-inch and 1/8-inch log rules are formula rules that incorporate log taper of 1/2-inch per 4 feet in log length. Their construction also includes product shrinkage of 1/16-inch per 1-inch full sawn board, around which the rule is developed. The allowances for shrinkage and taper make these rules more accurate than any of the other formula or diagram rules in common use. The International 1/8-inch kerf rule was modified by multiplying by the factor 0.905 to give the International 1/4-inch kerf rule.

The Brereton log rule assumes no saw kerf, slabs, or edgings. It gives the volume of a log in terms of board feet, assuming 12 board feet per cubic foot. The measurements used in the formula are the average of large and small end diameters, with the length to the nearest 1 or 2 feet, depending upon the individual log measure agreement. This rule finds its use mostly in the export log trade where actual volume displacement information is desired.

The Doyle rule assumes a 4 inch loss in slabs and edgings in its formula. Mill experience indicates inconsistent overruns in mill tally as compared to log scale up to 30 inches in log diameter, and the reverse in logs larger than 30 inches. This rule finds its use mostly in the southern and eastern parts of the United States.

Board foot log rules fail to measure precisely the volume of wood in logs. Their usefulness and acceptance seems to be in providing a basis for buyer-seller relationships. The rules cannot predict accurately what any mill will recover from the log input. Variations in sawing practices, production order sizes, and over-all mill efficiency are a few of the many factors that can influence product recovery from logs. Dilworth (1965) and Husch (1963), and others provide excellent sources of information on the construction of log rules.

The cubic foot has been proposed as an alternative to replace the various board foot rules for log measurement. Where cubic measure has been used exclusively for a long time, it is accepted as a standard. However in British Columbia, where the legal log measurement was changed from the British Columbia board foot log rule to the Smalian cubic foot rule, the change is far from being accepted. Before discussing the reasons for dispute in the acceptance of this change, it is important to discuss the various methods for obtaining cubic volume of logs.

Displacement of water by immersing a log in a tank called a xylometer is the most accurate method of cubic volume determination (Husch, 1963). Volume determination by computing various basal areas as a log changes in form and plotting this information as a taper curve is another method for determining volume. These two methods are not readily adapted to measuring log volumes in commercial situations.

Newton's formula is the standard against which other cubic formulas are compared. The top, middle and base diameters are used with the log length for the determination of cubic volume in the form of a prismoid.

Smalian's formula for the volume of the frustum of a paraboloid uses the average of the cross-sectional areas at the log base and the top, and the log length. Huber's formula, using the cross-sectional area at the middle of the log, and the length, also gives the volume for the frustum of a paraboloid. Huber's and Smalian's formulas will provide identical and correct answers if the log is a true frustum of a paraboloid. A conic or neiloidic frustum log form will be underestimated using Huber's formula, and overestimated using Smalian's formula (Husch, 1963).

The Sorensen rule assumes the log tapers 1 inch per 10 feet in length. The mid-diameter is projected from the small end diameter measurement and the Huber formula is applied to determine the volume. The Rapraeger rule differs only from the Sorensen rule in allowing for 1 inch taper per 8 feet in log length (Dilworth, 1965).

All of the cubic rules mentioned have limitations in their use. Getting top and base diameters for the Smalian formula is time consuming. The mid-diameter measurement is difficult or often impossible to determine for the Huber formula. Both Rapraeger and Sorensen rules assume standard tapers, a situation that does not hold true for the many log shapes encountered. In cubic log measurement, a precise volume determination is difficult to achieve. The need for such a determination can only be weighed by the situation in which parties using log measurement find themselves. The acceptance of cubic measure, and the manner in which it is obtained, depends on the understanding among the various parties involved.

Reported Applications of Log Measurement

The log measurement systems described indicates that a variety of answers can be obtained for one situation. In British Columbia stumpage is paid to the Crown on the basis of cubic foot measure. Often that is the only cubic value used. Other contractual obligations are handled by board foot scale, taken in addition to the cubic scale. The basic problem is in reconciling dollar cubic value to corresponding board foot value. If there were an actual constant ratio, such as the assumed 6 board feet per cubic foot used for conversion ratios, there would be no problem. In actuality, there is the previously mentioned range of from less than 4 to more than 8 board feet per cubic foot. Larger diameters and shorter lengths reflect a ratio approaching the larger figure (8), while smaller diameters and longer lengths reflect a ratio approaching the smaller figure (4). Failure to recognize this situation results in distorted values and a lack of confidence by those involved.

A practical proposal for determining actual change in values from board feet to cubic feet and vice-versa is reported by Sorensen (1945). The author introduces an alignment chart showing conversion from dollars per M board feet to cents per cubic foot. He first constructed a table of board feet per cubic foot by diameter. The table includes top log diameters from 6 inches to 50 inches with the board feet per cubic foot ratio ranging from 3. 200 to 8. 052. This ratio forms line X in the alignment chart; cents per cubic foot forms line Z in the chart; and dollars per M board feet forms line Y in the chart. By using a straight edge and reading the X chart with the appropriate board feet per cubic foot ratio, connecting the other edge with the given dollars per M board feet (line Y) the intersecting Z line gives the corresponding value in cents per cubic foot. Any combination of cubic foot and board foot rules can be used in conversion. The author used the Spaulding board foot and the Sorensen cubic foot log rules for logs 32 feet long in the preparation of his data. This system takes into account both the extreme range in board foot to cubic foot ratios and the wide range in log dollar values.

Improper application of basic information is recorded. Blackerby (1938) cites the practice of some scalers in reducing gross volume by half. This was accomplished to the detriment of the seller's interests by the deduction of half the diameter. Alexander (1962) cites examples of cruises and cutouts being compared on different bases with unhappy results.

James Thompson's "Treatise on the Mensuration of Timber," was published in 1805, at Troy, New York. It is the first recorded publication on log cubic volume measure for commercial purposes. Since the Doyle rule was published in 1846, 113 rules have been devised for log measurement (Belyea, 1953). Five classes of examples are:

1. Log rules based on mathematical formulas: Doyle, International, and Vermont.

2. Log rules based on a diagram: Scribner, Spaulding, and Drew.

3. Log rules based on mill studies: Massachusetts, Baxter, and Saco.

4. Combination: Doyle to 28 inches in log diameter and Scribner above 28 inches.

5. Log rules from standards: Adirondack Standard of 13 feet by 19 inches, and Saranac Standard of 13 feet by 22 inches. Logs of various sizes are given values in relation to the standard in use. Great Britain has a "standard" unit as an expression of board feet.

Belyea goes on to list 115 rules and their classification according to the 5 categories.

The timber processing industry is the only American business that measures raw material in terms of its final product. In North America trees have been developed into boards for 330 years but measured in terms of board feet for 130 years, according to Belyea and Sheldon (1938). Early manufacture produced boards and planks sold by the running foot. Standards were then set up by dimensions of products shipped from certain localities. Boards were sold by the "square" measuring 10 feet by 10 feet. In large quantities boards sold as 10 squares, or 1,000 board feet, and this has been handed down to present times.

It is interesting to note the backgrounds of some of the authors of board foot log rules. The Glens Falls Standard was a product of Norman Fox, a politician, and Leverett Dimick, a school teacher. The Doyle rule was devised by Edward Doyle, a small town merchant. The Scribner rule was devised by J. M. Scribner, a country clergyman whose hobby was mathematics. Judson Clarke was a college professor and the only one with any forestry training. His efforts produced the International log rule, the only board foot rule incorporating log taper and lumber shrinkage in its construction.

A sound description of the function of any measurement and a summary of some of the major problems associated with board foot systems is provided by Belyea and Sheldon (1938, p. 965-968).

> The purpose of measuring any material or product is to determine its exact quantity so as to adjudicate fairly the exchange between the buyer and seller. The sense of satisfaction to both parties of the contract is best attained when such measurement is standardized, and it is only then that the quantity, value, performance and service can be adequately gauged.

A thousand board feet log scale is, after all, a meaningless thing. To begin with, it has no absolute volume. It is larger with some log rules than it is with others. It varies from day to day according to the log run. It varies with the range of diameters and log lengths, and also with their relative distribution within such ranges. It varies with the relative skill of the scalers, and it varies with the method of scaling. Large logs produce one measure of a thousand board feet and small logs another. It has no meaning whatsoever when applied to veneer logs, pulpwood, railroad ties, and mine timbers.

Cubic measure is used in Central Europe, France, Switzerland, Scandinavia, South America, South Africa, in parts of the Far East, and in Australia. Arguments in its favor:

1. An absolute measure, independent of standards of utilization at all times (sic).

2. Precise value--lends itself to standard accounting methods, produces much truer picture of operating costs than does the variable board foot.

3. Avoids confusion and disparity between log scale and mill scale.

4. Its use necessitates no assumption as to products, efficiency or intensity of manufacture, necessity of a bonus for inefficient or badly managed manufacturing set-ups.

5. Cubic content more easily managed. Offers exact method of culling defective material.

6. Conversion from cubic feet to unit of measure appropriate to each manufacturing plant done simply, without uncertainty.

7. No difficulty in going from cubic feet to lumber tally. Results in more absolute and authoritative figures.

8. Provides a reliable milling efficiency--the yield of derivable product per cubic foot of raw material.

9. Banish forever that surreptituous hang dog of the lumber industry and the perennial cause of so many of its disputes--overrun. With the cubic foot there will be no overrun and there will be no underrun.

A difficulty is the antipathy of lumbermen toward any precise measurement of their raw material, inertia of the public, even among log sellers themselves, to any such radical change.

It is interesting to note parallel arguments given by Munger (1929) to demonstrate that cubic foot measurement would put log and stumpage merchandising on a more stable and confident basis.

While these and other arguments can be very persuasive in presenting a strong case on the weaknesses of the board foot scale or on the strong points of cubic scaling, caution must be used in being definitive and specific as to what a particular system or formula will or will not do.

Perry (1950), in discussing the measurement of veneer logs, suggests no changes be undertaken. Tradition is given as the reason for recommending no changes. Ker and Smith (1957) present an article on trends in timber measurement in Canada. An excellent bibliography is available for further reference.

The financial involvement in the non productive process of log measure can be substantial. Buckingham (1961) recommends the number of measurements be reduced and such measurements be made in units indicating utilization potential. Other suggestions include the sale of stumpage on lump-sum basis to avoid remeasurement, as well as sample measuring of wood with computer compilation.

Alexander (1962) cites the object of measuring timber as providing an estimate of the amount, kind, and value of end product that will be produced from that material. It can be debated that this concept of log measurement is rather narrow. It is suggested that log measurement be defined as a tool to be used in the process of determining the most valuable use for a log having certain size and value characteristics.

Any new measurement standards must have a thread of relationship to old standards for facilitating change. The listing of the United States Forest Resource in International 1/4-inch volume and in cubic foot volume gives such a relationship. The measure of log volume has been tied to forestry problems in the Douglas fir region by Hoffman (1940, p. 3):

> One of the chief obstacles to successful long term industry is the very incomplete use of the raw material, resulting from transport distances, and lack of by-product manufacture. Intensive research to convert more of the grown tree into products of commercial value is one of the things most needed to establish sustained-yield forestry on a general scale in the Pacific Northwest. Production and value-recovery studies are suggested in all forms of wood using industries.

Hoffman (1941) also cites the use of International rule in yield predictions and the use of the cubic foot as growing in importance in the field of log measure.

An interesting classification of log values is developed by E. J. Brigham of Weyerhaeuser Company (ibid). The basis is the classification of the first two logs in the tree for the ultimate grading of the entire tree. These grades are called clear, medium, rough, and defective logs, respectively.

Herrick (1940) defends the Doyle rule as conducive to better forest practices because of the undesirability of early liquidation of small logs. Moore (1943) further defends the use of the rule in New Jersey. The application of the Doyle rule in this area is to take the diameter in the middle of the log, inside the bark. The author reports good correlation of this method of measurement as compared with International 1/4-inch role taken by conventional small end measure.

This middle measurement Doyle application is well established in New Jersey.

Merrill (1945) introduces a device called the B-10 tree stick which measures basal area from direct readings. The measurement scale gives readings in tenths of square feet for each inch of diameter. The top edge of the stick is the usual Biltmore scale. Adjoining this are the B-10 numbers for each inch of diameter expressed in tenths of square feet, ten times. Examples of use are given in several situations. This introduces no new concepts in timber measurement, only bypassing diameter measurements in inches. This direct basal area reading reduces one source of human error in providing direct conversion from basal area to selected volume tables. Further work in this field is reported by Minor (1961).

Direct comparisons of the differences encountered in board foot volume tables are available from several sources (Mesavage, 1947), (Munns, Hoerner, and Clements, 1949), and (Hornibrook, et al., 1950). Schumacher and Jones (1940) describe a method of developing empirical log rules based on the production of specific sawmills. An algebraic expression is derived according to the method of least squares, from direct measurement of sawlogs and lumber manufacture. The authors utilize sampling units of log consumption and lumber production by working day. Detailed log and lumber tally for all production is reported as superfluous for the purpose. Weighted observations of data is treated in detail. Lodevick (1947) reports board feet lumber production compared with both board feet log scale Scribner and cubic feet Sorensen. The author concludes the number of board feet of lumber per board foot Scribner log scale decreases in general with an increase in log size; the number of board feet per cubic foot Sorensen increases with log size. The effect of tree taper on Scribner scale is discussed by Staebler (1953). A comparison is made between the use of Scribner and the International 1/4-inch rules. The article includes tables for the analysis of effects of specific conditions.

There is evidence that volume tables are modified to include volumes permitted by grade specifications. Grosenbaugh (1949) incorporates allowances for short narrow boards permitted lumber grade specifications for eastern red cedar by adjusting International 1/4-inch rule, assuming that boards 1 inch by 2 inches by 2 feet are merchantable.

The Department of Agriculture lists several authorized log rules for the measurement of Forest Service timber. These include: Scribner Decimal C; International 1/4-inch; Forest Service International 1/4-inch decimal log rule; or the cubic volume rule authorized under regulations S-15 for the uniform scale of saw timber. For Forest Service use, the International 1/4-inch rule is rounded to the nearest 5 board feet. The Forest Service International 1/4-inch decimal rule is rounded to the nearest 10 board feet. The Huber cubic formula is the authorized cubic rule.

Ramdial (1962) reports the successful use of basal area plotted with height in determining the cubic volume of a log or tree. He accomplishes this analysis by plotting diameter data at strategic places converted to basal area with log or tree length information. A direct ratio is achieved by projecting the largest basal area dimension for the length of the portion of the tree to be measured, thus forming a cylinder with given dimensions. A planimeter measures the area ratio of the cylinder in square inches and the area of the plotted log data in square inches. This provides the necessary factors for a simple ratio situation with the result being the cubic content of the log or tree. The author also discusses Spurr's and Reineke's methods of graphically illustrating tree volumes. The graphical method of volume presentation has significant value in the analysis of individual tree and log situations that formulas do not always provide.

In presenting the evolution of log scale in British Columbia, Orchard (1953) cites "horrible examples" of full length scale of a tree as compared with the scale of components of a tree. He then goes on to describe the application of the Smalian cubic foot rule as the British Columbia scale. Ker (1961) gives further examples of tree length versus short log multiple scale for the same tree. Empirical data are presented to show the lack of an accurate lumber recovery index that can be expected from the board foot log rule. The Smalian cubic foot rule was adopted for Interior timber in British Columbia in 1948. Butt flare must be accurately reduced to avoid over-scaling the log. The flare estimated in a study accounted for 1/6 of the butt diameter and was considered to be the most difficult physical obstacle to overcome in obtaining representative volume. Further comments by the author regarding human scale computation showed the chances for human error are great and can undo accurate field measurements.

Wood (1964) describes the operational use of cubic scale in the Quesnel, British Columbia area by Weldwood of Canada, Limited. The list of conclusions is presented in toto as a clear summation of factors to be considered in any operational application of log volume determination:

1. Log scaling is a measuring function. Its prime purpose is to determine as accurately as possible the quantity of wood material. The cubic scale estimates the content of the

log in terms of total wood volume regardless of end product. For this reason it is a better measure of volume than board foot rules which pre-suppose some specific product (sawn lumber).

2. Once the cubic scale is determined, the yield of products is dependent on the size and grade of log and the method and efficiency of the manufacturing process. Because it is relatively constant for log size, the original scale has little or no effect on that yield. The factor of the original measurement itself therefore, is largely removed from the volume of resultant products.

3. A knowledge of yields of products from various types of logs is still essential with the cubic scale. The amounts of these products is not dependent on the scaling method or rule, however.

4. The cubic volume for tree length as used in British Columbia results in an inflated volume compared to log length cubic scale. This is due to a slightly erroneous formula and a strong tendency of scalers to underestimate flare.

5. Problems of mechanics of scaling, inventory control, location of scaling are generally not dependent on the scaling method. Control of inventory shrinkage is probably easier because scaled volume does not change appreciably with further bucking of the logs (tree length excepted).

6. Scaling costs are higher by up to 25 percent with cubic scaling because more measuring is required.

7. Scale by weight presents the possibility of obtaining accurate estimates of net cubic content at a much lower cost and in a more useful form.

8. The entire scaling operation is a non productive function which affects neither the value of the log nor its cost. Therefore, it is possible that a

better method of timber cut recording exists. It would seem that a "lump sum" or "total cruise" type of timber sale disposal holds promise. This would require highly accurate cruising but once the sale is made, the scaling practice would have no effect on utilization of the timber (as it does now). The degree and type of scaling would then be in its true perspective of simple recording. The amount of money spent on this function would then be dependent only on the accuracy of the measurement desired.

9. The experience of Weldwood of Canada is that the use of the cubic scale is practical and desirable.

Quoting from the introduction to "Conversion Factors for Pacific Northwest Forest Products," (Institute of Forest Products, 1957) indicates the specific nature of any log volume analysis:

> The conversion factors contained in this publication were secured from reliable sources throughout the Pacific Northwest and apply to the commercial tree species of this region, and to regional utilization methods and equipment. They are largely the result of actual conversion of forest materials from one unit to another by manufactures.
>
> It must be definitely understood, however, that conversion figures which are accurate in one manufacturing plant may not apply exactly to another, due to divergence in methods, equipment and raw materials. For instance, a paper-pulp plant which uses one method of debarking, may obtain materially more or less pulp from a standard cord of wood or from a given unit of log measure, than a plant which debarks by a different method.
>
> Therefore, in the case of factors which show a definite divergence among our many informants,

> we may choose to give several figures which indicate such variation, rather than to strike an average which would have little practical application.
>
> It is fully realized that presentation of these conversion factors in tabular form, giving a single average figure for each conversion, would be much simpler and quicker for reference use. It would, however, ignore the variability of wood structure and of wood-utilization methods to the point of inaccuracy.

There are several international attempts to equate the several volume considerations applicable to the world trade in timber. Ferguson and Hellinga (1941) present a Dutch analysis. Almqvist and Hallmans (1946) present a Swedish discussion on different methods of scaling round timber. Michailoff (1944) has a German paper on the accuracy of different formulas for sectional volume determination.

Defect Considerations

Logs more often than not contain varying amounts of defect. This defective material can change the recovery from a log depending on the amount or type. Defect can be in the form of fiber breakdown from disease, imperfect log form, fiber separation as in frost or pitch shake, excessive roughness, twisted fiber alignment, mechanical damage and other causes. A comprehensive analysis of timber defect is provided by Dilworth (1965). A graphic presentation shows types of defect and the effect on gross volume. The traditional handling of defect and the rules involved for both board foot and cubic foot measurement systems is explained.

One of the pioneers in defect analysis is Kimmey (1956). In his thorough analysis on cull factors for Sitka spruce, western hemlock, and western redcedar, he defines the types and extent to which usable volume is affected. Kimmey and Hornibrook (1952) present cull and breakage factors for redwood. Defect studies have been undertaken by Kimmey for many other species in different parts of the country.

A new approach is presented by Smith (1963) in the consideration of handling defect. Instead of deductions in terms of diameter or length reduction, it is proposed that defect be identified by type. Fiber separation or roughness that would not affect use for pulping would be identified as such, and wood that was in various stages of decay would be identified as to amount and degree of decay, in keeping with the utilization potential of the material. The full component value and volume would be recorded in relation to its highest and best use.

Changing Utilization Standards

Change in the degree of utilization--in response to changing wood demand--has evolved continuously over the past 20 years (Grantham, 1965). It is not uncommon for operations to relog areas four or five times over a period of years as standards of utilization change. There are other pressures in addition to market demand that are changing standards of woods utilization. These include public pressures, conservation considerations with regard to possible flood damage, and the retention of soil nutritive values through the decrease in the need to burn logging residue. One of the main considerations in any attempt to design a complete raw material utilization scheme is the proper identification of values. Barnes (1945) reports on this problem with special reference to small logs. Such logs produce more finished product per M board feet than do large logs, and when sales are made on the board foot basis at a flat rate, the small log does not bring its real value. A cost table is presented that shows yarding to pond costs for various size logs on a board foot and cubic foot basis. British Columbia Chief Forester C. D. Orchard (1953) discusses cubic scale in Canada and its application in equitably evaluating logging salvage.

Another consideration is actual practices in utilization versus theoretical volume table prediction. One study of logging in second growth fir on the Siuslaw National Forest (Minore and Gedney, 1960) showed a smaller utilized top than the 40 percent d. b. h. assumption made in Girard's form class tables in the area sampled.

Ker (1961) uses three ratios in analyzing results from a British Columbia mill study:

$$\text{Lumber Recovery Factor (LRF)} = \frac{\text{board feet lumber tally}}{\text{cubic feet log scale}}$$

$$\text{Scale Ratio (SR)} = \frac{\text{board feet log scale}}{\text{cubic feet log scale}}$$

$$\text{Overrun Ratio (OR)} = \frac{\text{board feet lumber tally}}{\text{board feet log scale}}$$

Factors are cataloged to show how these ratios are increased or decreased. These include sawing practices; scant sawing; log size; log taper; long or short logs; and defect. Lumber recovery factor is always a variable, depending upon the factors mentioned above. This provides additional evidence to show the need for very definitive factors in log scale and product discussions.

The Pacific Logging Congress (Yoder et al., 1963) considered the subject of transition from board foot to cubic foot measure. A great deal of the discussion was concerned with the need to modernize our measurement systems and utilization practices. Modern business techniques were cited among other reasons for this consideration.

Problems connected with the implimentation of cubic scale in British Columbia were cited by John Hampton.

Carpenter (1950) records the amount of chippable waste at southern pine sawmills. The diameter of logs was cited as the main factor governing waste produced. The chippable waste ranges from about 0.8 cords per M board feet lumber tally at 8 inch diameter log group and drops to about 0.3 cords per M board feet lumber tally at 17 inch diameter class and then levels off. Mill classes; the ratio of log intake by diameter classes; and the specific log scale used are all factors in determining ratios of utilization.

A further consideration in any discussion on utilization is the increasing demand for forest products and the constant decrease in the number of acres available for timber growth. Power lines, roads, and reservoirs are cited as reasons for this situation(Gedney, 1963). This focuses the search for additional raw material from forested acres and from mill residuals (Corder, 1964). Size classes, minor species, and small cuttings, as well as additional defective material are generating new interest. Since less than half of the log volume (including bark) finds its way into finished plywood and lumber products, this source of residuals provides a vast opportunity for development. The number of railroad chip cars and chip trucks is evidence that progress is being made in this area of utilization.

Sawdust utilization is being tried by mills with processes to assimilate this material, providing absorbent quality in paper towling (Bryant, 1965). Grantham and Atherton (1959) present the disposition of products, residuals, and losses in percentage by volume for No. 2 peelers and special mill logs:

	No. 2 Peeler	Special Mill
Finished plywood	56.7	53.1
Panel trim	8.8	8.3
Sanding and compression	6.3	5.9
Cores	4.3	5.8
Spur trim	2.7	2.8
Roundup clippings	13.7	17.1
Shrinkage	7.5	7.0
TOTAL	100.0	100.0

The past 10 years has brought little difference in the ratio of residue to the amount of lumber or plywood produced from a log (Boubel, Thornburgh, and Pavelka, 1965). However, by-product markets have utilized much of the coarse residue previously burned in teepee-shaped waste burners. This has resulted in the remaining residue having greater compaction in the burner and subsequently poorer combustion. This situation has brought increased concern over air pollution and the long range effects on society. The magnitude of this situation is partially defined by the following quote (ibid., pp. 20-21).

> Wood residue consumed by combustion at the mill site amounted to a large quantity of material in the valley. Tabulation at the mills indicated the following amounts to

the waste burners: 431 tons of sawdust per day, 16 tons of sander dust per day, 168 tons of shavings per day, 552 tons of bark per day, and 689 tons of rough stock, such as slabs, edgings, and trim, per day for a total of 1856 tons each working day. If this were placed in railroad chip cars, it would take about 75 cars per day to remove the waste from the mill site. This amount is now being consumed by the teepee burners of the valley. In addition, the mills are burning about 300 tons per day in furnaces to generate steam for kilns or electrical power for mill use.

The particulate emissions charged to the lumber industry varies from 90 to 96 percent of the total released from all sources. It is obvious that anything that could reduce the emissions from the lumber industry would result in nearly a direct equal improvement in the air quality of the valley.

Further statistics on wood waste volume are provided by an 8 county survey of lumber and plywood residues of Western Oregon (Pacific Power and Light, 1965). The figures are averages by class of material in terms of dry tons per thousand board feet of logs Scribner Scale (MBFLS).

Type	Source	Amount
Coarse solid wood residues acceptable pulp chips	Sawmills	0.52 dry tons
Coarse solid wood residues acceptable pulp chips	Veneer Plants	0.88 dry tons
Shavings	Sawmills	0.24 dry tons
Sawdust	Sawmills	0.33 dry tons
Dry plywood trim	Veneer Plants	0.26 dry tons
Bark	Both	0.34 dry tons

The need for research and development in new products and markets for wood residues justifies more effort in these directions than has been expended in the past. New techniques need to be applied to old ideas. Previously proposed products need to be re-evaluated in the light of economic and market change. An aggressive approach would consider the needs of growing world markets. The demand for forest products and the shortage of timber supply in other countries creates a potentially large export market.

A word is in order concerning the possibility of change in standard sizes of products. Periodically different sources propose new size standards, for various reasons (Smith and Wood, 1964). Very often reasons other than technical are deciding factors for or against a proposed change. Solid content analysis of raw material provides a method to evaluate the effect on manufacturing and utilization changes. Industry must be informed of the effect of new standards resulting from new ideas as well as from new markets.

The Measurement of Logs by Weight or Displacement

As absolute commodity measurements, the units of weight or volume displacement have much to offer. These units are widely used, easily understood, easily determined and have the confidence of buyer and seller. Because of quality and defect considerations, displacement is pretty much limited to the measurement of pulpwood (Pulpwood, 1946). More than 80 cords an hour have been measured by displacing 4 foot pulpwood lengths in metal cages in water. The literature does not indicate wide usage of this method.

The use of weight, however, is more widely reported. Pratt (1939) presents results of sample weighing of loads of logs by using scale stick reading directly in log weights by diameter and length. Results showed 97 percent of log loads estimated by this method were within 10 percent of the actual log weights. Martin and Simard (1959) made several studies on different species, log lengths, and operating conditions. They reported the mean weight, wood and bark, per cunit (100 cubic feet of wood) was 5,634 pounds, with a plus or minus standard deviation of 539 pounds per cunit. The standard error of the mean was 23 pounds and the confidence limits at the 5 percent level were plus or minus 45 pounds. The authors further report: (ibid., p. 149-150)

> Wood measurement is essentially a service function of the industry, and as such, it must be adapted to the operating technique employed, provided internal controls are effected. There is some concern that traditional methods of application of volume measurement, and of volume as a basis, cannot adequately serve operating methods in effect now or in the future.
>
> Published literature indicates many variables affecting the weight of wood. The Wood Measurement

> Committee Report previously referred to indicates that the specific gravity of wood shows some variation from one district to another for the same species and that the rate of growth of the trees is directly correlated with weight.

Siegel and Row (1962) provide a local study of loblolly and shortleaf pine logs. They relate log weights to diameter and length as well as to board foot volume by Doyle, Scribner, and International rules. Other examples include weight as a measurement for raw material control of saw log volume (Guttenberg, Fassnacht and Siegel, 1960). The authors even go so far to show how the overrun of the Doyle rule can be preserved for the benefit of those mill managers who wish to retain this form of management. Some of the disadvantages of weight scaling are presented by Page (1961). There is a failure to establish price differentials for logs of different sizes and weights. Whole tree weight predictions must deal with variations in weight per cubic foot for different parts of the tree. The author states that weight transactions are less accurate for individual saw logs because of the wide range in lumber yield for the same weight of logs of different sizes. Measurement by weight has the advantage of total raw material accountability. Board foot log scales have been shown to give various yields for the same measurements for different sizes of logs. The use of weight for log measurement will continue to receive much attention. The physical and cost factors involved in conventional volume measurement of logs makes the simplicity and economy of weight measurement very attractive.

Changing Concepts in the Business of Converting Logs to Forest Products

A prime consideration in any field of forestry today is change. The capacity of modern business machines to compute solutions to a wide variety of problems makes it possible as never before to plan for the future growth and harvest of the timber resource. The traditional use of basic volume data is no longer completely applicable for today's and tomorrow's problems.

Honer and Sayn-Wittgenstein (1963) list replies to a poll of the Forest Mensuration Group on current mensuration problems. These subjects include growth and yield, volume tables, measuring instruments, statistics, computers and data processing, forest surveys, site evaluation, education, multi-mensuration, the application of the metric system, and forest regulation. Young (1965) discusses leadership, communications, and costs as being factors to be reckoned with in coordinating forest mensuration development.

In discussing log and tree quality, Lane (1962) in his conclusions states:

> The need for refinement in grading logs and trees is increasing, particularly as the forest industries become

> more integrated and institute more quality control with respect to their use of the timber resource. The benefits to be derived from more precise grading also increase as the need increases.
>
> Many people in industry are, or will be, involved in systems-engineering and operations-research to optimize return from production and marketing efforts. The analytical tools used, such as linear programming, are capable of accurate predictions, but their accuracy can be no better than the data fed into them. In other words, the potential of these new techniques can be realized only if realistic parameters, including dependable tree or log grade information, can be provided.
>
> The kind of log and tree grades required to meet this need are not generally available. If wood is to expand or even maintain its position as a desired product, the people who grow it and process it must have adequate timber quality standards to guide their operations.
>
> It is essential for industry and the public agencies--State, educational, and Federal--to collaborate in an accelerated research program to develop scientific log and tree grades that can adequately implement the advancement being made in product technology.

Several authors have made important contributions in the field of forest growth and operational research. Grosenbaugh (1958) presents a machine program designed to help those needing to fit any type of collected data into a formula. The application of linear programming to farm forestry problems is discussed by Coutu and Ellertsen (1960). Gould and O'Regan (1965) as well as Duerr (1960 and 1964) develop a basic business background in economic considerations plus an explanation of the innovation of techniques of simulation and linear programming . Row (1963) provides a computer program written in Fortran for the determination of rates of return on forest investments. Leak, (1964) in presenting an example of linear programming in estimating maximum allowable timber yields, concludes that restrictions set upon an analysis of this type must be carefully planned and specified to help insure a realistic and practical solution. In discussing linear regression methods, Freese (1964) says that these methods have been used by people who do not always fully understand the mechanisim and its limitations.

Row, Fasick, and Guttenberg (1965) discuss at length the factors involved in deciding how to saw various classes of logs. These factors include the amount, quality, and cost of timber; possible sawing patterns and their yields; machine time available on the mill equipment; and sales requirements. Electronic data processing is used in simultaneously analyzing these variables. The authors cite the heterogeneous nature of the log inputs, the large number of items produced, and the difficulties in obtaining suitable data on yields and time requirements, as reasons why linear programming techniques have been applied less often to sawmilling than to other industries.

Marty (1964) presents a formal method of analysis in the determination of investment problems and goals as applied to forestry. In choosing from among several alternatives, he recommends (1), developing a system for predicting the outcome of each alternative; (2), setting up formal comparisons of alternatives; and (3), posing the question of choice for the investor among the alternatives left. This is a good basic study of the analytic process involved in decision making. It concludes that there is no easy application of this method for the solving of problems. In a further discussion of the items of risk and uncertainty, Flora (1964) differentiates between the two items and provides a procedure for analyzing alternatives in forestry situations. He concludes that the factor of uncertainty can be ignored if certain assumptions are plausible and if the decisions are between forestry investments whose returns will mature about equally distant in time. The author cites 25 references for further background in this field.

The concepts of change and analysis are briefly presented as a foundation for further study in the field of forest growth and harvest. Enough evidence has been presented in this paper to show that we forest managers have an opportunity to achieve further utilization and profitability from our forest resource.

In this field of log volume concepts, Smith (1963, p. 23) states;

> It is not known what products will be invented or manufactured in the foreseeable future. It is not known

what competitive pressures will challenge us. The complete measurement of raw material should provide the identification of the component parts and their respective values. Whatever opportunity is opened to wood raw material, a complete measurement and quality standard (is) available.

THE MILL STUDY

A mill study provided operational data from which certain conclusions were drawn. Since this paper is concerned with complete raw material accountability, the study volumes are reported for primary lumber production and various classes of residuals. These component volumes were related back to the original log volumes. The cubic foot was the common denominator by which raw material input and production output was expressed. Lumber production was expressed in terms of cubic feet on the basis of sawing practices in use at the mill, in this case full sawn to nominal size and referred to as Treatment A.

The production analysis developed in Treatment A was used as a basis for making certain assumptions in manufacturing changes, referred to as Treatments B and C. The expected results were calculated and compared with the original Treatment A. The cubic foot as a common base for comparing the efficiency of manufacturing alternatives promises to be of significant value.

Milling Practices for Treatment A

For business reasons, the exact mill location is not mentioned. The mill cuts primarily second-growth Douglas-fir and occasional old-growth from west of the Cascades. Caution is urged in using these data for other situations without first checking the variance in conditions with those defined in this study.

The study logs were processed in a mill with a 7-foot band saw head-rig having 3/16-inch saw kerf. The 8" x 60" edger had 3/8-inch saw kerf. The 62-inch vertical band resaw had 5/32-inch saw kerf. A 26-foot gang trimmer completed the sawing arrangement. Sawing practices were consistent with the highest grade recovery to be obtained from the logs involved.

Milling Practices for Treatments B and C

There are two basic changes in milling practices for Treatments B and C as compared with Treatment A. The saw kerf at the edger is 7/32-inch for B and C, as compared with 3/8-inch for Treatment A. Certain production items, shown in Table 2, are assumed to be sawn 1/8-inch scant in Treatment B, and 1/4-inch scant in Treatment C. No other changes are contemplated and as with Treatment A, the total raw material accountability is calculated for Treatments B and C.

Mill Study Data

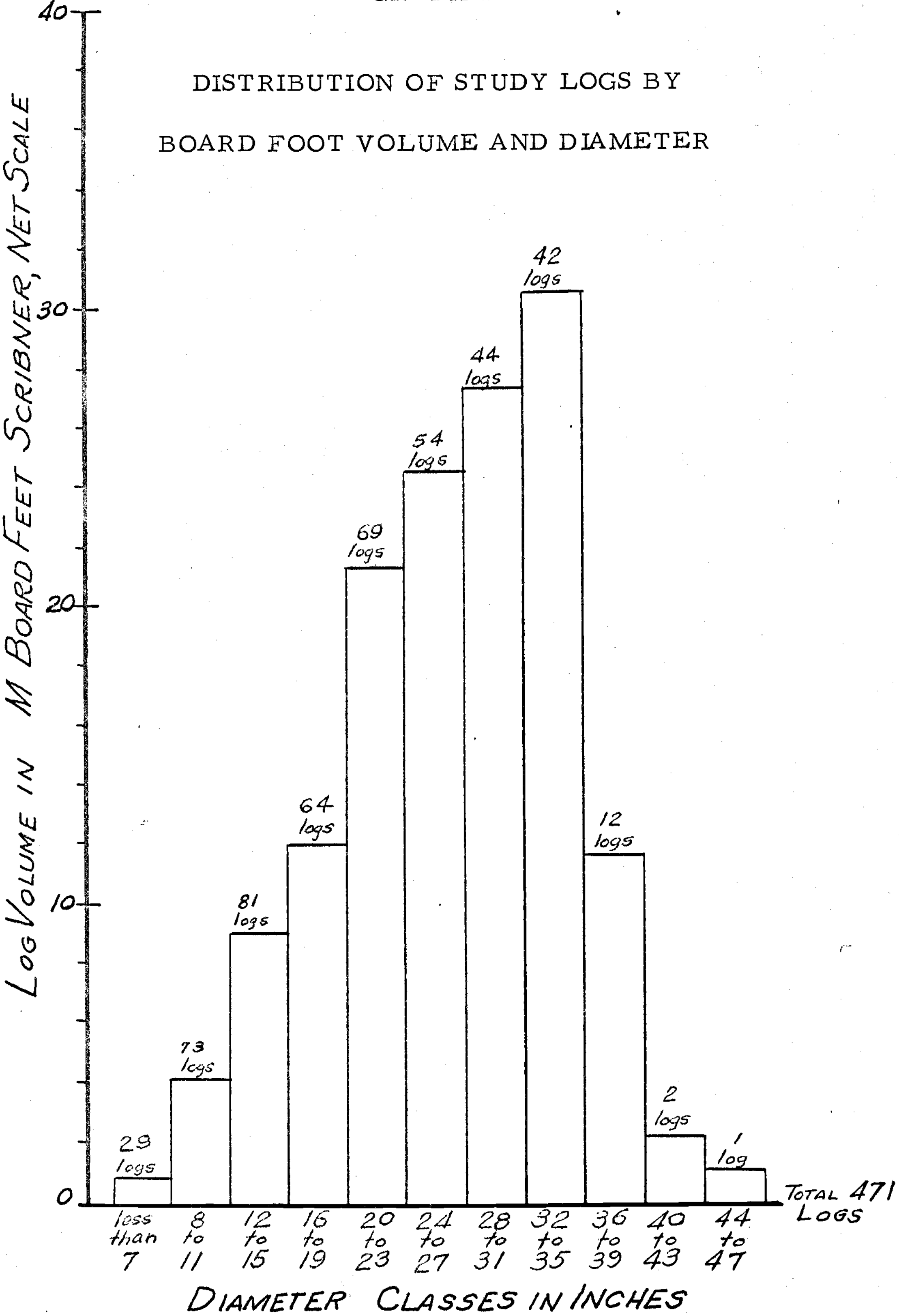
Detailed log and production data were obtained from 471 logs ranging in size from 5 inches to 45 inches in diameter. Both ends of the logs were measured using Smalian's cubic foot rule, and the Scribner board foot rule to obtain gross and net scales. All log measurements were taken inside the bark. The log grades and board foot volume information were based on the instructions set forth in the Official Log Scaling and Grading Rules of the Columbia River Log Scaling and Grading Bureau (1965). The procedures for recording log and lumber volumes parallel closely the instructions set forth by Grantham (1959). Graph Number 2 gives a breakdown of the logs by grade. Clear, shop and construction grades were tallied according to definitions in West Coast Lumbermen's Association (1956). Table Number 2 gives a detailed breakdown of the 19 percent clear and shop items and the 81 percent construction lumber and timbers.

The log scale input was 172,850 board feet gross, and 143,490 board feet net, Scribner scale, for a fall down of 17 percent. The logs had a volume of 24,574 cubic feet. Graph Number 1 shows the comparative number of logs producing various volume segments of the mill study. The range in production of lumber, sawdust and chip material is indicated by Table Number 1 for Treatment A. The lumber production tally of 173,119 board feet was 121 percent of the 143,490 board feet net log scale. This study data is analyzed in the next section to test the practical application of cubic content analysis and total raw material accountability.

GRAPH 1

DISTRIBUTION OF STUDY LOGS BY

BOARD FOOT VOLUME AND DIAMETER



GRAPH 2

PERCENTAGE LOG INPUT BY LOG GRADE

Board foot net log scale

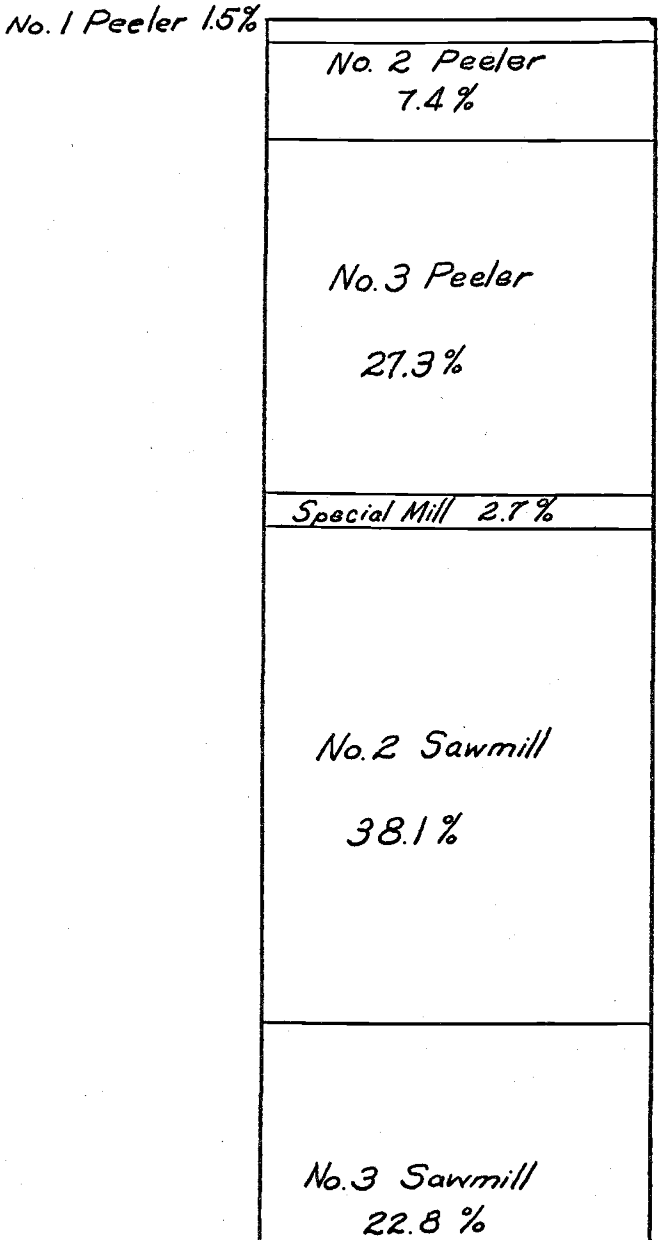


TABLE 1

CUBIC FOOT VOLUME OF STUDY LOGS AND DERIVED PRODUCTS FOR TREATMENT "A"

Diameter Range in Inches	Number Of Logs	Total Cubic Foot Volume of Logs and Products			
		Logs	Lumber	Sawdust	Chips
Less than 7	29	218 (100)*	102 (47)*	20 (9)*	96 (44)*
8 to 11	73	926 (100)*	490 (53)*	96 (10)*	340 (37)*
12 to 15	81	1,795 (100)*	1,010 (56)*	175 (10)*	610 (34)*
16 to 19	64	2,230 (100)*	1,326 (59)*	212 (10)*	692 (31)*
20 to 23	69	3,573 (100)*	2,306 (65)*	363 (10)*	904 (25)*
24 to 27	54	3,991 (100)*	2,513 (63)*	401 (10)*	1,077 (27)*
28 to 31	44	4,316 (100)*	2,674 (62)*	443 (10)*	1,199 (28)*
32 to 35	42	4,894 (100)*	2,932 (60)*	500 (10)*	1,462 (30)*
36 to 39	12	2,068 (100)*	1,198 (58)*	207 (10)*	663 (32)*
40 to 43	2	357 (100)*	230 (64)*	39 (11)*	88 (25)*
44 to 47	1	206 (100)*	77 (37)*	14 (7)*	115 (56)*
TOTALS	471	24,574 (100)*	14,858 (60)*	2,470 (10)*	7,246 (30)*

* Percent of Total Log Volume

TABLE 2

PRODUCTION FROM TREATMENT "A" SAWING PRACTICES

Nominal Size	Production By Grades			
	Clear and Shop		Construction	
	Board Feet	Percent	Board Feet	Percent
1" x 4"	1,721	1.0	5,428*	3.1
1" x 6"	925	.5	4,459*	2.6
1" x 8"	391	.2	1,192*	.7
1" x 10"	-		-	
1" x 12"	332	.2	-	
2" x 4"	763	.5	38,850*	22.4
2" x 6"	25,698	14.8	17,000*	9.8
2" x 8"	737	.5	12,251*	7.1
2" x 10"	603	.3	11,884*	6.9
2" x 12"	1,664	1.0	9,528*	5.5
4" x 4"	-		19,987*	11.5
4" x 6"	-		6,275	3.6
4" x 8"	-		7,109	4.2
4" x 10"	-		4,994	2.8
4" x 12"	-		-	
5" x 12"	-		1,328	.8
TOTALS	32,834	19.0	140,285	81.0

Total production 173,119 board feet.

*Those production items used in Treatments B and C, involving changes in rough lumber sizes.

Interpretation of Mill Study Data

As wood changes during the milling process from its original round log form into its final finished product form, some interesting observations are noted. Illustration Number 1 suggests a considerably larger cross sectional area including saw kerf than the cross sectional area of the final dressed board. Efficiency would dictate getting the dimensions from saw kerf ℄ to saw kerf ℄ as closely as possible to the dimensions of the finished product.

Various tables are found in the Appendix for converting inches and fractions commonly used in the wood industry to decimal foot equivalents. The fractional foot equivalents simplify the construction of tables for cubic foot volumes per MBF for different lumber sizes and sawing practices. The Treatment A sawing practices result in developed volumes calculated from saw kerf ℄ to adjacent saw kerf ℄ ranging from 106.7 cubic feet per MBF for 1" x 4" lumber; to 95.0 cubic feet per MBF for 4" x 4" lumber. Table Number 3 gives a detailed breakdown for all lumber sizes involved for Treatments A, B and C. Table Number 13 lists the cubic volumes figured for the final dressed sizes and range from 58.9 cubic feet per MBF for 1" x 4" lumber to 68.4 cubic feet per MBF for 4" x 4" lumber.

ILLUSTRATION 1

CROSS SECTION OF A BOARD SHOWING ITS FINISHED SIZE RELATED TO ROUGH SIZE AND SAW KERF

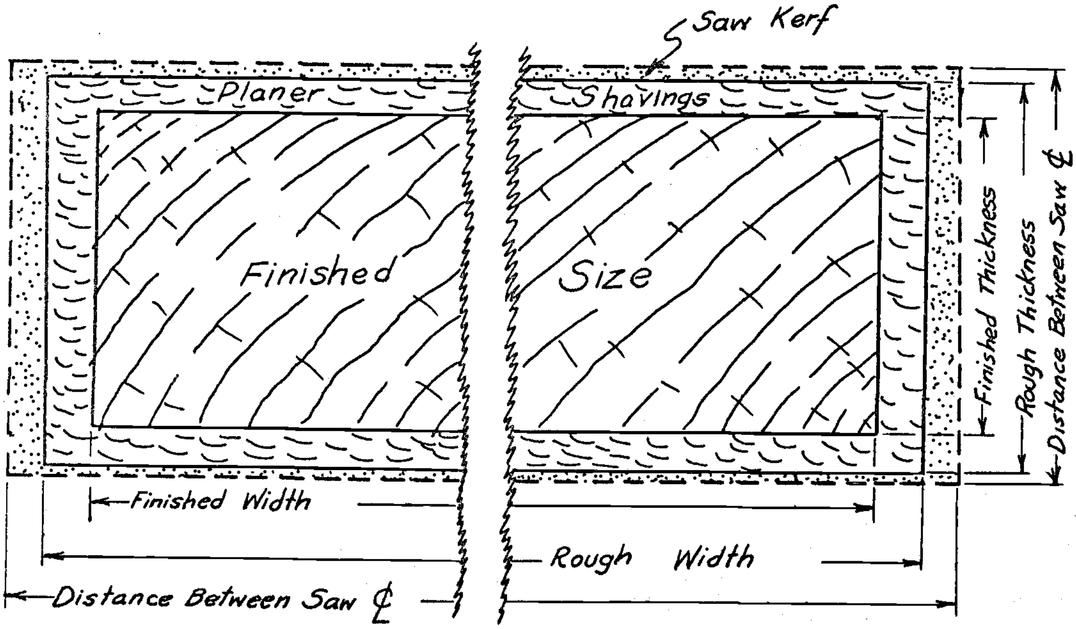


TABLE 3

LUMBER VOLUMES IN CUBIC FEET PER MBF BY

THE THREE TREATMENTS

Nominal Lumber Size	Cubic Foot Content Per MBF*		
	Treatment A	Treatment B	Treatment C
1" x 4"	106.7	89.1	89.1
1" x 6"	103.7	88.9	88.9
1" x 8"	102.2	88.1	88.1
2" x 4"	99.0	87.2	79.3
2" x 6"	96.1	86.5	79.5
2" x 8"	94.7	86.2	79.7
2" x 10"	93.9	86.0	79.7
2" x 12"	93.3	85.8	79.7
4" x 4"	95.0	86.2	81.0

*Lumber dimensions are calculated from saw kerf ℄ to adjacent saw kerf ℄.

The lumber recovery from this study was broken down in three categories; clear and shop items, 32,834 board feet; construction lumber 1" x 4" through 4" x 4" sizes 120,579 board feet, and larger construction timbers 19,706 board feet. The volume of 120,579 board feet is assumed to be further planed to finished size. The cubic content of this volume (including saw kerf) is found by multiplying the board foot tally by lumber size, by the cubic feet per MBF from Table Number 3. This volume totals 11,707.2 cubic feet. The details of this calculation are shown in Table Number 4.

The complete cubic volume recovery analysis for the test logs is presented in Table Number 5. The equivalent conversion volumes were extended on an assumed dollar value per unit to arrive at a total value for all products. Since a cost analysis was not part of the purpose of this paper, the $13,409 total product value has limited use. Its usefulness will be noted as a figure used to compare Treatment A values with the values derived by Treatments B and C.

Comparing Treatments A, B and C

How can the forester assess the probable results in economic terms when proposals are made to change existing operational practices? Here is an opportunity to test the usefulness of total raw material accountability. In this example, Treatments B and C are

TABLE 4

TREATMENT "A" PRODUCTION ITEMS SHOWN AS EQUIVALENT CUBIC FOOT VOLUMES AND THE PROJECTED BOARD FOOT VOLUMES FOR TREATMENTS "B" AND "C"

Treatment A				Treatment B	Treatment C
Nominal Size	Volume in Board Feet	Percent	Original Cubic Volume	Volume in Board Feet	Volume in Board Feet
1" x 4"	5,428	4.5	579.2	6,501	6,501
1" x 6"	4,459	3.7	462.4	5,231	5,231
1" x 8"	1,192	1.0	121.8	1,383	1,383
2" x 4"	38,850	32.2	3,846.2	44,108	48,502
2" x 6"	17,000	14.1	1,633.7	18,887	20,550
2" x 8"	12,251	10.2	1,160.2	13,459	14,557
2" x 10"	11,884	9.9	1,115.9	12,976	14,001
2" x 12"	9,528	7.9	889.0	10,361	11,154
4" x 4"	19,987	16.5	1,898.8	22,028	23,442
TOTALS	120,579	100.0	11,707.2	134,934	145,321

Explanation: Board foot tally of construction items manufactured in Treatment A are converted to original cubic foot volumes, including saw kerf. The projected board foot tally for Treatments B and C is found by dividing the Original Cubic Volume by Cubic Feet per MBF from Table 3.

TABLE 5

TOTAL VALUE ANALYSIS OF LUMBER GRADE AND RESIDUAL PRODUCT RECOVERY

FROM STUDY LOGS FOR TREATMENT "A"

Log Product	Cubic Foot Volume	Percent	Equivalent Conversion Volume	Dollar Value Per Conversion Unit	Total Value To Nearest Dollar
Clear and Shop Lumber	2,735	11	32,834 BF	$ 120 per MBF	$ 3,940
Rough Construction Timber	1,192	5	19,706 BF	60 per MBF	1,182
Dressed Construction Lumber	7,619	31	120,579 BF	60 per MBF	7,235
Planer Shavings	3,312	13	38 Units*	2 per Unit	76
Sawdust	2,470	10	28 Units*	2 per Unit	56
Chips	7,246	30	92 Units*	10 per Unit	920
TOTALS	24,574	100			$ 13,409

*Conversion Factors from Institute of Forest Products (1957)

Assume Douglas fir weight of 42 pounds per cubic foot

1 unit fir shavings 3,700 pounds, or 88 cubic feet solid wood

1 unit fir sawdust 3,700 pounds, or 88 cubic feet solid wood

1 unit fir chips 3,300 pounds, or 79 cubic feet solid wood

compared with the existing known sawing practices and the data from the mill study, Treatment A.

A summary of the mathematical results is found in Table Number 8. The volume of clear and shop lumber changes from 32,834 board feet for Treatment A, to 33,655 board feet for Treatments B and C. This increase is due to the narrower saw kerf at the edger. The larger construction timbers increase from 19,706 board feet to 20,080 board feet, again due to the narrower saw kerf at the edger. Both of these classes of items still retain their full sawn characteristics. The construction items from 1" x 4" change from the Treatment A production of 120,579 board feet to 134,934 board feet for Treatment B, and to 145,321 board feet for Treatment C. These changes are the result of reducing the saw kerf ℄ to saw kerf ℄ measurement as closely as possible to the final finished lumber measurement. Mathematically this is projected by using the Table Number 3. The original cubic volumes by lumber size shown in Table Number 4 were derived from the Treatment A mill study volumes. The board foot tallys for Treatments B and C were projected by using the cubic feet per MBF data for the new production standards in Table Number 4.

The complete cubic volume recovery for the test logs in Treatment A was reported as having a product value of $13,409, as detailed in Table Number 5. Treatment B produces a total product value of $14, 250, detailed in Table Number 6. Treatment C produces a total product value of $14, 857, detailed in Table Number 7.

For a mill with a cutting schedule of 30 MM board feet per year, the changes can have significant consequences. Table Number 9 presents an expansion of the data for such a yearly schedule. In summary, the change in product value for Treatment B as compared to the Treatment A is increased by $175, 769 per year. Treatment C shows a yearly increase in product value of $302, 632 over the Treatment A.

All of these figures are predicated on the assumption that the same cutting schedule, log mix, and production standards used in the test data would hold for a yearly schedule. Any changes from this schedule would change to some degree the results that could be expected in a given situation.

From the above discussion it appears the use of this type of raw material analysis can be of value in a mill situation. There are still many unknowns to be answered. Can the mill successfully cut material 1/4-inch scant, as defined by Treatment C? Will the edger cut to close tolerances using 7/32-inch saw kerf? Can material that is cut 1/4-inch scant be dressed, leaving only 1/16-inch on a side between rough and finished thickness? If the answers to these

TABLE 6

TOTAL VALUE ANALYSIS OF LUMBER GRADE AND RESIDUAL PRODUCT RECOVERY

FROM STUDY LOGS FOR TREATMENT "B"

Log Product	Cubic Foot Volume	Percent	Equivalent Conversion Volume	Dollar Value Per Conversion Unit	Total Value To Nearest Dollar
Clear and Shop Lumber	2,735	11	32,834 BF	$ 120 per MBF	$ 3,940
Rough Construction Timber	1,192	5	19,706 BF	60 per MBF	1,182
Dressed Construction Lumber	8,519	35	134,934 BF	60 per MBF	8,096
Planer Shavings	1,755	7	20 Units	2 per Unit	40
Sawdust	3,127	12	36 Units	2 per Unit	72
Chips	7,246	30	92 Units	10 per Unit	920
TOTALS	24,574	100			$ 14,250

TABLE 7

TOTAL VALUE ANALYSIS OF LUMBER GRADE AND RESIDUAL PRODUCT RECOVERY

FROM STUDY LOGS FOR TREATMENT "C"

Log Product	Cubic Foot Volume	Percent	Equivalent Conversion Volume	Dollar Value Per Conversion Unit	Total Value To Nearest Dollar
Clear and Shop Lumber	2, 735	11	32, 834 BF	$ 120 per MBF	$ 3, 940
Rough Construction Timber	1, 192	5	19, 706 BF	60 per MBF	1, 182
Dressed Construction Lumber	9, 176	37	145, 321 BF	60 per MBF	8, 719
Planer Shavings	1, 047	4	12 Units	2 per Unit	24
Sawdust	3, 178	13	36 Units	2 per Unit	72
Chips	7, 246	30	92 Units	10 per Unit	920
TOTALS	24, 574	100			$ 14, 857

TABLE 8

MATHEMATICAL RESULTS OF THREE TREATMENTS

OF STUDY LOGS

	Treatment A	Treatment B	Treatment C
	Volume in Board Feet	Volume in Board Feet	Volume in Board Feet
Clear and Shop	32,834	33,655	33,655
Construction Lumber	120,579	134,934	145,321
Construction Timber	19,706	20,080	20,080
TOTALS	173,119	188,669	199,056

	Volume in Board Feet	Percent Overrun
Net Scribner Log Scale	143,490	
Treatment A Manufacture	173,119	121
Treatment B Manufacture	188,669	131
Treatment C Manufacture	199,056	139

TABLE 9

DATA EXPANDED TO REPRESENT 30 MM YEARLY CUTTING SCHEDULE ASSUMING SAME LOG INPUT AND PRODUCTS AS IN STUDY

Given: 143,490 BF net Scribner log scale mill study data.

30,000,000 BF assumed yearly net log input schedule.

$\frac{30,000,000 \text{ BF}}{143,490 \text{ BF}}$ = 209 Factor needed to expand data to a yearly cutting schedule.

	Total Value Products		Factor		Value on Yearly Basis
Treatment A	\$ 13,409	x	209	=	\$ 2,802,481
Treatment B	\$ 14,250	x	209	=	\$ 2,978,250
Treatment C	\$ 14,857	x	209	=	\$ 3,105,113

Yearly product value for Treatment B is \$175,769 more than Treatment A

Yearly product value for Treatment C is \$302,632 more than Treatment A questions suggest the proposed schedules are mechanically practical, then the next question to be asked concerns the design of machinery to operate under closer tolerances. It has been demonstrated that product value can be defined for given conditions. Knowing the stakes involved, it should be possible to assess the costs involved to affect a change of known dimensions.

SUMMARY AND CONCLUSIONS

It appears that wherever timber transactions occur, at least for the forseeable future, a variety of log measurement systems will be used. The shortcomings of the various systems have been recorded over a long period of time, and yet there is no consensus among timber users as to a universal system of timber measurement. Cubic foot measurement is not wholly accepted in British Columbia. In the United States the International 1/4-inch rule is finding increased usage; however the Doyle and Scribner rules are still widely used.

If there is any trend in the reporting of different measurement systems, it seems to be in the comparison of two or more systems in a particular study. The use of cubic volume is included in most recent mensurational studies and texts. The use of weight, particularly with the speed, ease, and economy of recording information, is finding increased attention from those involved in the buying and selling of timber.

The use of conversion factors associated with forest products must be carefully defined and qualified as to specific conditions involved.

The residual values resulting from logging and forest products manufacture are receiving more attention than in the past. There is ample evidence that this volume is considerable. A primary problem associated with this development is the measurement, or inventory of this material. Various sources are named as being instrumental in gathering data about residual volumes. Recent studies include a major one on air pollution in the Medford, Oregon area and one concerning forest products refuse burners throughout Oregon. Researchers are finding that traditional measurement systems must be modified to suitably measure this defective raw material and residual wood fiber.

In review, the forest industry has a serious problem resulting from the methods used in measuring the log raw material and the manufactured products. It is truly a paradox where the board foot production exceeds the net log scale by 21 percent and at the same time only 60 percent of the log cubic content is converted to lumber. In the past this situation has been excused because of relatively low timber values and a plentiful supply, plus a lack of opportunity for complete utilization. It can only be concluded that this situation has resulted in a tremendous waste of usable wood fiber with the mistaken notion that a satisfactory job was being done in utilization.

With every problem there must be a suggestion for improvement. The paradox in the previous paragraph suggests the need for a "common denominator" in log and forest product analysis. An opportunity was utilized to develop log volumes and product derivatives in terms of cubic feet. The usefulness of this type of analysis was demonstrated in projecting two changes in manufacturing on an economic basis. The dollar values were very significant and must be carefully considered. The concept of solid wood content analysis is extremely flexible in following the translation of wood raw material to the final yield of numerous products. This is in contrast to the complete inflexibility of the board foot system. The projection of the Treatment A production schedule to Treatments B and C with product values changing by more than $300, 000 on a yearly basis is impressive evidence of the worth of solid wood content analysis. No residuals in a manufacturing situation can be ignored. The most important step in their management is first to measure the volume and assess their value. No lengthy development is necessary to implement cubic analysis in the field of forest products. Cubic foot log tables are available and tabulation of products by cubic content is not difficult or time consuming. Industry can be better equipped to more efficiently manage the volume and value of the wood.

In conclusion, it is recommended that a concerted effort be made to design mensurational techniques that will act as incentives toward the most complete and profitable utilization of our forest resource. Toward this end it is suggested that those in the field of forest mensuration coordinate their efforts with the research and utilization fields toward a complete understanding of the complex problem of wood measurement. The scope of this subject covers many disciplines. Complete wood fiber management is required to meet the challenge presented by a dynamic economy. The type of analysis presented in this paper is a step in this direction.

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APPENDIX

TABLE 10

DECIMAL FOOT EQUIVALENTS

Inches	Feet
1/64	.0013
1/32	.0026
1/16	.0052
1/8	.0104
1/4	.0208
1/2	.0416
1	.0833
2	.1667
3	.2500
4	.3333
5	.4165
6	.5000
7	.5832
8	.6667
9	.7500
10	.8333
11	.9163
12	1.0000

TABLE 11

DECIMAL FOOT EQUIVALENTS FOR VARIOUS LUMBER SIZES

Full Sawn

Inches	Feet
1	.0833
2	.1667
3	.2500
4	.3333
6	.5000
8	.6667
10	.8333
12	1.0000

1/8" Scant Sawn

Inches	Feet
7/8	.0729
1 7/8	.1563
2 7/8	.2396
3 7/8	.3229
5 7/8	.4896
7 7/8	.6563
9 7/8	.8229
11 7/8	.9896

1/4" Scant Sawn

Inches	Feet
1 3/4	.1459
2 3/4	.2292
3 3/4	.3125
5 3/4	.4792
7 3/4	.6459
9 3/4	.8125
11 3/4	.9792

Dressed Finished Size

Inches	Feet
25/32	.0650
1 5/8	.1353
2 5/8	.2187
3 5/8	.3020
5 1/2	.4583
7 1/2	.6248
9 1/2	.7916
11 1/2	.9579

TABLE 12

LINEAL FEET/MBF BY LUMBER SIZES

Nominal Size in Inches	Lineal Feet
1" x 2"	6,000
1" x 3"	4,000
1" x 4"	3,000
1" x 6"	2,000
1" x 8"	1,500
1" x 10"	1,200
1" x 12"	1,000
2" x 2"	3,000
2" x 3"	2,000
2" x 4"	1,500
2" x 6"	1,000
2" x 8"	750
2" x 10"	600
2" x 12"	500
4" x 4"	750

TABLE 13

CUBIC FEET PER M BOARD FEET FOR VARIOUS SIZES OF LUMBER: FULL SAWN; 1/8" SCANT SAWN; 1/4" SCANT SAWN AND DRESSED SIZES

Nominal Size	Full Sawn	1/8" Scant Sawn	1/4" Scant Sawn	Dressed
1" x 2"	83.3	68.4	----	52.8
1" x 3"	83.3	69.9	----	56.9
1" x 4"	83.3	70.6	----	58.9
1" x 6"	83.3	71.4	----	59.6
1" x 8"	83.3	71.8	----	60.9
1" x 10"	83.3	72.0	----	61.7
1" x 12"	83.3	72.1	----	62.3
2" x 2"	83.3	73.3	63.9	54.9
2" x 3"	83.3	74.9	66.9	59.2
2" x 4"	83.3	75.7	68.4	61.3
2" x 6"	83.3	76.5	69.9	62.0
2" x 8"	83.3	76.9	70.7	63.4
2" x 10"	83.3	77.2	71.1	64.3
2" x 12"	83.3	77.3	71.4	64.8
4" x 4"	83.3	78.1	73.2	68.4

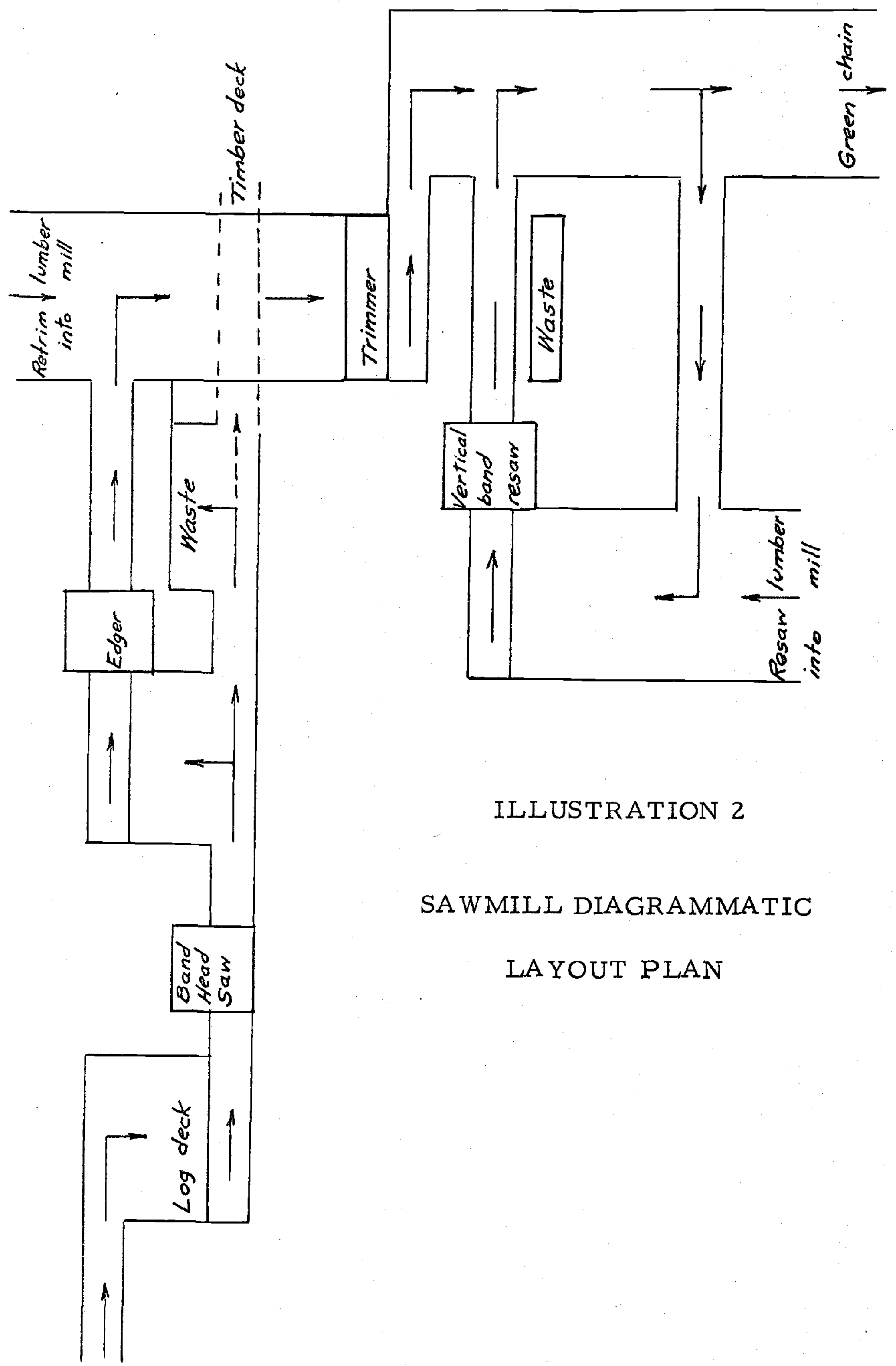

ILLUSTRATION 2

SAWMILL DIAGRAMMATIC

LAYOUT PLAN