BF INTO CUBIC METERS

By
Henry Spelter

Noted forest products industry researcher and writer says the conversion factor traditionally used to convert logs measured in board feet to cubic meters has risen.

EDITOR'S NOTE: The following paper by Henry Spelter, Economist, USDA Forest Service, Forest Products Laboratory, Madison, Wis., originally appeared as a Forest Products Laboratory General Technical Report. Released in June 2002, it is entitled, "Conversion of Board Foot Scaled Logs to Cubic Meters in Washington State, 1970- 1998." Its data and conclusions have prompted reaction with regard to the ongoing Canadian softwood lumber imports issue. Following this paper, beginning on page 28, David Briggs, Professor. Forest Products & Operations Research Director at the College of Forest Resources, University of Washington, Seattle. refutes the methodologies and data in Spelter's paper with an article released in August 2002 and entitled. "Comments on Errors in New Paper on Log Rule Conversion Factors."

In the U.S., most timber is measured in terms of board feet. The log scales currently in use to estimate lumber recovery from roundwood, however. were created in the 19th century according to sawmill technology. timber resource and lumber sizes used at the time. Because log scales have not been modified since to reflect changes in these factors, they are outdated and inadequately serve their purpose of accurately determining recoverable lumber volumes.

With regard to mill technology, most log rules assume ¼ in. for saw kerf and shrinkage, typical of 19th century circular head saws, but not the ⅛ in. characteristic of contemporary thin-kerf band saws. Improvements in log scanning, positioning, and cutting accuracy have allowed mills to boost recoveries. The advent of curve-sawing means that logs with deductions for sweep now yield more lumber or some that were heretofore usable only for pulp can now be sawn,

In terms of the resource, much of the large diameter old-growth timber has now been used up or placed off limits, forcing the industry to use smaller diameter thinnings and younger second-growth. The board foot log rules determine recoverable volumes based on a cylinder defined by a log's small end. Therefore, a bias is introduced as diameters decrease because the volume outside the cylinder becomes larger. Second-growth trees tend to be more tapered, which also boosts the portion outside the core.

Finally, with respect to lumber dimensions, size standards in the late 1960s were reduced, allowing boards to become dimensionally smaller, but the same nominal width and thickness designations were retained. Thus the "board feet" that are now produced are thinner than those upon which the log rules were based.

These changes have widened the gap (known in the industry as the "overrun") between log rule predictions and nominal lumber recoveries. Knowledgeable industry buyers know this and account for it in higher apparent prices where sellers are equally well informed. But many small timberland owners are unaware of these subtleties. and there is a perception that they often are at a disadvantage when selling their timber.

There is a further disconnect between the board foot and cubic log scaling systems used in much of the rest of the world. The two measurement systems are fundamentally different. Board foot rules project only the portion recoverable as lumber based on the small end diameter, whereas cubic rules measure the total volume of sound wood. inclusive of lumber, chips and sawdust, based on both end diameters. As such, the cubic rules are not affected by changes in sawing technology and lumber dimensions and are less affected by changes in log size.

AN EXAMPLE

If U.S. stumpage is U.S.$400 per thousand board feet (MBF) and a conversion factor of 4.81 cubic meters per MBF is used, then,

($400/MBF) x (1MBF/4.81 cubic meters) = U.S.$83.2/cubic meter.

If Canadian stumpage is U.S.$50/cubic meter, then according to the theory applied in the dispute there is a "subsidy" of U.S.$33.2/cubic meter.

However if the appropriate conversion factor is, say 6, then repeating the calculations above we get:

($400/MBF) x (MBF/6 cubic meters) = U.S.$66.6/cubic meter and the "subsidy" shrinks to U.S.$16.6/cubic meter, a big difference, and the CVD (countervailing duty) rate would fall by about half.

When comparing log values measured by different systems, the choice of conversion factor is one critical element. For example, in the recent dispute over softwood lumber trade between Canada and the U.S., board foot prices in Washington were designated as the benchmark for comparison with cubic meter prices in British Columbia. To convert board foot prices to a cubic meter basis, one side advocated the widely used traditional conversion factor, dating back to at least 1950, of 4.53 m^3 per thousand board feet (MBF) of log. In support, they conducted dual scaling measurements in which a sample of logs was measured according to both systems. These resulted in conversion factors of 5.1 m^3/MBF for coastal Washington and 3.6 m^3/MBF for the interior.

The opposing side also presented data from dual scaling log measurements. Conversion factors were derived for each species and grade (but not by diameter classes within grades) and the results weighted by the grade and species distribution of logs sold in Washington. Their estimated factors were 6.7 m^3/MBF for coastal Washington and 6.2 m^3/MBF for the interior. These differences are not inconsequential, because they represent a substantial amount in potential yearly duties on Canadian lumber imports.

In this paper, I investigate what conversion factors from board feet to cubic meters are appropriate to translate present-day Washington log prices into cubic terms.

(**Note:** Dual-scaling exercises were conducted in both British Columbia and Washington. The numbers reported here were results for four coastal and four interior softwood timber species weighted by Washington sales volumes of those species.)

DATA

The primary data used came from 15 industry censuses conducted over the past 30 years by the Washington State Dept. of Natural Resources. These reports represent the most consistent and comprehensive statistics on aggregate wood utilization by sawmills in Washington. Additional results from log yield studies conducted by the USDA Forest Service for the coast were used to convert some descriptive industry census data into estimates of ratios of finished lumber to raw logs.

PROCEDURE

In dual-scaling exercises, the conversion factors are derived from direct measurements of log samples. By contrast, the approach here was to work backwards from three basic lumber processing variables that, when multiplied together, collapse into the sought-after conversion factors. The three variables are ratios of (1) actual board foot content of lumber to nominal board foot content, (2) nominal board feet of lumber recovered to scaled board foot log input (overrun), and (3) cubic volume of log to lumber derived from it.

Step 1. I start with the tautological conversion of a thousand board feet (MBF) into cubic meters using metric equivalents to imperial measurements:

$$1 \text{ actual MBF lumber} = 2.36 \text{ m}^3 \qquad (1)$$

or a conversion factor of

$$\frac{2.36 \text{ m}^3 \text{ lumber}}{1 \text{ actual MBF}}$$

Step 2. The actual board foot contents of finished lumber are less than their nominal sizes imply. A nominal 2x4 in. surfaced dry piece, for example, is actually 1.5x3.5 in., resulting in 0.656 actual board feet for each nominal board foot. Using ratios between nominal and actual sizes as given in the American Softwood Lumber Standards definitions for surfaced green and surfaced dry lumber (U.S. Dept. of Commerce 1999) and weighting each size by the proportions reported in Western Wood Products Assn. production statistics (WWPA 2000), I calculated regional ratios. I extrapolated them over time based on the proportions of green and dried lumber. Multiplying equation (1) by this variable I define as X yields

$$\frac{2.36 \text{m}^3 \text{ lumber} \times X \text{ actual MBF}}{1 \text{ actual MBF} \times 1 \text{ nominal MBF}} = \frac{2.36 \times X \text{ m}^3 \text{ lumber}}{1 \text{ nominal MBF}} \qquad (2)$$

Step 3. The ratio between the nominal board feet of lumber recovered from a log and the projected recovery from the scale (the so-called overrun) can be determined from lumber output and log input figures contained in the Washington Mill Survey. Multiplying equation (2) by the overrun ratio Y gives

$$\frac{2.36 \times X \text{ m}^3 \text{ lumber} \times Y \text{ nominal MBF}}{1 \text{ nominal MBF} \times 1 \text{ MBF, log scale}} = \frac{2.36 \times X \times Y \text{ m}^3 \text{ lumber}}{1 \text{ MBF, log scale}} \qquad (3)$$

Step 4. The cubic recovery ratio (CRR) measures the volume of finished lumber recovered from the log input. Typical sawmill CRR factors vary from as low as 0.3 to more than 0.6. Among the many operational factors that influence this, log size is one of the more important and is normally the variable about which a schedule of CRR values is built. Stud mills supplied with small logs tend to lie at the lower end of the range, whereas grade recovery mills processing large diameter timber for high quality lumber achieve higher recoveries.

Table 1—Diamier assumptions (and corresponding CRR ratios) used to calculate regional CRR factors (cm)

	Old growth	Young growth
Coastal		
1970–1988	76 (0.50)	30(0.44)
1990–1998	76 (0.50)	28 (0.43)
Interior		
1970–1988	56 (0.48)	25 (0.39)
1990–1998	56 (0.48)	23 (0.37)

Except for a late 1960s study used to estimate residue volumes in the Washington Mill Survey, data on CRR values were not available. The logs utilized, however, were identified by whether they were "old-growth' or "young-growth," defined as older or younger than 100 years. Forest Service lumber-yield studies on such logs relate CRR values to log size. To proceed, I selected a combination of diameters for old- and young-growth (Table 1) whose corresponding CRR factors, weighted by the 1970 shares of old- and young-growth, approximated the CRR value of the late 1960s study (0.474 and 0.445 for coastal and interior Washington, respectively). I kept these CRR values and continued to weight them by the changing shares of old- and young-growth to derive subsequent CRR estimates, except that in 1990 I reduced the young growth diameter by 2.54 cm (1 in., Table 1) to reflect the increasing share of thinnings that began to appear with the change to second-growth timber economy.

Multiplying equation (3) by the inverse

Table 2—Log and lumber characteristics for coastal Washington

	Actual to nominal lumber (X)	Green lumber (%)	Lumber tolog volume (overrun) (Y)	Old growth logs (%)	Ratio of log to lumber (1/CRR) (Z)	Log conversion factor (m^3/MBF)	Estimated average regional diameter (cm)
1970	0.700	41	1.21	56	2.12	4.22	56.2
1972	0.701	43	1.35	59	2.11	4.71	57.3
1974	0.701	44	1.19	55	2.13	4.19	55.5
1976	0.702	48	1.27	53	2.13	4.48	54.7
1978	0.705	53	1.37	46	2.15	4.90	51.4
1980	0.707	58	1.32	51	2.14	4.70	53.8
1982	0.707	59	1.34	34	2.18	4.88	45.9
1984	0.708	60	1.42	32	2.19	5.19	45.3
1986	0.707	58	1.41	33	2.19	5.13	45.6
1988	0.706	57	1.47	31	2.19	5.38	44.7
1990	0.707	59	1.56	24	2.23	5.81	39.5
1992	0.706	56	1.63	17	2.25	6.10	36.1
1996	0.703	50	1.79	4	2.30	6.84	29.8
1998	0.701	43	1.88	na	2.31	7.18	28.9

Note: The Washington Mill Survey was not carried out in 1994. Columns 3,4 and 5 were data reported in the survey. Columns 2, 6, 7 and 8 were derived from data in the survey and Forest Service yield studies, as described in the Procedure section.

of the CRR (variable Z), the cubic meter to MBF log scale conversion that is the focus of this investigation results:

$$\frac{2.36 \times X \times Y \text{ m}^3 \text{ lumber} \times Z \text{ m}^3 \text{ log}}{1 \text{ MBF, log scale} \times \text{m}^3 \text{ lumber}} = \frac{2.36 \times X \times Y \times Z \text{ m}^3 \text{ log}}{1 \text{ MBF, log scale}} \quad (4)$$

values for X, Y, and Z are displayed in Tables 2 and 3 along with underlying data from the Washington Mill Survey characterizing the resource and product.

RESULTS

A striking trend in the coastal Washington data is the decline of the share of old-growth. By 1996, it had nearly disappeared. This contributed to the large increase in overruns especially evident during the past 15 years. A second outcome of smaller log sizes is a decrease in the cubic recovery ratio (or an increase in its inverse). Together these trends would have caused the conversion factor from board feet (Scribner long-log scale) to cubic meters to rise from approximately 4 to 4.5 in the 1970s to greater than 7 by 1998.

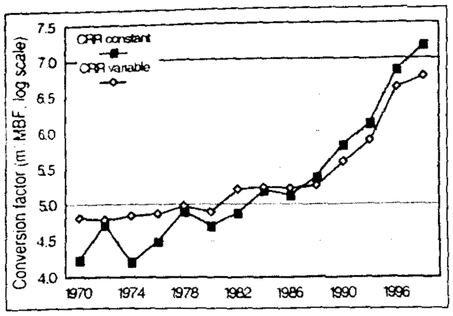
However, the CRR factors used in these calculations were derived from 1960s-era mill studies. Improvements in sawing over the past three decades have ostensibly increased lumber yields, offsetting some of the yield-reducing impact of smaller log sizes. To what degree that occurred we can estimate by translating the derived log diameters into conversion factors using generalized schedules developed from USDA Forest Service sawmill recovery studies (Figures 1 and 2). For the coast, the differences in the two series imply an approximate increase of 15% in the CRR ratio over 28 years. This results in higher conversion factors of about 4.7 at the beginning of the period and a lower factor of 6.76 in 1998 (down from 7.18).

Trends in the log mix in interior Washington followed a similar course. The old-growth share in the interior had not declined by as much as it had on the coast, hence the increase in overruns was ➤ 26

Table 3—Log and lumber characteristics for interior Washington

	Actual to nominal lumber (X)	Green lumber (%)	Lumber to log volume (overrun) (Y)	Old growth logs (%)	Ratio of log to lumber (1/CRR) (Z)	Log conversion factor (m^3/MBF)	Estimated average regional diamter (cm)
1970	0.713	23	1.18	52	2.23	4.42	41.2
1972	0.713	26	1.22	68	2.14	4.38	46.0
1974	0.714	29	1.26	67	2.15	4.54	45.7
1976	0.713	26	1.27	61	2.18	4.67	43.9
1978	0.714	29	1.28	65	2.15	4.64	45.2
1980	0.713	24	1.32	57	2.19	4.86	42.9
1982	0.714	29	1.34	44	2.27	5.12	38.7
1984	0.713	26	1.44	49	2.24	5.43	40.4
1986	0.710	9	1.42	50	2.24	5.41	40.7
1988	0.712	19	1.40	50	2.24	5.28	40.6
1990	0.711	15	1.41	28	2.45	5.80	32.0
1992	0.710	8	1.43	32	2.41	5.76	33.5
1996	0.709	4	1.41	16	2.54	5.99	28.2
1998	0.709	4	1.47	na	2.61	6.42	25.3

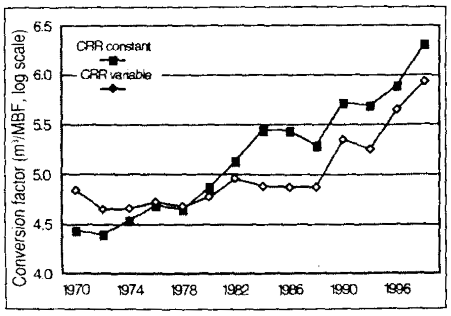
Figure 1—Metric conversion factors from constant and variable cubic recovery ratio estimates, coastal Washington 1970-1998.



22 ➤ not as large. The form of the Scribner scale used is also based on shorter logs. which makes this version of the scale more accurate, and the overruns lower, for the same size log. Thus the rise in the conversion factor from board feet (Scribner short-log scale) to cubic meters was more moderate. from approximately 4.5 to only 6.4 by 1998.

However, the diameter-derived conversion factor does not rise as fast as its fixed technology counterpart (Figure 2). Overall, the implied improvement in recovery is about 12%, and the metric conversion factor is reduced from 6.42 to 5.93 for 1998. (These data and the submitted data in the lumber dispute were

Figure 2—Metric conversion factors from constant and variable cubic recovery ratio estimates, interior Washington 1970-1998.



for different years. and the trends exhibited in the 1970-1998 data are likely to have carried forward into 2000.)

DISCUSSION

These results place into perspective the conflicting conversion factors in the recent softwood lumber dispute. The factors advocated by one side were obtained from a large sample of logs scaled by both cubic and board feet. The results were segmented by grade and species and converted to a regional estimate by weighting them by Washington's grade and species mix (though not by diameter class within the grades). The results came close to what was found here based on essentially the entire population of logs processed in the state of Washington in 1998.

The data advocated by the other side of the dispute also resulted from a dual scaling exercise in which a conversion factor of 5.14 m^3/MBF, using coastal scaling protocols, was found along with an average diameter of 45 cm. The conversion factor is basically consistent with USDA Forest Service log conversion factors for that diameter (5.26 m^3/MBF), but the diameter is higher than the 29 cm that was the average calculated from the 1998 Washington Mill Survey. Similarly, the interior log sample scaled according to interior protocols had an average diameter of approximately 42 cm and yielded a conversion factor of 4.52. This again is consistent with USDA Forest Service conversion factors for that diameter (4.81 m^3/MBF), but the sample diameter is higher than the average of approximately 25 cm in the Washington Mill Survey for eastern Washington.

Beyond the issue of softwood lumber trade is the problem of how to harmonize trade data where different scaling systems are employed. Analysts have used "standard" conversion factors to make North American (now exclusively U.S.) data compatible with data from the rest of the world, and over time, a factor of 4.53 m^3/MBF has become established. However, details on its provenance, the embedded assumptions on log size, and the type of scale used have been lost. A factor of 4.53 can be related to specific diameters in all currently used U.S. log scales, but those diameters are considerably larger than the average log sizes prevalent today. The results here show that a conversion factor of 4.53 was reasonably close for West Coast logs scaled by the Scribner system prior to the 1980s, when a big share of logs consisted of large diameter old-growth trees. Since then, however, change to a second-growth timber base has made that standard conversion factor too low.

The appropriateness of a standard conversion factor then has to be weighed according to the purposes for which it is used. The foregoing illustrates the need for a more consistent and transparent log measurement system in U.S. timber markets. TP

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APPENDIX—CONVERTING BOARD FOOT LOG VOLUMES TO CUBIC METER EQUIVALENTS

Table 4 contains factors to convert logs measured in board feet (scaled by the long and short log versions of the Scribner rule) to cubic volumes. Equations (5) through (8) were derived from data collected in the course of extensive USDA Forest Service sawmill efficiency studies.

In these studies. a large population of logs was measured by both a customary board foot rule and a cubic scaling system, and relationships between the two were statistically estimated as a function of log diameter. The original cubic volume data and the equations derived from them were in terms of cubic feet. These were converted to cubic meters. Equations (5) through (8) were developed using inches. Therefore, they are only valid using inch inputs for diameter.

Table 4—Conversion factors derived from equations for logs 15 to 41 cm in diameter

Log diameter		Factors	
in.	cm	Long logs	Short logs
6	15.2	8.60	8.05
7	17.8	8.81	7.20
8	20.3	8.43	6.63
9	22.9	7.89	6.23
10	25.4	7.36	5.92
11	27.9	6.90	5.67
12	30.5	6.51	5.46
13	33.0	6.19	5.28
14	35.6	5.92	5.13
5	38.1	5.70	4.99
16	40.6	5.51	4.87

Board feet (net volume basis measured by Scribner, long log basis) per cubic foot:

$$10.16 - 0.04 \times D - 88.18/D + 290.58/D^2 \quad (5)$$

where D is diameter. This is converted to m^3/1,000 board feet by the following conversion:

$$1{,}000/((10.16 - 0.04 \times D - 88.18/D + 290.58/D^2) \times 35.31) \quad (6)$$

Board feet (net volume basis measured by Scribner, short log basis) per cubic foot:

$$5.336 + 0.085 \times D - 13.93/D \quad (7)$$

This is converted to m^3/1,000 board feet by the following conversion:

$$1{,}000/((5.336 + 0.085 \times D - 13.93/D) \times 35.31) \quad (8)$$

These equations result in the conversion factors in Table 4. for logs 15 to 4 1 cm in diameter.