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Contents



# Evaluating the measuring accuracy of harvesters and processors

**Abstract**

The Forest Engineering Research Institute of Canada (FERIC) examined the measuring accuracy of common harvesters and processors operating in British Columbia and Alberta. The results showed large variations in length and diameter performance of the machines, which was attributed partly to differences in emphasis placed on measuring accuracy at the harvesting site. Other factors affecting measuring accuracy included variation in tree characteristics, lack of properly calibrated measuring systems, and wrong target lengths programmed in the measuring system's computer. Based on the findings, FERIC made suggestions to improve measuring performance.

**Keywords**

Measurement accuracy, Harvesters, Processors, Western Canada.

**Authors**

Björn Andersson and Peter Dyson, Western Division

## Introduction

Manufacturing of stems into company-specified log lengths, either long logs (LL) or cut-to-length (CTL) logs, prior to mill delivery is a common harvesting practice in western Canada that can lead to substantial value loss if done poorly. These losses result from selecting sub-optimal bucking points or incorrect measurements of the stems before bucking (Murphy et al. 1996). Selecting the appropriate bucking points that will maximize the revenue from individual stems is best done through the use of computerized merchandizing systems that can calculate and compare the values for various bucking alternatives. This technology for cut-to-value optimization is used by log merchandizers at millyards but has not been introduced on mobile processors in western Canada.

Mobile processors are expected to manufacture logs within company-specified length and diameter tolerances. However, information on their measuring performance in western Canada has been lacking. This has raised concerns that manufacturing logs at the harvesting site using mobile processors results in substantial revenue losses to the forest industry. Studies done in Sweden (e.g., Hallonborg 1982; Berg and Helgesson 1993; Sondell and von Essen 1996) also confirm that harvesters sometimes have difficulty in achieving the level of measuring accuracy desired by the sawmilling industry. However, as operating conditions and some of the machines tested in Sweden differ from those in western Canada, the results of the Swedish studies may not be directly applicable in Canada.

To address this issue, FERIC began an extensive study in the fall of 1996 to examine the measuring accuracy of common harvesters and processors in British Columbia and Alberta. This report presents length and diameter measuring accuracy data on several types of computerized measuring systems and processing heads collected during a three-year period, identifies factors that influence measuring performance, and discusses means to improve measuring accuracy.

## Objectives

The study aimed to provide information to forest companies and logging contractors to control the fibre/value losses that commonly occur during the log manufacturing process with mobile equipment at the harvesting site. To achieve this, FERIC identified the following three key objectives:

- Conduct field tests to record measuring accuracy of harvesters and processors in different stand and operating conditions, during spring, summer/fall, and winter.
- Quantify the influence of specific tree characteristics, climatic conditions, and operating factors on log measuring accuracy.
- Recommend possible solutions to reduce log-measuring errors.

## Study methods

FERIC conducted 103 studies[1] from October 1996 to September 1999 on active logging operations at 18 locations throughout British Columbia and Alberta (Figure 1). All machines were tested "as found", and all logs were processed to the specifications of the host company.

The study included single-grip machines operating either as harvesters or processors (at the stump or at the roadside or landing) in CTL and LL operations, double-grip processors at the stump in CTL operations, and strokers and roll-strokers primarily at roadside landings in LL operations (Table 1). All machines used log-measuring systems with microprocessor-based technology that controlled most of the log-making functions, but generally with some operator input during processing. All systems measured length, while some also measured diameter and calculated log volume.

The length measuring on single- and double-grip machines was in all but one case[2] done by a measuring wheel connected to an encoder. The resetting of the length measuring was mostly done by the cut-off saw being activated, but some processors (Rottne double-grips and one Waratah single-grip) were equipped with a photocell located near the cut-off saw for resetting the computer prior to measuring the first log. The diameter measuring was done by one or two potentiometers (or encoders) connected to the delimber arms or the feed rollers.

The length measuring on strokers and roll-strokers was done by a combination of boom


Figure 1. Study locations throughout British Columbia and Alberta.

[1] Results of individual studies available on request from FERIC.

[2] In one study, the encoder was connected to the stem feeding device.


**Forest Engineering Research Institute of Canada (FERIC)**



**Eastern Division and Head Office**
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9
(514) 694-1140
(514) 694-4351
admin@mtl.feric.ca

**Western Division**
2601 East Mall
Vancouver, BC, V6T 1Z4
(604) 228-1555
(604) 228-0999
admin@vcr.feric.ca





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**Table 1. Summary of studies**

| Log measuring system | Type of processors | Studies by harvesting phase (no.)[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | CHA | CPR | CPS | LHA | LPR | LPS |
| Dasa 280 | Woodking 650 | 1 | | | | | |
| Denharco MD II | Denharco T3 500 | | | | | 1 | |
| Entek TY 5000 | Ultimate 4500, 5300 | 1 | 1 | | | | |
| Entek TY 5000 | Ultimate 5300 | 1 | | | | | |
| Lim-mit COMS | Lim-mit 2000, 2000B | | 1 | | | 8 | |
| Lim-mit COMS | Lim-mit 2100 | | | | | 2 | |
| Lim-mit COMS | Lim-mit 2200 | | | | | 1 | |
| Lokomatic 90 | Timberjack 762B | 24 | | | 1 | | |
| Motomit | Lako 550 | 1 | | | | | |
| Optilog | Denharco 550 | | 6 | | | 1 | |
| Rolly (Risley) | Rolly II | | 1 | | | | |
| Scanmet 512 | Keto 500 | 1 | 2 | 1 | 1 | | |
| Scanmet 512 | Keto 1000, 1000 | | | | 1 | | 1 |
| System 90 | Rottne Snoken 860 | | | 5 | | | |
| System 90 | Rottne Skoken 940 | | | 3 | | | |
| System 90 | Rottne EGS 85 | 2 | | | | | |
| Timberjack 3000 | Timberjack 762B | 3 | | | | | |
| Timberjack 3000 | Timberjack 763C | 1 | | | | | |
| Toshiba (Target) | Target, Hornet 825 | | 3 | | | | |
| Valmet VMM 1000/1100 | Valmet 960 | 10 | 1 | | | | |
| Valmet VMM 1000 | Valmet 965 | 2 | 2 | 2 | | | |
| Waratah AS593/595 | Waratah (Pierce) HTH-20 | 2 | 5 | 1 | | 2 | 1 |
| Total studies (no.) | | 49 | 22 | 12 | 3 | 15 | 2 |

[a] CHA = cut-to-length harvester, CPR = cut-to-length processor at roadside, CPS = cut-to-length processor at stump, LHA = long-log harvester, LPR = long-log processor at roadside, LPS = long-log processor at stump

and feed roller[3] movements connected to encoders and proximity switches. Photocells at one or two locations provided the reference points needed to detect the position of the butt of the stems during infeed and during processing.

### Field data collection

The field data were collected both in a somewhat controlled environment and in regular harvesting operations. In the controlled studies, the machine manufactured logs from approximately 50 pre-selected trees of known characteristics (species, dbh, height, tree branchiness, and tree class). The logs from each processed tree were placed in separate piles so that they could be tracked back to their "original" tree. Where conditions allowed a FERIC researcher to be in the cab during processing, FERIC recorded the length and diameter displayed on the computer screen at the time the cut-off saw was activated. When this was not possible, only logs measured to the company-specified lengths were included in the study. Following processing, FERIC measured the end diameters and the length of each log, and recorded the intended target length (definitions in Appendix I). The log length was measured with a logger's tape, and recorded to the nearest centimetre. The diameters were measured outside bark at 20 cm from the end of the log with a caliper. If the diameter displayed on the computer screen had been recorded, the log diameter was measured to the nearest 0.1 cm. Otherwise, it was measured to the nearest centimetre.

[3] On roll-stroke processors while in the roll-stroke mode.

Information on company log specifications was typically provided by staff members of the respective companies' Woodlands department, while computer target lengths and saw window settings were normally obtained from the operators at the test site.

In the production-oriented studies, FERIC collected only length accuracy data on randomly selected logs manufactured under normal harvesting conditions (e.g., pressure to produce, operator fatigue, etc.). To minimize the risk of including random-length logs in the sample, FERIC excluded logs with top diameters near company-specified minimum, and logs that appeared to have been cut off-length due to a stem defect. The procedure for measuring the logs was the same as described for the controlled studies.

### Data analysis

As there is no industry standard for measuring accuracy, FERIC opted to present the results of the studies in several different ways. In its truest sense, the measuring is accurate when the dimension of the manufactured log is exactly the same as the dimension measured (displayed) by the machine. However, operationally this level of accuracy is impractical. Instead, machine operators and company personnel typically use company log specifications to define measuring accuracy (company-accepted logs), while from an engineering point of view the system's saw window settings would best define the target for measuring accuracy (computer-accepted logs). While either method will quantify the portion of manufactured logs within the specified target, they do not show the variability in measuring accuracy among individual logs. Therefore, FERIC also examined the distribution of length measuring errors of individual logs in 1-cm error classes. To capture the essence of the error distribution, FERIC adopted the method used in Sweden to quantify length measuring accuracy (Berglund and Sondell 1985). Best-5 and Best-10 quantify the frequency of logs (as a percentage of all logs) within the five and ten adjacent error classes with the highest number of logs, respectively (Appendix I, Figure I:1).

To quantify the diameter measuring performance, FERIC compared the machine-measured diameter displayed on the computer screen at the time the cut-off saw was activated with the actual top diameter of the log. The difference between the two measurements (diameter error) was compared to three different levels of accuracy targets: ±2 mm (common diameter measuring precision for millyard log scanners), ±4 mm (Swedish forest industry standards for evaluating harvesters), and ±8 mm. The number of logs meeting the accuracy requirement for each target class was expressed as percentages of the total number of logs measured.

Information on actual machine-measured volume was only obtained in a few cases. When available, FERIC compared this volume to a scaled volume calculated with Smalian's formula and actual length and end diameter data.

## Results

### Length measuring performance

#### Company-accepted logs

The specification for company-accepted logs varied somewhat among operations. Common accuracy requirements in CTL operations were to manufacture no less than 90% or 95% of the logs within length tolerances ranging from ±3 to ±7.5 cm, with ±5 cm being most common.[4] Long-log operations typically required that at least 85–95% of the logs be within length tolerances ranging from ±5 to ±9 cm. The CTL machines achieved the 95% and 90% company-acceptable levels in 23 and 41 cases, respectively, while the LL machines achieved

[4] Specified length tolerance often allowed a larger measuring error above than below the stated target length, e.g., -2.5 cm to +7.5 cm rather than ±5 cm.

the 95% and 85% company-acceptable levels in 1 and 7 cases, respectively (Figure 2). These results were generally lower than the cooperating company's own information. Part of the difference could be attributed to the conversion of log specifications from imperial to metric units, and the subsequent measuring of logs to the nearest centimetre. Had FERIC recorded the log lengths to the nearest inch, an overall average of 5% more logs would have been recorded as company-acceptable.

### Computer-accepted logs

The width of the saw window on the machines studied was typically less than half the width of the company length tolerance. A common width was 4 cm (e.g., -2 to +2 cm), but it ranged from 1 cm (e.g., 0 to +1) to 10 cm (e.g., -5 to +5). The location of the saw window relative to the mid-point of the company length tolerance range also varied. Some machines had the saw window set near the mid-point of the company length tolerance range, while some were offset by up to 5 cm.

The percentages of computer-accepted logs among the CTL machines ranged from 6% to 90%, and averaged 50%, while among the LL machines they ranged from 6% to 69% and averaged 35% (Figure 2). The lower percentages of computer-accepted logs compared to those of company-accepted logs were expected because of the narrower target range. However, a low percentage of computer-accepted logs did not always correspond to a low percentage of company-accepted logs. This suggests that the target lengths programmed in the computer were sometimes set to compensate for measuring errors in the system. Consequently, FERIC believes that the results in terms of percentage of computer-accepted logs recorded in these studies are not representative of the machines' length measuring accuracy.

### Best-5 and Best-10 from length deviation data

Logs within Best-5 and Best-10 ranged for the machines in the CTL operations from 26% to 92% and from 45% to 100%, respectively. The corresponding percentages for the machines in LL operations were from 23% to 67% and from 41% to 91%, respectively (Figure 3). The lower Best-5 and Best-10 percentages for the long-log machines compared to the CTL machines is mainly attributed to the former machines manufacturing long logs rather than short logs, thereby magnifying the length error.

Machines with the higher Best-5 percentages generally also had a higher percentage of company-accepted logs, but there were exceptions. The combination of high Best-5 and low percentage of company-accepted logs meant that the machines, despite being consistent in their length measuring, missed the company length specification ranges. Likely reasons for this would be that

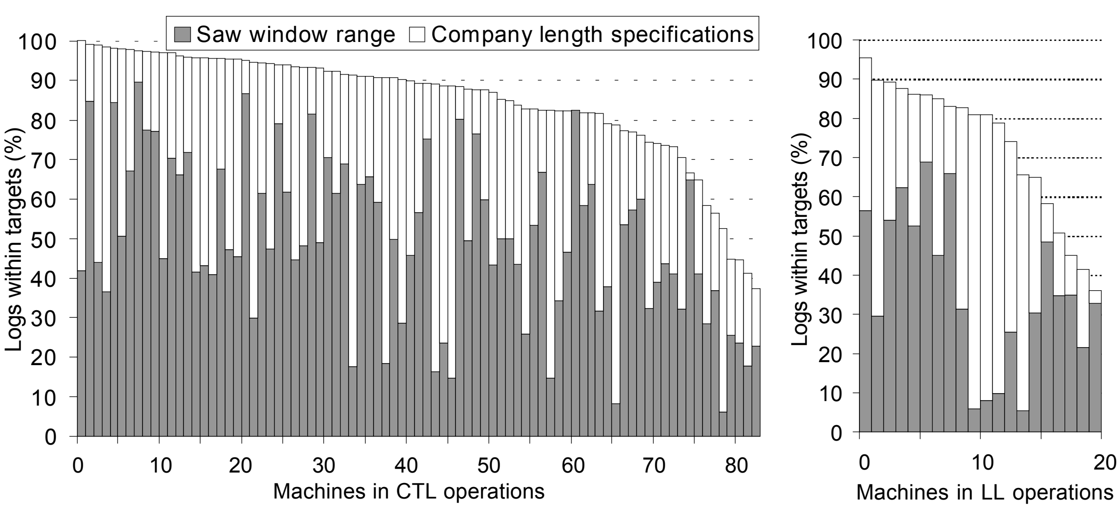



Figure 2. Logs manufactured within company length specifications and system saw window settings from studies of 83 CTL and 20 LL operations.

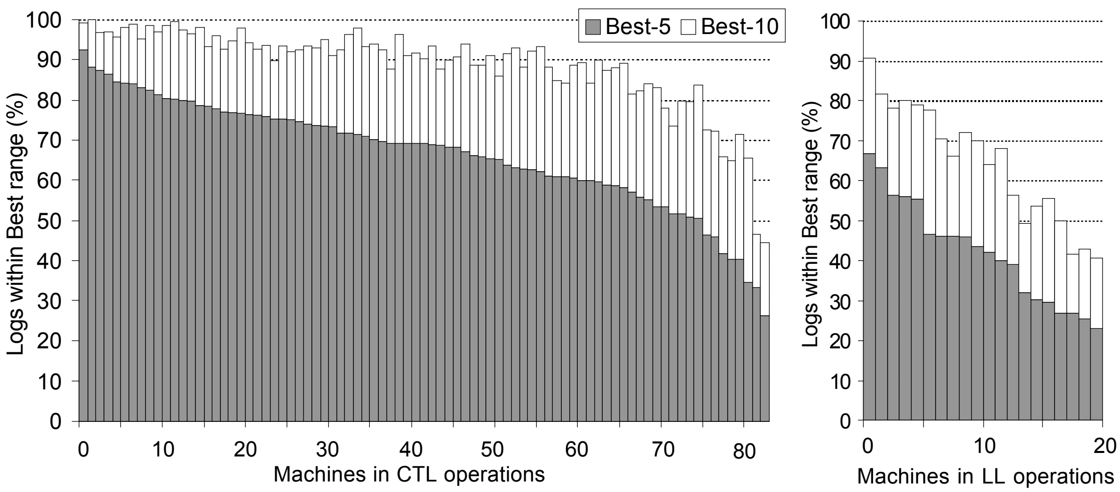



Figure 3. Best-5 and Best-10 percentages from 83 CTL and 20 LL operations.

the measuring system on these machines had not been properly calibrated or that the length settings in the computer did not match one or more of the company length specifications.

## Diameter measuring performance

FERIC recorded the diameter measuring performance on 31 machines in CTL operations. Most machines tested only used their diameter measuring systems to find the appropriate topping diameter (typically 10 cm), and occasionally also the minimum or maximum diameters of one or two log sorts. At other diameter ranges, the measuring accuracy was not important, which undoubtedly influenced the results.

Overall, 19%, 34% and 57% of the logs per study were within a measuring error of ±2 mm, ±4 mm, and ±8 mm, respectively. However, the results of individual studies varied considerably (Figure 4). For example, logs within the ±4 mm error range varied from 1% to 69%. As none of the cooperating companies had set any specific diameter measuring accuracy standards, it is difficult to determine whether or not the machines achieved the level of accuracy required by the forest industry.

## Volume measuring performance

None of the cooperating companies required the machines to measure volume, but a few logging contractors used that capability of the measuring system to track the production of their machines. However, differences in volume calculations between the measuring systems and the official British Columbia and Alberta scaling

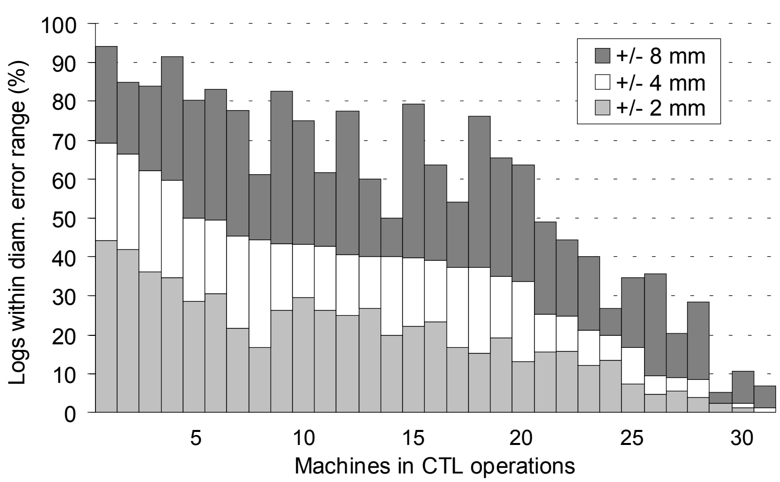



Figure 4. Diameter measuring accuracy from 31 CTL operations.

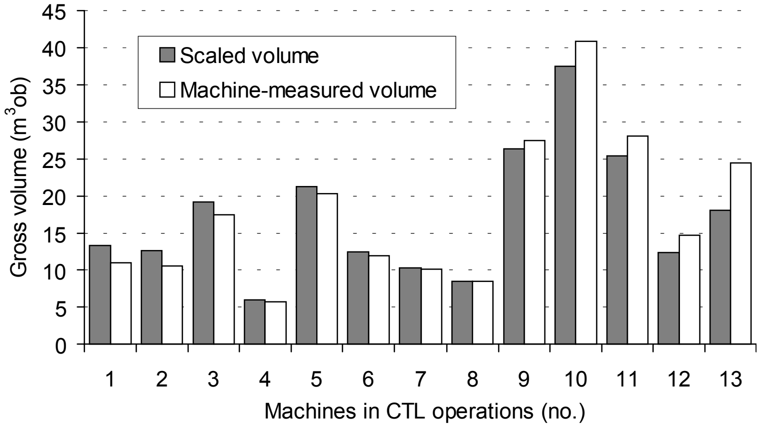



Figure 5. Comparison of machine-measured and scaled log volume from 13 CTL operations.

procedures made it difficult for the contractors to evaluate the accuracy of the machine-measured volume data.

FERIC compared the machine-measured volume to scaled log volume[5] in 13 studies (Figure 5), and recorded a difference in volume ranging from -17% to +35%. In five of the studies, the difference between machine-measured and scaled volume was within 6%.

## Discussion

### Factors influencing measuring performance

The results showed that the measuring accuracy of the machines studied varied greatly, regardless of what yardstick was used to measure the performance. The analyses of factors believed to have contributed to the variation in measuring accuracy produced sometimes conflicting results, i.e., a factor that was found to influence the measuring performance in some studies appeared not to have impacted the results in other studies. Thus, it is more appropriate to assess a factor's probability of affecting a machine's measuring accuracy than to quantify its impact in absolute terms. FERIC examined six factors and although their impacts were analyzed primarily with respect to length measuring accuracy, FERIC believes they are also applicable to diameter measuring accuracy.

### Quality control at the harvesting site

While all companies required that the manufactured logs meet certain length specifications, the quality control on measuring accuracy at the harvesting site differed considerably. Although there were exceptions, the machines that operated for companies that regularly checked length accuracy at the harvesting site and provided feedback to the operators performed, as a group, much better than those machines working in operations with limited quality checks at the harvesting site (Figure 6).[6]

[5] Calculated using Smalian's formula and actual length and over-bark diameter measurement with no deductions for defects.

[6] Figure 6 is only intended to illustrate the importance of regularly checking the measuring performance of the machines at the harvesting site, not to suggest that one quality program is better than another, or that operators may not, on their own initiative, make sure that manufactured logs are within company specifications.

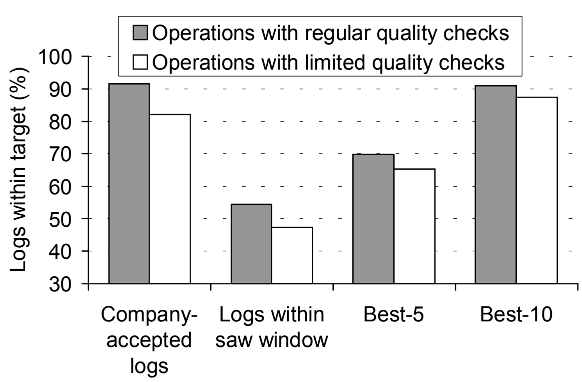



Figure 6. Comparison of length measuring performance of operations with regular and limited quality checks at the harvesting site.

FERIC believed that the regular company checks motivated the operators to check the measuring performance of their machines daily, and thus were able to detect and correct problems with the measuring system before large amounts of off-length logs had been manufactured. FERIC also felt that the operators in these operations took as much pride in doing a good job on measuring accuracy as they did in high machine productivity.

## Log specifications and target setting information

FERIC identified the relative saw window settings as a potential source of the variation in computer-accepted logs. The saw window settings would be expected to be near the mid-point of the corresponding company length tolerance ranges, but this was not always the case. In some of these cases, the saw windows appeared to have been deliberately set near the maximum allowed length to compensate for a tendency of the measuring system to measure short. Company-accepted logs in those studies were usually high, while computer-accepted logs were low and not representative of the system's measuring capability. However, in other cases there appeared to be no logic for one or more of the saw window settings.

FERIC can only speculate on the reasons for the odd saw window settings in these and some other cases. Perhaps it was because of a programming error, incorrect information on company log specifications, or a calculation error when converting from imperial units (which most companies used for their log specifications) to metric units (which many measuring systems use). Regardless of the reason, the problem could have been easily detected had the operators in these cases checked some of the logs for accuracy. This problem did not occur among operations with strong emphasis on measuring accuracy.

## Calibration

Lack of calibration of the measuring system is often cited as a key reason for poor measuring accuracy. To examine if this was the case, FERIC examined the relationship between length errors and log lengths in those studies where the machines had manufactured adequate numbers of logs of different target lengths. FERIC assumed that the measuring system needed to be calibrated if there was a statistically significant correlation between the magnitude of the measuring errors and the length of manufactured logs (Figure 7). In those cases where no such relationship could be detected and the average measuring error of all logs was near 0 cm, FERIC assumed that a calibration of the measuring system had not been needed, even with a wide range of measuring errors. In those cases where the majority of logs either were too long or too short, but no correlation could be found between measuring error and log length, FERIC assumed that adjustments to the measuring system other than calibration had been needed to improve the measuring performance.

The results indicated that roughly one-third of the measuring systems were in need of length calibration at the time of the study, while nearly half were deemed to have been properly calibrated. The remaining systems exhibited some systematic length measuring errors (logs were either consistently shorter

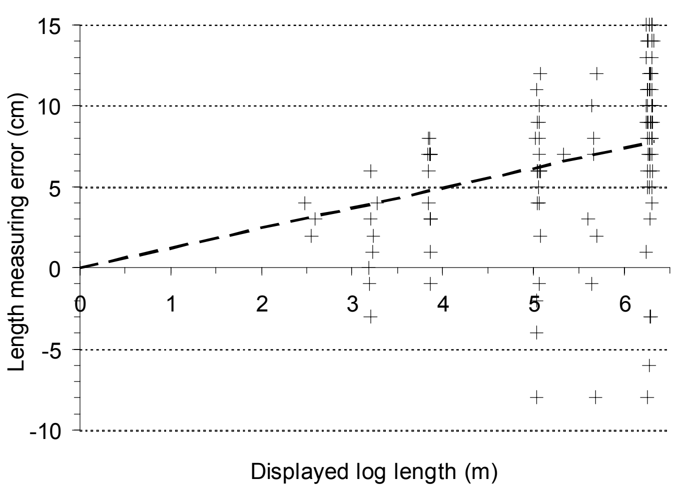



Figure 7. Example of length-correlated measuring errors where calibration is needed.

or longer than the intended target lengths) that were most likely caused by factors other than lack of calibration.

The results also indicated that, where length calibration was needed, the portion of the measuring errors attributed to lack of calibration was quite varied. FERIC estimated that had the measuring systems of this group of machines been properly calibrated, company-accepted logs would have been 1–23% higher than recorded. While the approach used by FERIC to estimate the impact of proper calibration on measuring accuracy may not reflect the true impact of calibration, it suggests that calibration alone will not necessarily be the answer to poor length measuring performance. Even measuring systems deemed properly calibrated sometimes exhibited a wide range of measuring errors. It also showed the need to collect length data for a sufficient number of logs and analyze the trend before calibrating the measuring system. The number of logs needed for the sample might vary. The Timberjack 3000 manual (Anon. 1996) recommends about 100 logs, but fewer logs may be sufficient if there is a clear trend.

FERIC also examined the need for diameter calibration of the measuring systems studied. Checking the need for diameter calibration is more complex than for length calibration as the diameter measuring accuracy must, on most machines, be checked at several points (diameters) over the entire measuring range. The amount of correction at each point could also vary. For the purpose of this study, FERIC assumed that a diameter calibration was needed if a statistically significant correlation existed between the magnitude of the measuring errors and the small-end diameter of manufactured logs. FERIC further assumed the appropriate calibration factor was that of a regression equation (Figure 8). Based on these assumptions, FERIC found that 23 of the 31 machines studied should have been calibrated at the time of the study. The projected improvement from calibration was substantial. On average, the percentage of logs with a measuring error within ±2 mm increased from 19% to 33%, while the measuring error within ±4 mm increased from 34% to 55%.

### Tree characteristics

Although tree branchiness was not found to impact measuring accuracy in all studies, FERIC attributed some of the variation in the measuring performance of single- and double-grip machines to the branchiness characteristics of the stems being processed. In those cases where FERIC could detect an impact, logs manufactured from the upper (branch-covered) portion of the stems were typically shorter (relative to the target lengths) and had a wider error range than those manufactured from the lower (normally branch-free) portion of the stems. Tree branchiness is also believed to have caused the differences in the measuring performance between spruce (most commonly white spruce), lodgepole pine, and true firs recorded in some studies. Results from those studies tended to suggest that the logs manufactured from the species with the most branches were slightly shorter than the logs manufactured from the species with less branches.

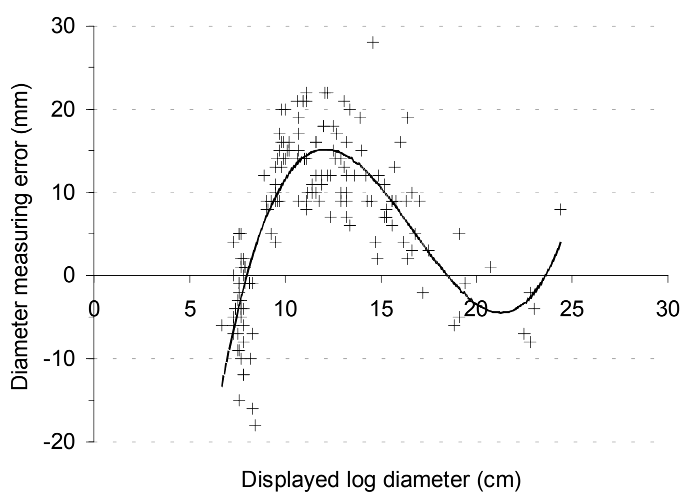



Figure 8. Example of diameter measuring performance from a CTL harvester study.

FERIC could not detect an impact from tree branchiness on measuring accuracy in the studies on stroker-type processors. However, there appeared to be a slight tendency for stems with smooth bark to slip from the holding grapple while the machine removed large-diameter branches.

### Seasonal differences

There was no strong indication that differences in the operating season affected the length measuring performance of the machines. Often, the machines operated in different types of stands in winter and summer, which made it difficult to compare the seasonal impact on the measuring performance. However, several machine operators told FERIC that they had found temperature fluctuations during the day in winter operations affected the measuring system, which required the measuring system to be re-calibrated. A likely cause of this would be that the teeth of the measuring wheels would penetrate to different depths depending on whether the bark/wood was frozen or had begun to thaw.

While FERIC conducted a couple of studies during the late spring/early summer period when the bark of the trees was soft, no conclusive evidence was found to suggest that the measuring accuracy during this period was different from those studies conducted during the winter or late summer/fall. However, several machine operators had experienced additional problems with measuring accuracy during springtime because of the soft bark.

### Machine types

The length measuring performance of the machines in CTL operations was better than for the machines in LL operations if measured in absolute terms, i.e., measuring error per manufactured log. However, if the measuring errors were expressed in proportion to the length of the manufactured logs (i.e., cm/m), the difference in measuring accuracy was not significant. Also, FERIC found no difference in the measuring accuracy between stroker-type processors and single-grip processors in LL operations when the majority of logs are in the 12- to 15-m length range.

FERIC found no difference in the length measuring performance between single-grip machines operating either as harvesters or as processors in CTL operations, nor was there a difference between such processors working at roadside or at the stump. However, the double-grip processors studied were found to be more consistent in their length measuring than the single-grip processors. While this difference may have been caused by factors other than the machine type, the double-grip machines had the advantage of being equipped with a much larger measuring wheel (100 cm circumference) than those commonly used on single-grip machines (circumference 50–70 cm). Large measuring wheels have been shown to be less prone to measuring error from irregularities or residual branch knots than those with small measuring wheels. Also, operators on the single-grip machines typically had to "zero" the measuring system by activating the cut-off saw when beginning to process the first (butt) log of the stems. If the operator missed the end of the stem (which occasionally happened), the butt log would not be accurately measured. Studies in Sweden also found that length measuring was more consistent on double-grip harvesters than on single-grip harvesters (Berg 1992).

Differences in the measuring performance between different measuring systems operating under similar conditions could not be adequately analyzed. However, there was no clear evidence that suggested that one measuring system was significantly more accurate than the others. No evaluation was done comparing the ease of programming the computers, retrieving information, or the ergonomics of working with the different measuring systems.

## Effects of length measuring performance on sawmill operations

The length accuracy of logs manufactured at the harvesting site can have a significant impact on the revenue from lumber or other solid wood products processed at subsequent mill operations. To illustrate this, FERIC calculated lumber recovery and production for a theoretical sawmill from the logs manufactured in seven studies on CTL machines. The results in Figure 9 are based on the following assumptions:

- The logs were sawn to lumber in 0.6-m length increments from 2.4 m to 6.0 m. The lumber yield by length and diameter classes is tabulated in Appendix II (Williston 1981).
- Logs manufactured at the harvesting site to within company length specifications yielded lumber of the intended length (i.e., no lumber losses). Logs shorter than the minimum length specification could only be sawn to lumber of the next shorter nominal length class. Logs longer than the maximum length specification yielded no lumber gain or any additional by-product of commercial value.
- The productivity of the breakdown saw was based on a constant feed speed of 84 m/min with a 30-cm space between logs.

The results from this theoretical mill study suggest that a machine that manufactures 20% of its logs below the minimum company length specification would cause a 2.5% reduction in the lumber yield and a 1.5% reduction in the lumber throughput. If this machine were to process 40 000 $m^3$ annually, and the average lumber recovery was 250 fbm/$m^3$ valued at Cdn $340/Mbfm, the annual loss of lumber revenue would amount to approximately $85,000. Thus, the forest industry could potentially gain millions of dollars in increased revenue if length measuring errors were reduced.

Producing logs that are longer than necessary (excessive trim allowance) will also result in lost sawmill revenue because it reduces sawmill productivity as more time is used by the breakdown saw to process the logs. While the actual production loss would depend on many factors, a rough estimate is that the sawmill production would decrease by 0.15% for every centimetre that the average log is longer than necessary. Because of log taper, it is also possible that excessively long logs would be cut with a different sawing pattern yielding less lumber than would have been the case had the log been slightly shorter.

To guard against forest machines producing logs that are too short, companies

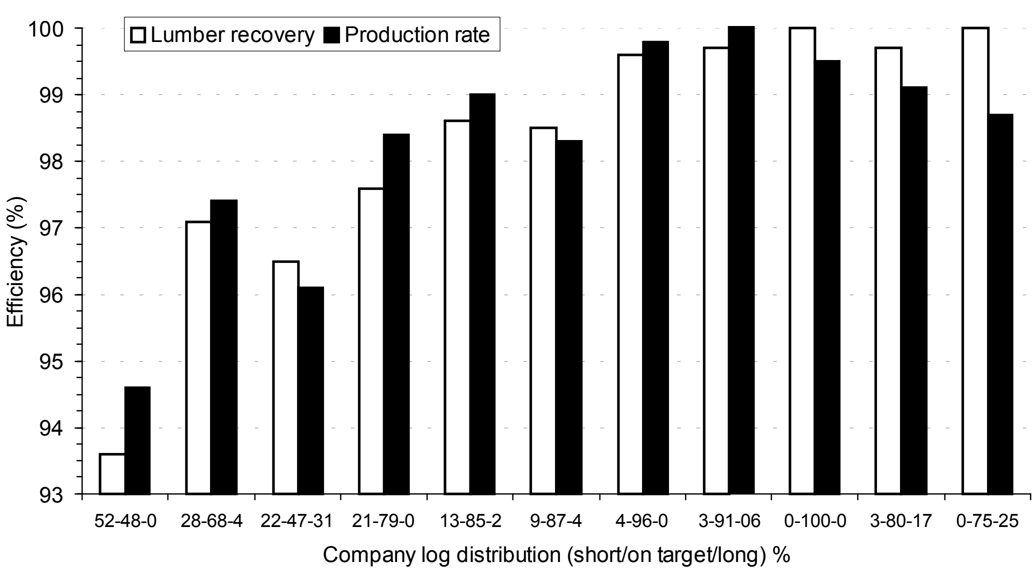



Figure 9. Projected results of lumber recovery and mill productivity for 11 different CTL studies.

commonly include a trim allowance in their log specification. The size of trim allowance should be such that it minimizes fibre losses from logs being too short or too long. FERIC found that the optimum size of the trim allowance is dependent on the length measuring consistency of the machine manufacturing the logs. The more consistent the machine is in its length measurement, the smaller the trim allowance required to minimize wood fibre losses at the mill operation (Figure 10).

## Recommendations to improve measuring accuracy

This study has shown that the length measuring accuracy that currently is achieved among machines processing CTL logs at the harvesting site is potentially costing the forest industry in western Canada millions of dollars annually. While it would be very difficult to completely eliminate the causes for measuring errors, the study showed that machine operators and company personnel can, to some extent, control several of the factors causing poor measuring accuracy. This can be done by taking some simple and cost effective actions that could substantially increase the value of the manufactured logs.

### Committment

FERIC believes that a fundamental condition to achieve an acceptable level of measuring accuracy is that all parties involved in the harvest operations are committed to the log accuracy program. Tasks required ensuring good accuracy need to become part of the operators' and supervisors' regular work, and not regarded as "something extra that has to be done".

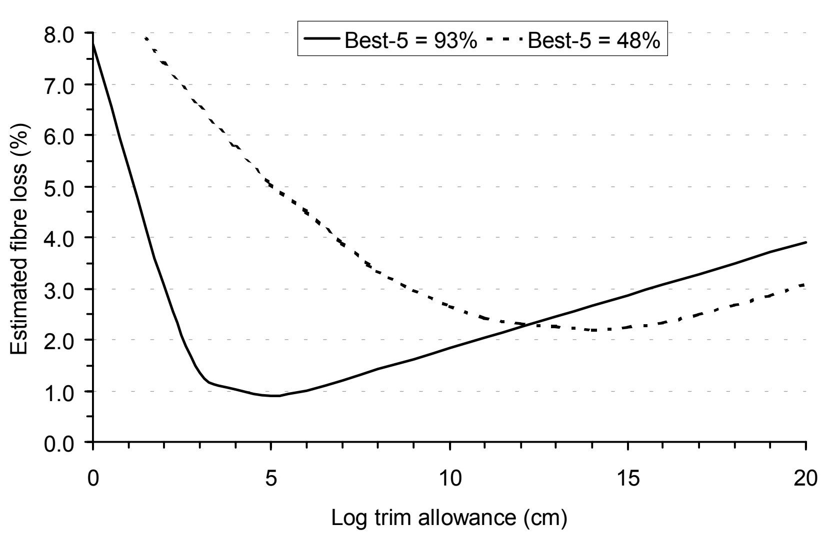
### Communication

Information on the log specifications must be clear and well understood by operators, machine owners, and company staff. They should be documented in both imperial and metric units and distributed to all concerned. FERIC strongly suggests that metric and imperial units should not be used interchangeably. Operators whose machines display log dimensions in metric units should get into the habit of only using metric measurements when checking log accuracy and when communicating with their harvesting supervisors.

### Realistic log specifications

Targets for length measuring accuracy need to be realistic, and should reflect the value of the product to be manufactured from the logs. Results from this study suggest that CTL machines should, under most operating conditions, be able to manufacture 90% of the logs within a length tolerance of ±5 cm, while machines in LL operations could achieve either 75% of the logs within ±5 cm,

Figure 10. Example of relationship between trim allowance and wood fibre losses for two studies with different length measuring consistencies.



or 90% of the logs within ±10 cm. However, it would be reasonable to set a narrower length tolerance for logs that are to be manufactured from the branch-free (clear) portion of the stem. The studies showed that the top logs typically spoiled the overall length measuring performance of the machine. Because top logs are less valuable than the other logs from the same tree, it would be reasonable to accept a slightly higher length tolerance for these logs than for butt and mid logs.

### Log accuracy checks

Part of the operators' daily work should be to check a number of logs for measuring accuracy (Makkonen 2001). The number of logs and times during the shift that logs should be checked might vary with operating conditions and past experience, but 3–5 logs twice a day should be sufficient. The selected logs should be representative of the stand. FERIC recommends that the data be plotted (log length versus length error) and that no adjustment be made to the measuring system until an adequate number of logs have been sampled to determine if there is a tendency for the measuring system to measure short or long.

Log accuracy checks should also be done by the company on a regular basis and should include a sufficient number of logs (e.g., 50–100 per check). The company should conduct these checks at the harvesting site, and provide the result to the operator that manufactured the logs.

### Maintenance of equipment

Keeping the components of the measuring system in good working condition is essential to obtaining good measuring accuracy. Other processing components should also be kept in good working order. The condition of the delimber knives is especially important.

### Understanding the measuring system

The machine operators need to have sufficient knowledge of the measuring system so that they can access the information programmed in the computer, and be able to detect when the system is not working properly. This may be a challenge because trained operators may not always be available when needed. The time and cost invested in providing new operators with the basic training would be money well spent and would benefit both the company and the owner of the machine. Manufacturers of the measuring systems could greatly contribute to this by providing instruction to inexperienced operators in the form of field visits by qualified instructors, and videotapes and operator manuals describing the basics of the measuring systems.

Logging supervisors should have some basic understanding of both the measuring system and how measuring accuracy can be affected by various operating conditions.

### Sharing the gain

Implementing a log accuracy program can adversely affect both machine productivity and operating costs. Non-productive time may increase because the operator needs time to check logs for accuracy, and for service, repair or waiting for parts to the measuring system. The cost may increase due to additional capital investment and maintenance of the measuring system. Despite that, the gain through higher revenue from the logs should offset the extra cost. However, as the cost often is borne by the harvesting phase while the milling phase reaps the reward, there could be some issues that need to be addressed. Some companies have opted for a quality incentive program that recognizes logging contractor quality performances. Other companies feel that log quality is a basic requirement of logging and, therefore, have no special quality incentive program. The authors of this report neither support nor oppose the two policies. However, achieving good measuring accuracy has an associated cost.

## Conclusions

Harvesters and processors with computerized log measuring systems that operate in western Canada are primarily using these systems to ensure that the logs they manufacture are within their respective company's log specifications. The diameter and volume measuring features available on most measuring systems are not commonly required for making operational bucking decisions. Thus, less emphasis is placed on these components for measuring accuracy.

Using company log specifications as the standard for length measuring accuracy, FERIC found that between 37% and 100% of the logs processed in 83 CTL operations were accurate, while the corresponding percentages in 20 LL studies were 36% and 95%. Approximately half of the machines studied exceeded the minimum level of company-accepted log specifications. Other standards used by FERIC to evaluate length measuring accuracy, such as percentage of logs manufactured to within the measuring system's saw window setting and the length measuring consistency in terms of Best-5 and Best-10, also showed a large variation in the length measuring performance among the machines studied.

FERIC studied the diameter measuring accuracy on 31 CTL machines. The results were expressed as percentages of the small-end diameter of the logs measured by the machines within errors of ±2 mm, ±4 mm, and ±8 mm. On average, FERIC found that 19%, 34% and 57% of the logs were within these error limits, respectively. These results were not considered representative of the machines' diameters measuring accuracy, as the diameter measuring systems in 23 cases were not properly calibrated. FERIC estimated that had they been properly calibrated, 33% and 55% of the logs would have been within ±2 mm and ±4 mm, respectively.

FERIC concluded that the variation in measuring performance recorded in this study was caused by several factors. Some of this variation was attributed to factors over which loggers have little control, such as the design of the measuring system or the characteristics of the trees being processed. However, a number of controllable factors also influenced the results. These were particularly evident among the studies on the machines in operations where the emphasis on measuring accuracy at the harvesting site was somewhat relaxed. By implementing a log quality program with strong emphasis on measuring accuracy, a substantial improvement in the industry-average measuring performance is possible. FERIC estimated that under most operating conditions, machines in cut-to-length operations should be able to manufacture 90% of the logs within a length tolerance of ±5 cm, while machines in long-log operations should achieve 90% of the logs within ±10 cm. FERIC identified the following items as important to achieving good measuring accuracy:

- A procedure for designated company staff members to regularly check measuring accuracy of an adequate number of logs (50–100) at the harvesting site, and provide the operators with immediate feedback.
- Well-defined company log specifications, in both imperial and metric units, that are readily available in a understandable format for operators and field staff.
- A process that will ensure that machine operators are sufficiently familiar with their machine's measuring system, so that they can access the information programmed in the computer and detect when the measuring system is not working properly.
- A process that will ensure that operators, as part of their daily work routine, check a small number of logs that are representative of the stand for accuracy. Approximately 100 lengths and 30 diameters should be collected to determine any trend in the measuring performance before the measuring system is re-calibrated.
- Training to ensure that harvest supervisors understand how the measuring systems work and what factors influence their measuring performance.

FERIC estimated the loss in revenue to the forest industry in B.C. and Alberta from the length measuring accuracy data recorded in this project to be in the millions of dollars annually. The investment needed to improve this measuring accuracy is estimated to be insignificant compared to the potential increase in the value of logs delivered to sawmills and other solid-wood users. Improving measuring accuracy of harvesters and processors also opens the opportunity to utilize these machines for true value optimizing of logs manufactured at the harvesting site.

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# Appendix I

## Definitions

| | |
|---|---|
| Actual diameter | The diameter measured over bark using a caliper. Two readings were taken 20 cm from the end of the log at 90° to each other, and averaged. |
| Actual length | The length of the log (stem) measured end-to-end along its surface using a logger's tape, and recorded to the nearest centimetre. |
| Best-5 and Best-10 | A measure of length measuring consistency. The length error (or length deviation) is calculated for each log, and tabulated by 1-cm error classes. Best-5 and Best-10 are the ranges of the five and ten adjacent error classes, respectively, with the highest number of logs, expressed as percentages of all sampled logs (Figure I:1). Best-5 and Best-10 represent the machine's ability to produce logs within length variations of ±2.5 cm and ±5 cm, respectively. |
| Butt log | The log nearest the butt of the stem. For stems producing only one log, the log is classified as a butt log. |
| Company-accepted logs | Logs manufactured to within company length specifications, and expressed as a percentage of all measured logs. |
| Computer-accepted logs | Logs manufactured to within the computer saw window range. |
| Company length | The length specification supplied by the forest product company. The nominal lengths were often the same as target lengths. |
| Diameter error | Displayed diameter minus actual diameter. |
| Displayed diameter | The diameter shown on the computer screen at the time the log is bucked. |
| Displayed length | The length shown on the computer screen at the time the log is bucked. |
| Length deviation | Actual length minus target length. |
| Length error | Actual length minus displayed length. |

| | |
|---|---|
| Machine measured volume | The volume calculated directly by the machine's computer according to its volume calculation program (likely different from Smalian's formula). |
| Measured log | A log intended to be manufactured to a specific length, usually to comply with company length specifications. |
| Mid log | Any logs manufactured from the middle section of the stem, i.e., any log that is not a butt log or a top log. |
| Random-length log | A log manufactured to a non-specified length. |
| Saw window | The range around each target length at which the machine is programmed to buck the stem. Could be set either as ± X cm around target length, or as 0 to +X cm of target length. |
| Scaled volume | The volume determined based on actual length and diameter measurement and Smalian's formula (Vol = $(A_1 + A_2)/2 \bullet L$, where $A_1$ and $A_2$ are the areas of the log at butt and top, and L is the log length). |
| Target length | The lengths programmed in the machine's computer. |
| Top log | The log manufactured from the uppermost portion of the stem. |

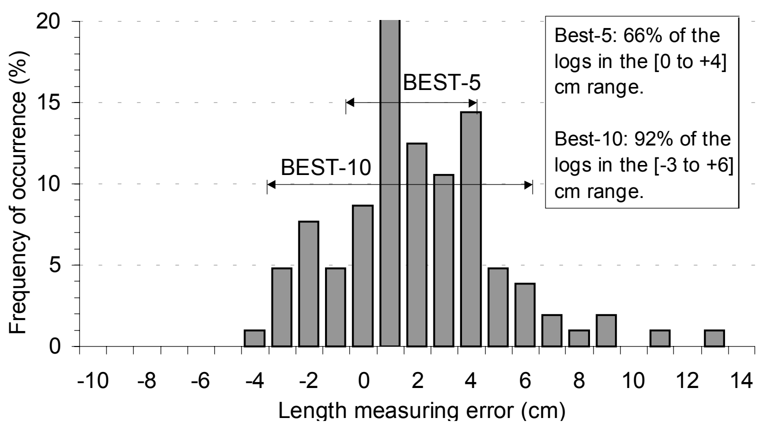


Figure I:1. Example of Best-5 and Best-10 in a length error distribution.

# Appendix II

## Lumber recovery table (fbm/log)

| Top diam. (in.) | Nominal length of log (feet) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| 5 | 11 | 13 | 19 | 22 | 25 | 29 | 33 |
| 6 | 16 | 23 | 28 | 33 | 37 | 42 | 47 |
| 7 | 21 | 29 | 35 | 41 | 47 | 53 | 61 |
| 8 | 32 | 40 | 48 | 56 | 64 | 73 | 81 |
| 9 | 40 | 50 | 60 | 70 | 81 | 91 | 102 |
| 10 | 53 | 67 | 80 | 93 | 107 | 120 | 134 |
| 11 | 61 | 77 | 93 | 107 | 125 | 141 | 157 |
| 12 | 75 | 93 | 112 | 131 | 149 | 171 | 192 |
| 13 | 87 | 108 | 130 | 152 | 173 | 200 | 224 |
| 14 | 104 | 130 | 156 | 182 | 208 | 234 | 261 |
| 15 | 116 | 145 | 174 | 203 | 232 | 265 | 296 |
| 16 | 133 | 167 | 200 | 233 | 269 | 306 | 343 |
| 17 | 152 | 192 | 231 | 270 | 309 | 352 | 392 |
| 18 | 168 | 210 | 255 | 297 | 340 | 383 | 431 |
| 19 | 187 | 233 | 281 | 332 | 381 | 431 | 480 |
| 20 | 213 | 267 | 320 | 373 | 427 | 485 | 541 |