METSÄTEHON katsaus

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SCANMAT 256 MEASURING EQUIPMENT

By Kaarlo Rieppo

The Scanmat 256 is a measurement device for calculation of timber volume, suitable for use with the most common boom-mounted harvesters. Structurally and functionally it is as simple as possible, which should pave the way for general use and acceptance. The volume calculation of saw logs is based on top diameter and length, and that of pulpwood bolts on mid-diameter and length.

Tests showed that the bucking accuracy for saw logs and pulpwood was acceptable: 77 % of the saw logs were within +3 cm of the target length, and 89 % were within +5 cm, while 93 % of the pulpwood was within +1 % (1 % of 5 m pulpwood is 5 cm), and 97 % was within +3 % of the target length. However, only less than one-third of the measurements of diameter were accurate within +2 mm. Deviation of diameter measurements was about 5 mm. According to this study, the device seems to be sufficiently accurate for volume calculation of saw logs: errors varied between -4.8 and +2.1 %. Volume results for pulpwood, however, were still poor. Part of the blame lay in the programming, and it should be possible to improve on the results.

Conscientious calibration is a prerequisite for an acceptable measurement accuracy. During testing, the equipment was calibrated by a representative of the manufacturing company. Despite this, calibration was not always sufficiently precise.

Fig. 1. The diameter sensor of the Scanmat 256 measurement equipment. Both photos by Metsäteho

GENERAL

The Scanmat 256 measurement equipment for use in boom-mounted harvesters has been developed by Mittalaite Oy (nowadays Savon Mittalaite Oy). The first device was installed in the spring of 1987. The equipment is designed for the control of delimbing and bucking of the tree as well as for the calculation of timber volume and amount.

The length of the timber is measured with a common measuring wheel, and the diameter over bark with a spécial measurement cylinder installed in the feeding device. The volumes of saw logs are calculated according to the timber measurement rule using a rounding-off 2 cm top diameter classification and 3 dm length classification. The volume of pulpwood bolts is calculated as if it were a cylinder formed by its mid-diameter and length.

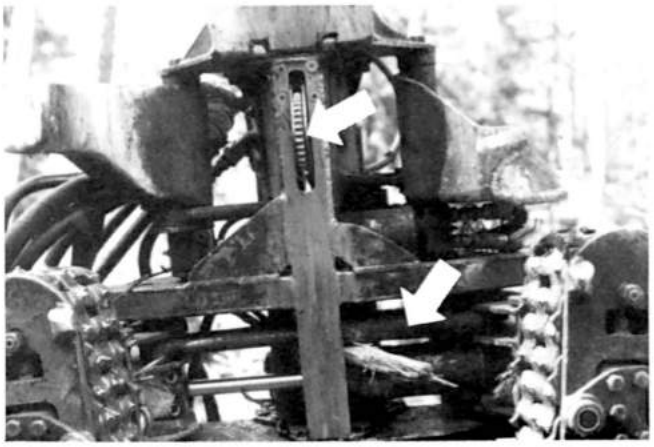

Fig 2. The measuring wheel for length measurement and the cylinder for diameter measurement

In an attempt to make the equipment reliable, the design is simple and the demands of the hard working environment of forest machinery has been taken into account. The equipment may be mounted on most of the common boom-mounted harvesters. It is guaranteed to function at temperatures ranging from -40 to +70 °C.

The Scanmat 256 measurement equipment is manufactured and marketed by Mittalaite Oy at Oravikoski in Central Finland. The price of the equipment in September, 1987, was 55,000 Fmk. The computer carries a 2 year warranty, and the components, sensors etc. the importer's warranty.

TECHNICAL DESCRIPTION

The Scanmat 256 measurement equipment is micro-computer-based. It is composed of a central processing unit, a terminal and various sensors. The electronic components are placed in a dust-and-splash-proof casing. The components are MIL classified.

The measurement equipment is operated through keys mounted on the control levers of the harvester. The keys are also used for programming the changeable settings. The display shows 8 figures and the functioning of the equipment may be followed continuously on the display.

The sensors of the automatic functions and the programming of the equipment are set according to type of logging machine. For instance, the following sensors may be used:

- Upper and lower position of sawbar
- Feeding equipment open or closed
- Feeder pulse (length of timber), two channels
- Diameter of stem
- Tilt of multiprocessing unit

The automatic functions are connected electrically to the hydraulic system of the logging machine. If the logging machine has an electro-hydraulic control system, the automatic functions may be installed parallel to it; otherwise separate electrical valves must be installed. The following functions may be automatically controlled:

- Feeding forward
- Slowing down of feeding (forward)
- Stop at bucking point
- Feeding backward
- Slowing down of feeding (backward)
- Sawing
- Return of sawbar in upper position
- Closing of delimbing knives
- Opening of delimbing knives
- Closing of feeding equipment
- Opening of feeding equipment
- Rpm regulation

The length of the stem is measured using a common measuring wheel. The length information from the wheel is transferred through two sensors and cables to the display and into the computer memory. Feeding is automatically slowed down before the chosen length is reached. The slowing down distance may be set at 1 cm intervals from 0 to 100 cm.

Diameter measurement is based on the opening angle of the feeding device arms. The movement of the measurement cylinder installed into the feeding device is transferred with a simple block chain to the absolute or angle sensor. The variations in chain gap have been eliminated by keeping the chain taut with a spiral spring. The sensor is in a vibration-proof casing, the diameter of which is 11 cm and length about 22 cm. The sensor does not require that the closing movement of the feeding tracks or rollers is linear.

The opening angles of the feeding device arms, the corresponding sensor values, and the stem diameter data in the feeding device are used for composing an appropriate table for each individual logging machine type. During operation, the measurement equipment selects from the table the diameter data corresponding to the sensor value. The equipment is programmed so as to take into account the difference between the point of measurement and the point of bucking for the purpose of volume calculation.

The volume calculation program does not allow for the effect of the mean length correction of the saw logs in the timber lot on the solid volume, nor does it allow for the effect of the mid form factor on the solid volume of pulpwood. There are programs for all volume calculation tables for saw logs.

During measurement, the display shows the length and diameter. The volume calculation results may be printed out (Fig. 3) using a printer designed for

```
Deleted: Deleted by:
  020787  1
Date?
  111111
Area? (3)
111
Stand? (5)
11111
Work site? (2)
11

Tree species?
Spruce
South=1 Coast=0
1111111
Diam.  No of   m3(s)
cl.   saw logs
13        0     0.000
15        0     0.000
17       25     3.778
19       14     2.599
21       19     3.983
23        4     1.056
25        2     0.475
27        0     0.000
29        0     0.000
31        0     0.000
33        0     0.000
35        0     0.000
37        0     0.000
39        0     0.000
41        0     0.000
43        0     0.000
45        0     0.000
47        0     0.000
49        0     0.000
51        0     0.000
53        0     0.000
55        0     0.000

Total    64    11.892
Saw log running metre
    3175 dm
Pulpwood of saw log
 stems
   6.260 m3(s)
No of pulpwood bolts
     107
No of saw log stems
      48
Pulpwood stems
   5.210 m3(s)
No of pulpwood bolts
      95
No of pulpwood stems
      37
Rot volume
   1.400 m3(s)
No of rotten pulpwood
 bolts
      13
```

Fig. 3. The volume calculation result is outprinted by tree species as above

use in the terrain. Alternatively, there is a data recorder which may be used for transferring the data directly into a computer memory.

The memory unit of Scanmat 256 is battery-secured. There is 128 kB of RAM.

WORKING DESCRIPTION

Before starting work, the limit values are fed into memory. These values remain there until changed. The minimum top diameter of the saw log at which point the system automatically begins to cut pulpwood length is fed into the system by tree species. The lengths of saw logs and pulpwood bolts may be set by tree species. Pulpwood lengths are cut automatically for as long as there is stem left by pushing a button once. The diameter for bucking the top may be set at the desired value.

When the tree is felled, saw log length and tree species are chosen by pushing the desired buttons. Feeding is started automatically. The equipment through its sensors continually follows up the movement of the stem through the logging machine's handling system and, on the basis of the information from the sensors and according to preset instructions, decides on the bucking points on the stem. When the chosen length is fed, the stem is automatically bucked or the system stops to await the command to saw, i.e. the pushing of the button. The saw log length may be changed by pushing the button at the desired length either during feeding or during the pause before sawing.

The machine will not automatically buck a stem at less than the absolute minimum length and diameter values. When the system seeks the correct stopping point before sawing, it automatically takes into account the length and diameter data of the stem, as well as earlier speeding up and slowing down values, and decides on an optimum stopping point.

When length is calibrated, the system is given a stopping area within which the stem must be stopped. In addition, a braking distance is defined, which shows how far the stem typically travels after braking has started. The distance is dependent on many factors. The braking distance must, if necessary, be changed according to the lengths of test logs.

Diameter calibration, with an allowance of ± 15 mm, is done from the cab. For purposes of calibration, the diameters of the test logs are measured at the point of the measurement sensor.

The central processing unit has a built-in testing program for pinpointing possible malfunctions. The CPU itself is quickly replaced by another. If necessary, manual control is always possible.

TESTING

Metsäteho tested the Scanmat 256 measurement equipment in Karhula and Elimäki in Southern Finland in June - July, 1987. The device to be tested was a prototype installed on a Keto 100 boom-mounted harvester. During testing the weather was both sunny and rainy. The machine operator was experienced in handling harvesters, but was not fully familiar with the measurement equipment.

Testing concerned the accuracy of length and diameter measurement and volume calculation for both saw logs and pulpwood. Accuracy of length measurement was evaluated both during operation of the logging machine and afterwards. When the machine handled a log, the length displayed by the measurement equipment was manually noted and afterwards compared with the actual length measured with a measuring tape. Remeasurement was used to check the module measurements and standard lengths measured by the equipment against the actual lengths of the saw logs and the pulpwood bolts.

In order to check diameter measurement accuracy, the diameter displayed by the equipment was manually recorded, with an accuracy of 1 mm, and compared with the actual diameter, measured at the same point, perpendicularly to a measuring wheel, using calipers with a mm distribution.

The accuracy of volume calculation was evaluated by control measurement of individual logs and by remeasurement of small cutting lots. During operation of the machine, the volume results of individual saw logs and pulpwood bolts were checked by measuring either the top or the mid-diameter and the length, on the basis of which volume calculation was done. Corresponding values were obtained directly from the display. Small cutting lots were harvested and their volume calculated for remeasurement purposes with the measurement equipment and a print-out of the volume was obtained. After harvesting, the same lot was measured manually using the same measurement method as used by the equipment.

RESULTS

Accuracy of length measurement

The length as measured by the equipment on the one hand, and manually using a measuring tape on the other, were the identical to the centimetre in about one out of four

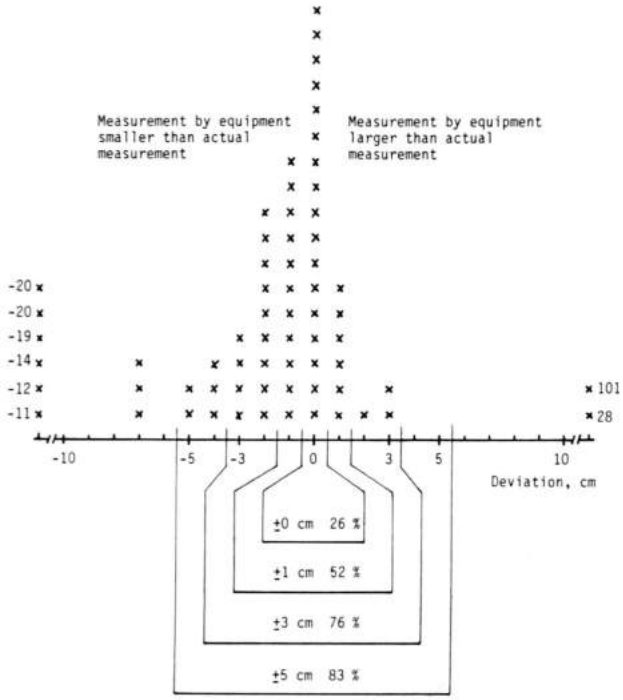

Fig. 4. The deviation between the length measurements by the equipment and actual length measurements done with a measuring tape

cases of the 66 measurement tests carried out (Fig. 4). A difference of no more than ±3 cm was noted in 76 % of the test measurements, and in 83 % of the tests the difference was at most ±5 cm. Greater differences were generally a result of the stem having moved in the multiprocessing unit during felling. Another reason for difficulties in length measurement was the fact that bark easily comes off during the period of sap flow; at times a loose piece of bark stuck to the front of the measurement wheel preventing it from rotating. Deep butt crevices, where the measuring wheel did not reach the stem, also resulted in measurement inaccuracies.

Accuracy of saw log bucking, according to 61 saw logs measured at the second work site, was as follows: 77 % were within ±3 cm of target length, 89 % within ±5 cm and 98 % within ±10 cm. At the same work site, accuracy of bucking pulpwood to 5 m lengths was as follows: 93 % were within ±1 % of target length (1 % for 5 m pulpwood is 5 cm), and 97 % within ±3 %. At the first work site bucking accuracy was slightly poorer than at the second, due to poor calibration; the measurement equipment made the saw logs too long by 3 cm on average.

Accuracy of diameter measurement

The difference in the diameter of pine as measured by the equipment on the one hand and manual measurement on the other was -2.4 mm on average, and of spruce -3.0 mm on average (Figs 5 and 6). The corresponding deviation was 5.5 mm and 4.8 mm. Judging

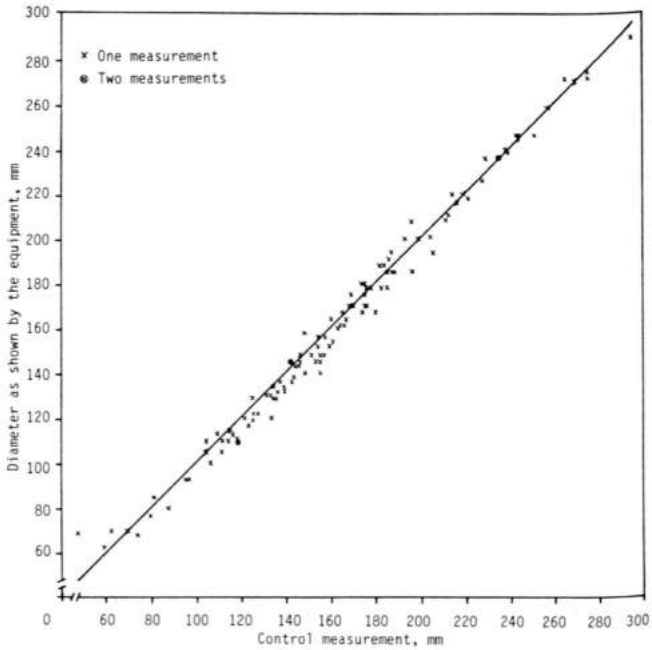

Fig. 5. Measurement accuracy for diameter of pine

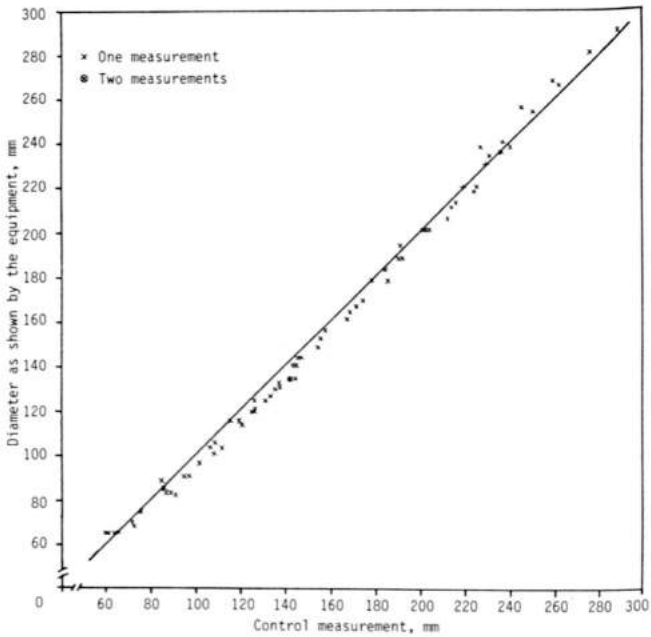

Fig. 6. Measurement accuracy for diameter of spruce

by the results, the calibration was not quite accurate; the equipment showed the diameter as too small. The smaller deviation for spruce is probably due to its thinner bark.

The difference in the measurements given by the equipment and manual measurement was ±2 mm at most in 29 % of the material (Fig. 7). The difference for pine was 33 % and for spruce 24 %. If calibration had been entirely accurate, the proportion would have been 38 % of the entire testing material.

The accuracy of top diameter setting was checked using the last pulpwood bolt taken from the stem. Top diameter over bark was 71 mm, from a sample of 46 pulpwood bolts. The proportion of top diameter under 65 mm was slightly over 30 %.

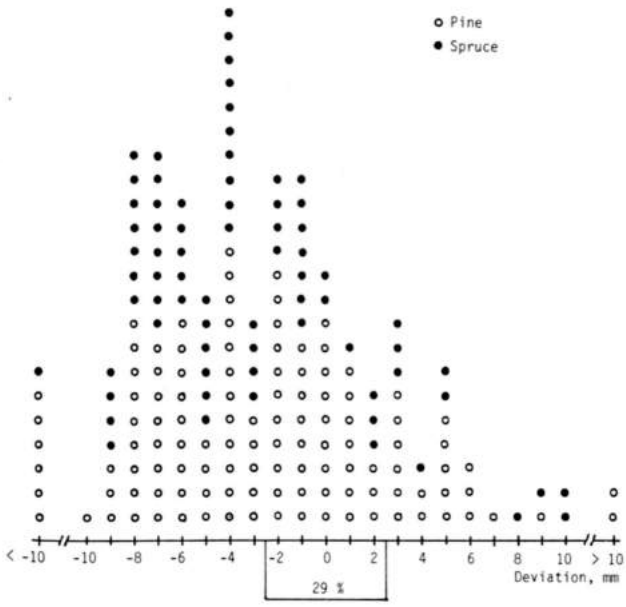

Fig. 7. The deviation between the diameter measurements by the equipment and the actual diameter measured using calipers

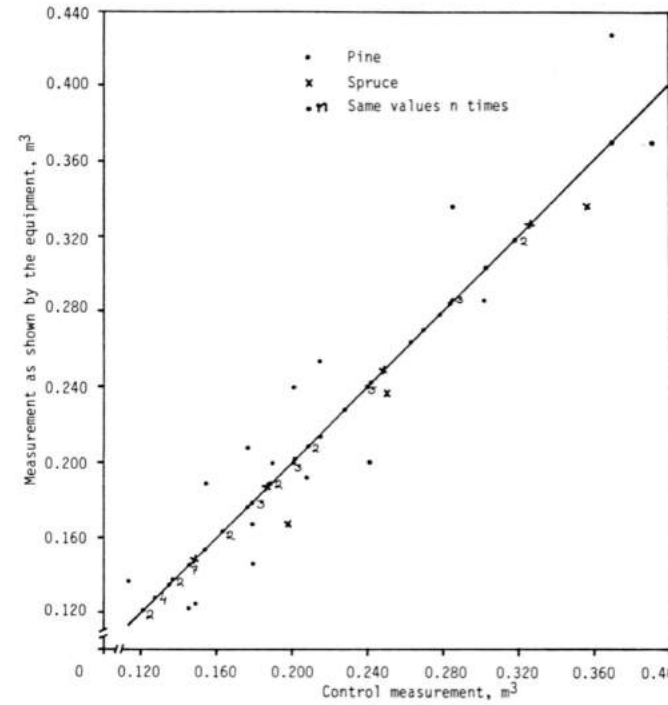

Fig. 8. Volume calculation of individual saw logs

Accuracy of volume calculation

During control measurement of the calculation of individual saw log volumes, automatic and manual measurement gave the same diameter class in eight cases out of ten. In every tenth case there was a difference in length class. In one case only, both the diameter class and the length class were incorrect at the same time. A total of 73 test measurements were carried out, 66 of which on pine saw logs.

During control measurement of the calculation of individual saw log volumes, three out of four measurement results were completely correct (Fig. 8). The results shown by the equipment were too large nearly as often as too small. In the overall volume, these inaccuracies compensated for each other. The overall volume error in this material, in fact, was only -0.2 % (pine -0.7 %, spruce +3.8 %). The absolute error, where errors are added up regardless of sign, was 3.5 % (pine 3.5 %, spruce 3.8 %). A total of 13.6 m^3 (s) was control measured.

During control measurement of the calculation of individual pulpwood bolt volumes, the results showed that automatic measurements were too small on average (Fig. 9). The overall volume error was -8.4 % and the absolute one was 9.6 %.

Accuracy of saw log volume calculation was checked at two work lots: at the first, 42 pine logs and 8 spruce logs were remeasured, and at the second 50 and 11 logs correspondingly. Volume calculation errors for pine were +2.1 % and -1.1 %, and for spruce -0.9 % and -4.8 % (Table 1). The number by count was correct.

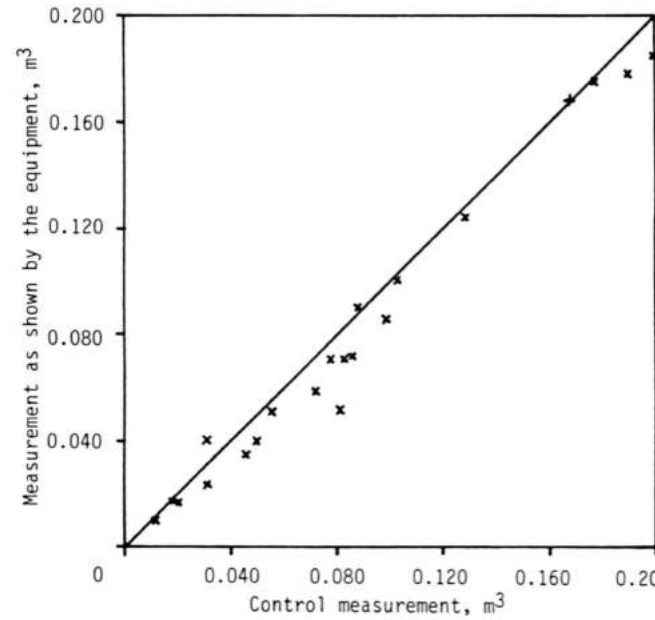

Fig. 9. Volume calculation of individual pulpwood bolts

TABLE 1 Volume checking of saw logs

Cutting lot	Pine			Spruce		
	Equipment m^3	Man (s)	Difference, %	Equipment m^3	Man (s)	Difference, %
1	9.309	9.121	+2.1	1.982	2.000	-0.9
2	7.850	7.938	-1.1	1.963	2.063	-4.8
Total	17.159	17.059	+0.6	3.945	4.063	-2.9

TABLE 2 Volume checking of pulpwood bolts

Cutting lot		Pine			Spruce		
		Equipment	Man	Difference, %	Equipment	Man	Difference, %
1	m^3 (s)	7.879	8.821	-10.7	2.110	2.502	-15.7
	no	133	127	+4.7	58	57	+1.8
2	m^3 (s)	5.905	6.822	-13.4	1.628	1.888	-13.8
	no	117	116	+0.9	28	30	-6.7
Total	m^3 (s)	13.784	15.643	-11.9	3.738	4.390	-14.9
	no	250	243	+2.9	86	87	-1.1

The results for pulpwood were poorer; the equipment measured both pine and spruce pulpwood volume as too small at both work lots. Volume calculation errors were -11 to -16 % (Table 2). Only work lot 1 contained hardwood (birch, 21 bolts). The error was -18.1 %.

The error in the number of stems by count at work lots 1 and 2 was 2.9 %. There were a total of 171 stems.

EVALUATION OF THE RESULTS AND CONCLUSIONS

As far as length measurement was concerned, the Scanmat 256 measurement equipment, mounted on a Keto 100 boom-mounted harvester, almost completely fulfilled the requirements set out in 1987 (see Notes below). The testing was done during the worst period of sap flow in June - July, which made the results slightly poorer. If a larger processing unit than the Keto 100 is used, the measurement error may be reduced as a result of better gripping and a reduction of slipping of even slightly larger diameter trees.

Diameter measurement did not fulfil the general requirement (see Note 2); only less than one-third of the control measurements fulfilled the requirement. The requirement of a ±2 mm measurement accuracy is hard, but it is a prerequisite for accurate volume calculation and above all bucking optimizing. For control measurement of diameter, it is difficult to define the correct measurement point both in the lengthwise direction and particularly in the crosswise direction of the stem. The measurements were always carried out in the same manner, and therefore the possible error was a systematic one. The deviation of the measurement results seem to indicate that diameter measurement accuracy should be improved.

A reasonably accurate volume result may be obtained even though diameter measurement accuracy is not achieved. In such a case, however, the diameter measurement error must not be systematic but should vary. That way the measurement errors compensate each other. In this case - as a result of the type of volume calculation - the volume errors due to the measurement of diameter generally occured near the diameter class limits. In the middle of the class a measurement error of -10 to +9 mm would not result in a change of class.

On the basis of control measurements, it seems that the Scanmat 256 measurement equipment is sufficiently accurate for measuring softwood saw logs (Note 3). On the other hand, the equipment did not fulfil the requirements for volume calculation of pulpwood. According to the manufacturer of the equipment, an error was found in the pulpwood volume calculation program after this test was done. After correction of the program, the volume error was in the other direction. Better results than those shown in Table 2 may be possible if the program is corrected carefully.

Accurate calibration is a prerequisite of successful measurement. Calibration must be carried out conscientiously and often enough, at least once at each work site and always when the circumstances affecting the functioning of the equipment - for instance temperature - change. This is particularly true for measurement of pulpwood; as a result of its small diameter, even a small error will result in a large error in the final result. For instance, in the measurement of 5 m pulpwood - mid-diameter 100 mm - an error of 1 mm results in a 2 % error in volume, and a 2 mm error in a 4 % error in volume.

Notes 1 to 3 (Metsätehon katsaus 12/1987):

1. Bucking accuracy:
   saw logs 70 % at an accuracy of ±3 cm
   90 % " " " " ±5 cm
   pulpwood cut to standard length
   70 % at an accuracy of ±1 %
   all " " " " ±3 %
2. Diameter measurement at an accuracy of ±2 mm
3. Volume may not deviate by more than ±4 % from the volume measured with the same measurement method in the stand

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