Wagner Europe Ltd.
Mr Richard Vivers
PO Box 312
Folkestone, Kent CT20 2GL
GREAT BRITAIN

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Martin Kemmsies, Building Technology Tel +46 33 16 51 31	1998-06-29	97B2,1983	1 (14)

Comparative testing of Wagner L612, electrical resistance meters, and the oven-dry determination of wood moisture content on Norway spruce and Scots pine

(2 appendices)

Summary

A test sequence was carried out to compare the accuracy of hand-held wood moisture meters based on the principle of electrical resistance (on-site mill readings and a calibrated meter), and Wagner's L612 capacitance moisture meter (mill readings). Results were compared to those provided by the oven-dry test method, which served as a benchmark value for the comparisons.

Wood species tested were Swedish Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*), the two most common coniferous species in Scandinavia. Two hundred samples per wood species were collected at three geographically distinct sawmills in Sweden, both in southern and northern Sweden.

1 Introduction

1.1 Customer's name

Wagner Electronics
326 Pine Grove Road
Rogue River, OR 97537
USA

1.2 Scope

To compare the accuracy of hand-held resistance wood moisture meters using the electrical resistance principle and Wagner's L612 capacitance moisture meter, as compared to results provided by the oven-dry test method.

To calibrate and verify Wagner's L612 settings to Swedish Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*).

1.3 Date of the test

Testing began Dec. 3rd, 1997 and ended on Feb. 24th, 1998.

2 Test procedure

2.1 Species and dimensions

Two hundred samples of the two most common Swedish coniferous species were tested: Norway spruce and Scots pine. The dimensions were representative industrial dimensions found within the Swedish sawmilling industry, varying in thickness from 22 mm to 50 mm.

2.2 Sawmills

Timber from three Swedish sawmills was sampled and tested. All mills harvest their timber from a large area.

- Anderssons AB (Borgstena), southern Sweden, visited on December 3rd, 1997. Fifty samples per wood species were taken: S1 - S50 and P1 - P50.
- Martinssons AB (Byggdsiljum), northern Sweden, visited on December 9-10th, 1997. One hundred samples per wood species were taken: S51 - S150 and P51 - P150.
- Södra Timber AB (Värö), southern Sweden, visited on February 24th and March 2nd, 1998. Fifty samples per wood species were taken: S151 - S200 and P151 - P200.

SP sampler and tester was Martin Kemmsies. The resistance moisture meter operator for the respective sawmills was always one and the same person.

2.3 Sampled moisture content range

The range of the material's nominal moisture content at the sawmill was between 8 % and 21 %.

2.4 Measurements and instruments used

Four types of measurements were made, resulting in four sets of data:

Measurement I - Mill readings with a resistance meter

Readings using electrical resistance meters normally used by the sampled sawmills, and used by the operator on-site in the way he usually took his readings when measuring wood moisture content. The meters used at all three sawmills were of one make: Delmhorst RDM-2S.

Only one small extra instruction was given to the operator before taking the measurement: that he drive in the pins 0,3 X thickness of the board into the board, as stated in the draft to the European norm prEN (175-13.01-2) - in contrast, the national Swedish standard SS 232740 states that pins must go in 0,2 X thickness of the board.

This instruction was given to make the data comparable to SP's electrical resistance meter readings.

No further instructions were given to the operators, neither concerning the calibration of the meters, nor of the temperature the meters should be set to while measuring the m.c., which should thus typify exactly how mill operators use their m.c. measuring devices in real-life situations. Only after the sampling was carried out, the wood temperature was taken and compared to the setting the operator had set his meter to.

Measurement II - SP readings with a resistance meter

A calibrated electrical resistance meter of good quality (Delmhorst RDM-2), used by SP, and tested according to the current European draft proposal prEN (175-13.01-2): 1997E, whereby the moisture content must be measured at 0,3 X thickness of the board, along the fibres, after having adjusted the moisture measuring device to the wood temperature. At Martinssons sawmill these measurements were carried out at the sawmill's premises; material from Anderssons and Södra sawmills was measured at SP premises.

Measurement III - Wagner L612 capacitance meter

A Wagner L612 moisture meter using the capacitance measuring principle, used as per Wagner's recommendations, measured the same samples on-site simultaneously to Measurement I. The meter was set at SG setting 0,34 for Norway spruce and SG setting 0,41 for Scots pine, as agreed on with Mr Vivers (Wagner Europe).

Measurement IV - Oven-dry measurement

Oven-dry moisture measurements according to the current draft proposal prEN (175-13.01-1): 1997E. The material was dried for 3 days at 103 °C before being weighed. This was carried out at SP premises.

2.5 Testing procedure

Measurements I (mill readings with a resistance meter) and III (Wagner L612)

Sampling was carried out straight from the dried timber batches available at the sawmill. Samples ca. 300 mm long were capped from the end of the stacked boards in a given timber batch, ensuring that boards were not close enough to one another, so as rule out sampling from boards which had been sawn from the same tree. Samples were marked. Measurements I and III were carried out on-site.

Measurement II (SP readings with a resistance meter)

Measurements were carried out in the operator's shed at Martinssons; for material from Anderssons and Södra the samples were individually, tightly sealed in transparent plastic bags so as to prevent any loss in the sample's moisture content. Samples were immediately transported to SP, where measurement II was carried out. Care was taken to measure the m.c. at precisely the same location where measurements I and III had been carried out.

Measurement IV (oven-dry measurement)

Samples were removed from the sealed plastic bags as soon as they arrived at SP (in Martinssons case this was two days after sampling, in the case of the two other sawmills this was done on the same day), and cut into test pieces ca. 70 x 70 (x depth) mm, i.e. approximately the area of Wagner's measuring plate. The weight of each test piece was noted. After 3 days oven-drying at 103 °C, the sample's weight and volume were recorded. The density of the samples determined and expressed in oven-dry terms.

2.6 Adjustment of Wagner L612 settings for Swedish pine and spruce

After the initial readings were collected, data for the Wagner L612 and the oven-dry readings for all samples were submitted to Wagner Europe Ltd.

Before the Wagner L612 meters were tested on-site, they had been set to certain so-called "SG-settings". As Wagner Europe was not yet sure which settings were to be used for the species in question, estimates were used based on measurements made on Scandinavian conifers elsewhere, namely: SG 0,34 for spruce, and SG 0,41 for pine. These were not necessarily the optimal settings for these species for material originating from Sweden - this was still to be determined by using the raw data provided, i.e. an adjustment of the meters' settings based on the raw data provided was made.

Moisture content values were first converted from the SG 0,34 resp. 0,41 settings to so-called MM values, or benchmark (reference) values. To reach the new m.c. values, MM values were then recalculated using the new, adjusted SG settings. The formula for the recalculation with the new SG settings was provided by Wagner Europe and is shown in their manuals.

The new, adjsuted settings for the species tested are thus:

Spruce: SG 0,36 for southern and northern Sweden.
Pine: SG 0,42 for southern Sweden and 0,43 for northern Sweden.

It is of value to point out that the new, adjusted m.c. values have not been double-checked against a new set of data, but that they would have been achieved had the new SG settings been used.

3 Test results

Test results from the measurements are summarised in Appendix 1 for Norway spruce and in Appendix 2 for Scots pine.

Statistical analyses were made so as to facilitate the comparison between the different types of moisture measuring devices, and the methodology behind them. Oven-dry readings are to be considered to be the reading closest to the true m.c. of the sampled material, and therefore serve as the benchmark parameter in the comparison of the m.c. measuring methods. Samples P69, P137 and P141 were considered to be faulty ("outliers") and were not considered in the analyses.

3.1 Mean values for the batches

Measurements made on the material were carried out on batches of timber dried to a certain m.c., so that groups of samples with the same m.c. could later be compared. Batches typically had ca. 10-25 samples each, at times 50 samples per batch. Results are expressed as the difference between a given batch's mean m.c. and the mean oven-dry m.c. reading, in absolute m.c. % terms.

Table 1 Difference between a batch's mean m.c. to the mean oven-dry m.c. reading for the respective measurement methods (expressed in absolute m.c. % terms), for spruce.

Batch (Spruce)	Mill resistance meters	SP calibrated resistance meter	Wagner L612 SG 0,34	Wagner L612 SG 0,36
S1-S15	0,6	-0,1	2,2	1,7
S16-S30	1,1	0,5	-4,0	-4,5
S31-S40	0,7	0,2	-0,6	-1,1
S41-S50	-0,3	0,4	0,7	0,2
S51-S100	1,1	0,6	0,6	0,2
S101-S125	3,9	2,5	0,0	-0,4
S126-S150	4,3	2,2	-1,5	-2,0
S151-S175	0,3	-0,6	-0,4	-0,8
S176-S200	1,4	0,0	0,6	0,1

Table 2 Difference between a batch's mean m.c. to the mean oven-dry m.c. reading for the respective measurement methods (expressed in absolute m.c. % terms), for pine.

Batch (Pine)	Mill resistance meters	SP calibrated resistance meter	Wagner L612 SG 0,41	Wagner L612 SG 0,42/0,43
P1-P20	-1,0	-1,5	-2,4	-2,6
P21-P40	0,4	-0,2	2,2	1,9
P41-P50	-0,5	6,9	-1,6	-1,9
P51-P85	-1,0	-1,3	-4,3	-4,8
P86-P118	-0,7	-0,3	1,1	0,6
P119-P134	-0,1	0,0	-2,1	-2,6
P135-P150	-0,2	-0,5	1,2	0,8
P151-P175	0,8	0,0	0,3	0,1
P176-P187	2,7	2,9	1,4	1,2
P188-P200	1,9	2,2	1,7	1,5

Such a comparison is of interest to sawmills which typically take readings from many samples in a batch of timber, calculate the mean for the batch, and then compare this to the mean oven-dry readings of that batch.

For all four measurement methods there are certain batches in which a better or worse estimate of the oven-dry m.c. may be achieved. See Sections 3.2 and 3.3 for a more detailed analysis of the data seen as a whole, and not in batches.

3.2 Comparison : percentage of the readings for the respective measurement methods within ± 0,5 % and ± 1,0 % (expressed in absolute m.c. % terms) of the oven-dry reading

For all three m.c. measurement methods a comparison was carried out to check what percentage of the readings were within a certain interval around the oven-dry readings (expressed in absolute % m.c.) - see Figures 1, 2 and 3. A clarifying example from Figure 1: 14,0 % of the individual spruce readings for the mill resistance meter were within ± 0,5 % m.c. of the oven-dry reading they were compared to (expressed in absolute m.c. % terms).

In this manner, one may compare how close the respective measurement methods for the whole data series of each species were to the oven-dry reading.

However, this data analysis cannot ascertain whether a skewness around the oven-dry readings is present or not, and whether there is a difference in accuracy of prediction along the whole operative m.c. range - see Section 3.3 for this comparison.

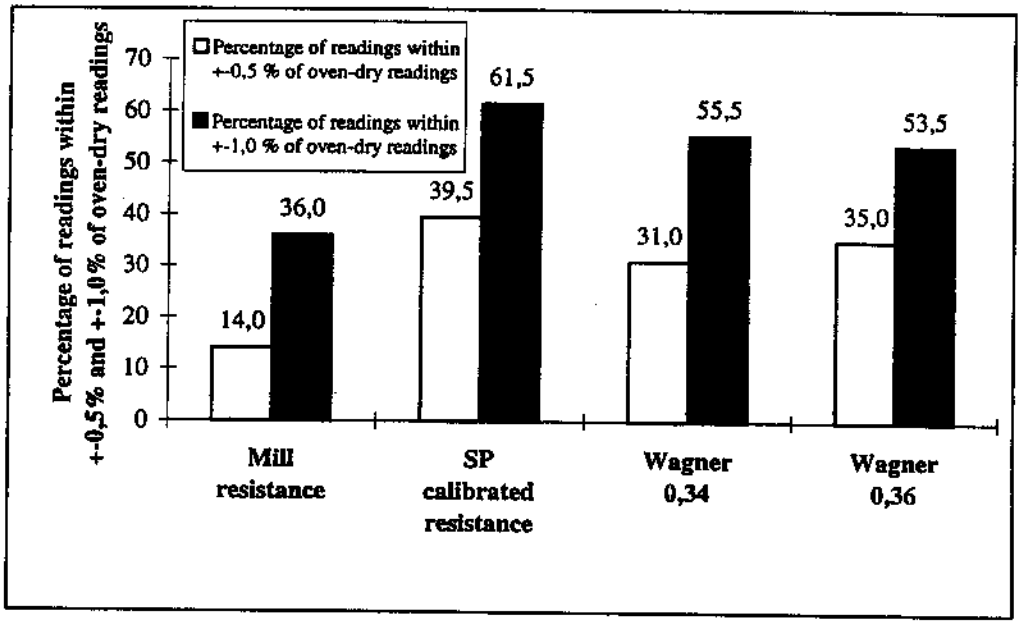

Figure 1 Percentage of the readings for the respective measurement methods within ± 0,5 % and ± 1,0 % (expressed in absolute m.c. % terms) of the oven-dry reading, for **spruce**.

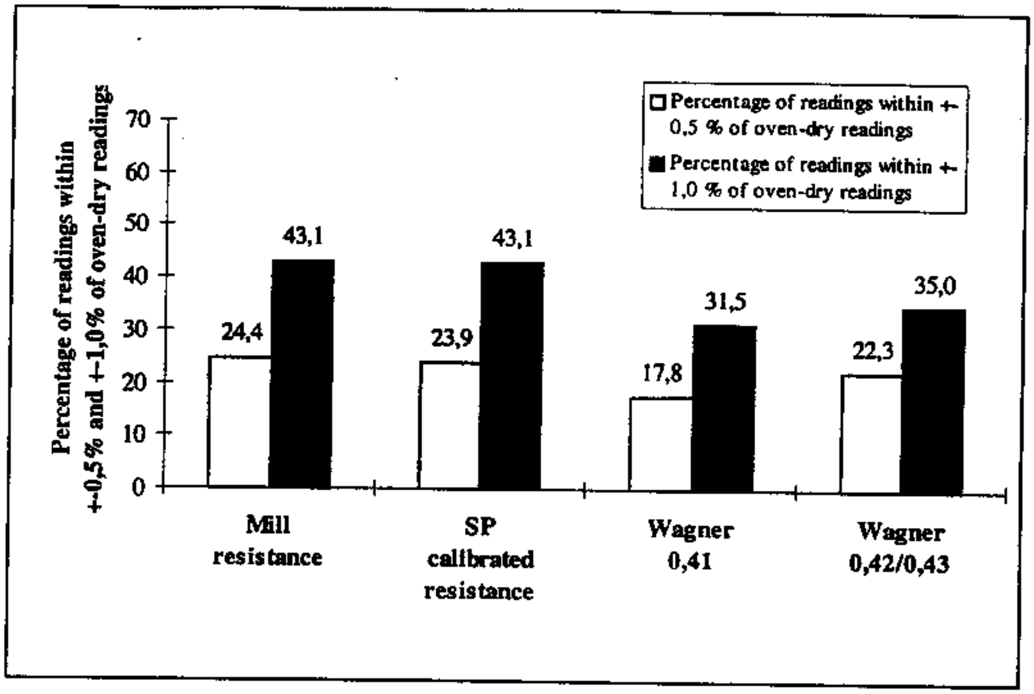

Figure 2 Percentage of the readings for the respective measurement methods within ± 0,5 % and ± 1,0 % (expressed in absolute m.c. % terms) of the oven-dry reading, for **pine**.

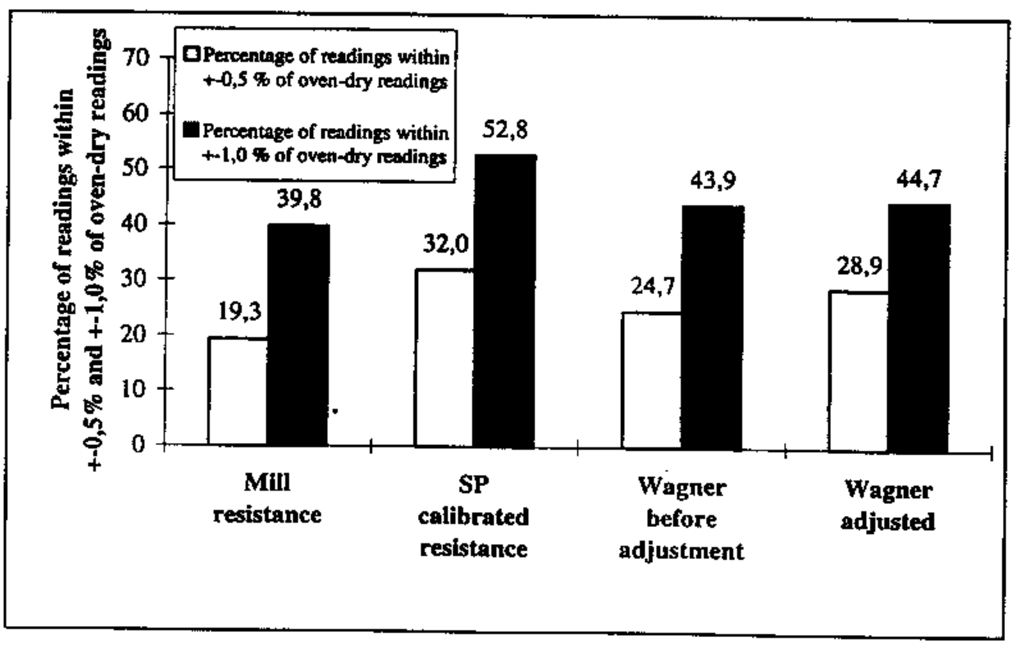

Figure 3 Percentage of the readings for the respective measurement methods within ± 0,5 % and ± 1,0 % (expressed in absolute m.c. % terms) of the oven-dry reading, **combined mean results for spruce and pine**.

For spruce: the readings from the mill resistance meters were poorest of all at 36,0 % at the ± 1 % level, or ca. 25 % lower than the SP readings, while those performed with the Wagner L612 meter were at 53,5 % at the ± 1 % level, or ca. 8 % points lower than results for the SP calibrated resistance meter. SP resistance meters had a reading of 61,5 % at the ± 1 % level.

For pine: generally speaking, results were lower for pine than for spruce. The difference between the results for the respective measurement methods was not as large as for those in spruce. Mill resistance meters readings were equal to those of the SP calibrated resistance readings at 43,1 % at the ± 1 % level, while those performed with the Wagner L612 meter was 35,0 % at the ± 1 % level, or ca. 8 % points below the SP resistance meters.

For both species: the combined mean results for both coniferous species show that the SP resistance meter readings achieved 52,8 % within 1 % of oven-dry m.c.. The Wagner L612 meter averaged 44,7 % within 1 % of oven-dry m.c.. The mill resistance meters achieved 39,8 % within 1 % of oven-dry m.c..

Results were highest when carried out with SP's calibrated resistance meter, which here may be considered the most exact test method.

3.3 Diagrams: deviation from the oven-dry reading against oven-dry readings

To check for skewness in the data over the whole measured moisture content range (nominally 8-21 % m.c., practically circa 7-29 % m.c.), diagrams plotting the deviation from the oven-dry reading were made for all three measurements methods, and for both species.

The best results are achieved when the readings are as close to the oven-dry moisture content (x-axis) as possible; when a point is above the x-axis, this means the reading was over-estimating the true moisture content.

Figures 4-7 show results for spruce:

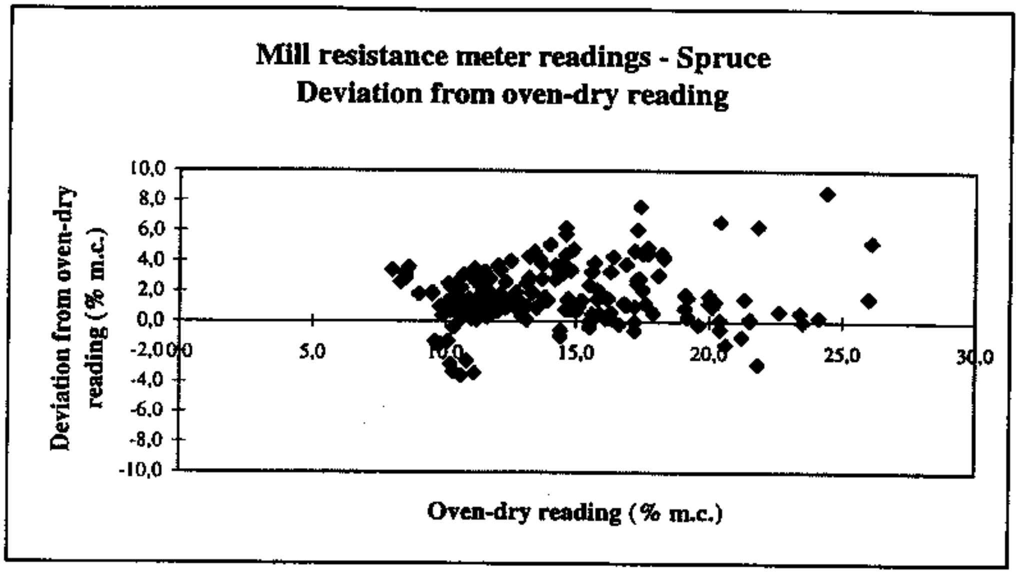

Figure 4 Mill resistance meter readings for spruce - deviation from oven-dry readings

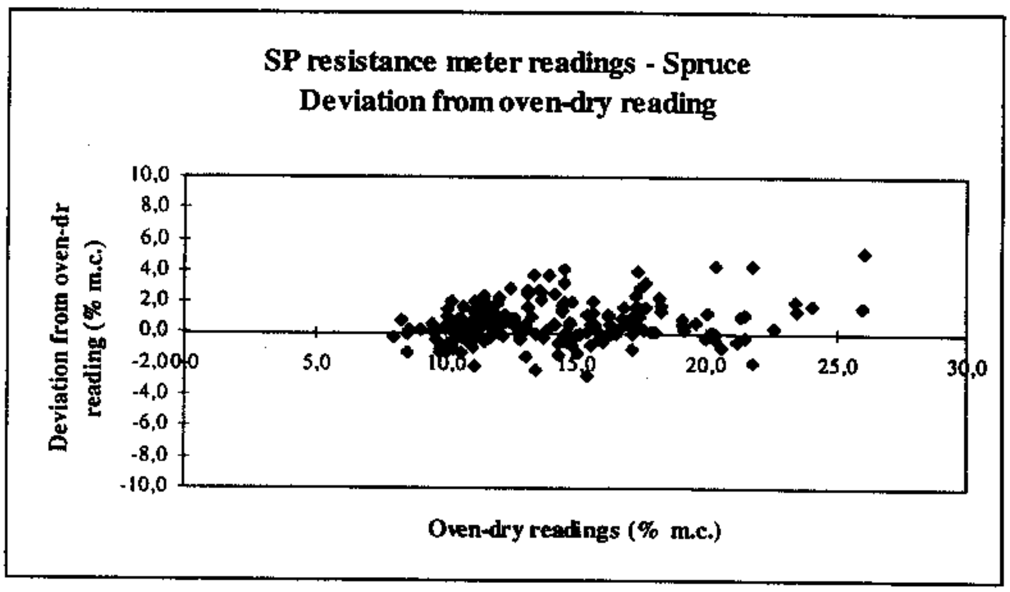

Figure 5 SP calibrated resistance meter readings for spruce - deviation from oven-dry readings

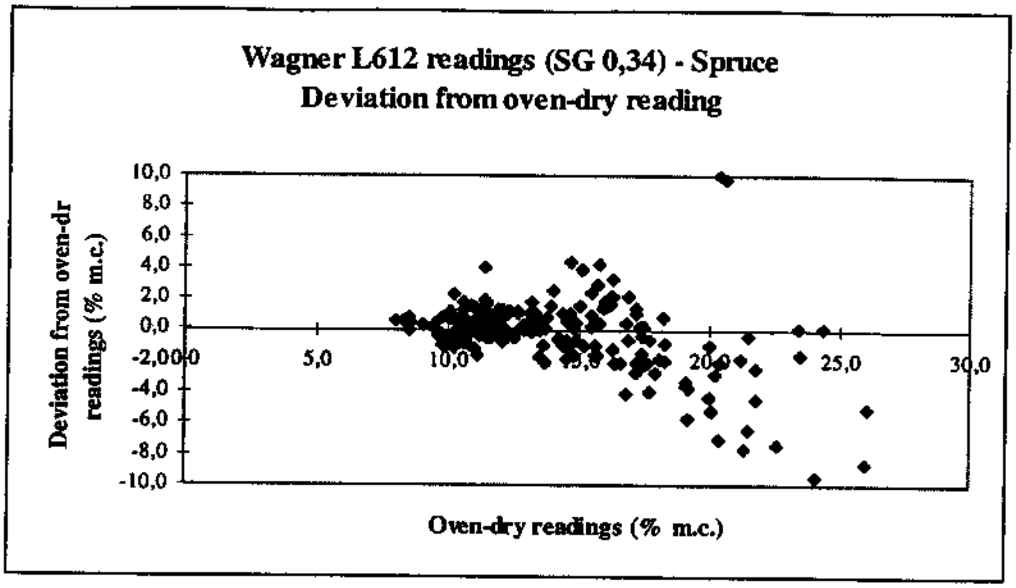

Figure 6 Wagner L612 meter readings (SG 0,34) for spruce - deviation from oven-dry readings

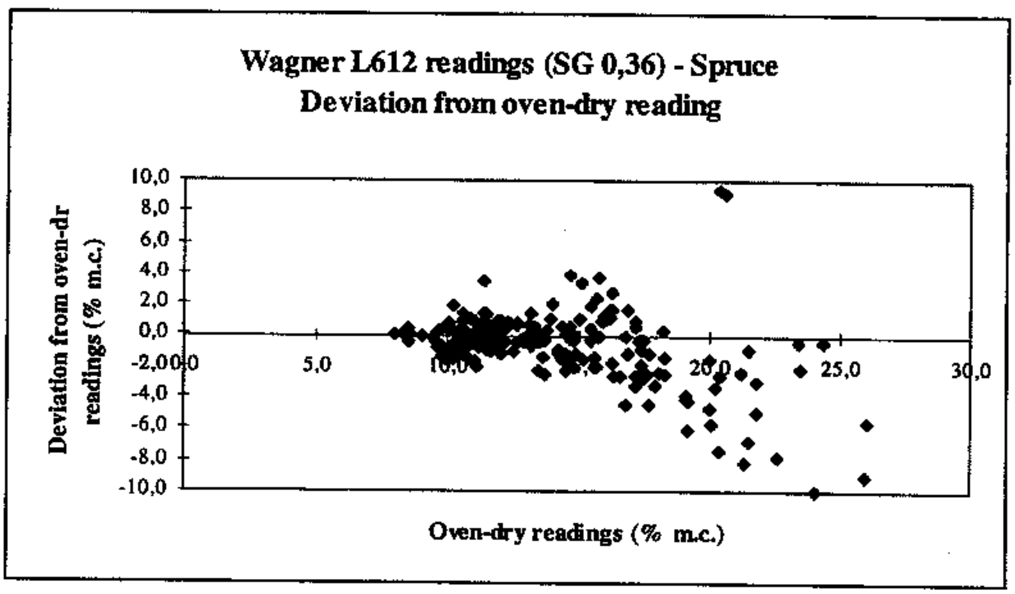

Figure 7 Wagner L612 meter readings (SG 0,36) for spruce - deviation from oven-dry readings

Figures 8-11 show results for pine:

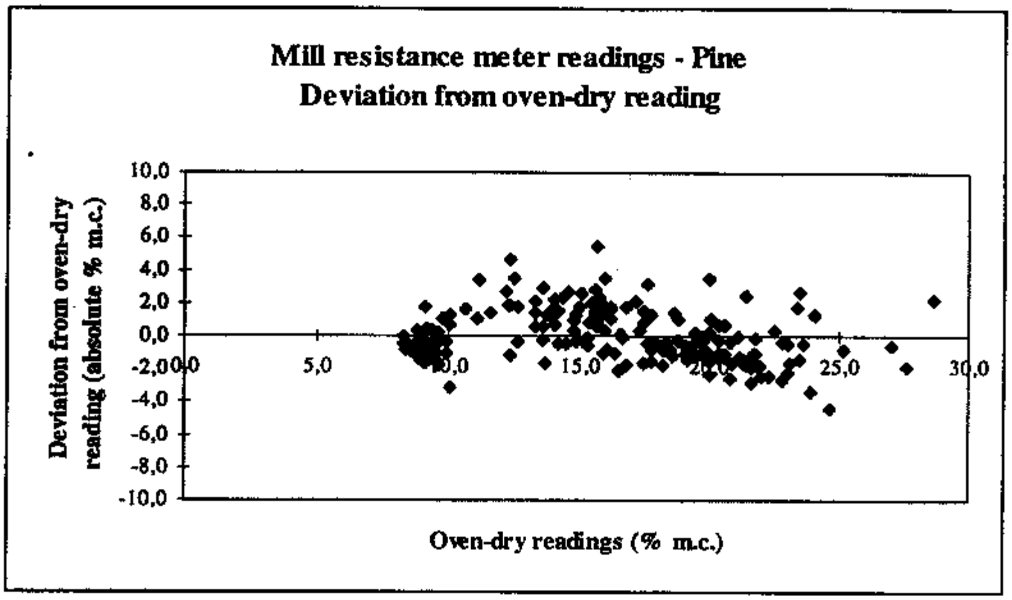

Figure 8 Mill resistance meter readings for pine - deviation from oven-dry readings

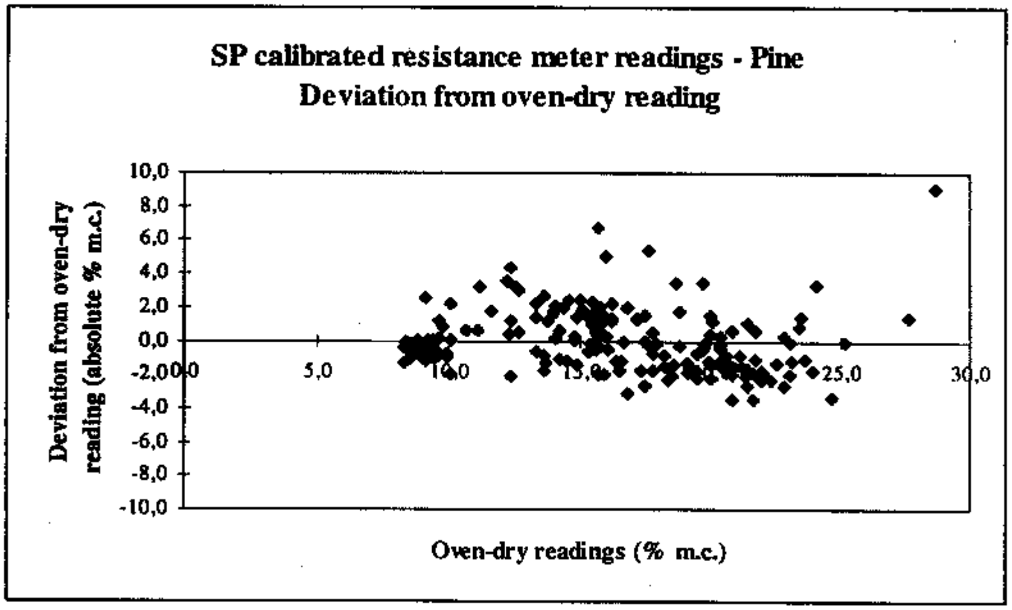

Figure 9 SP calibrated resistance meter readings for pine - deviation from oven-dry readings

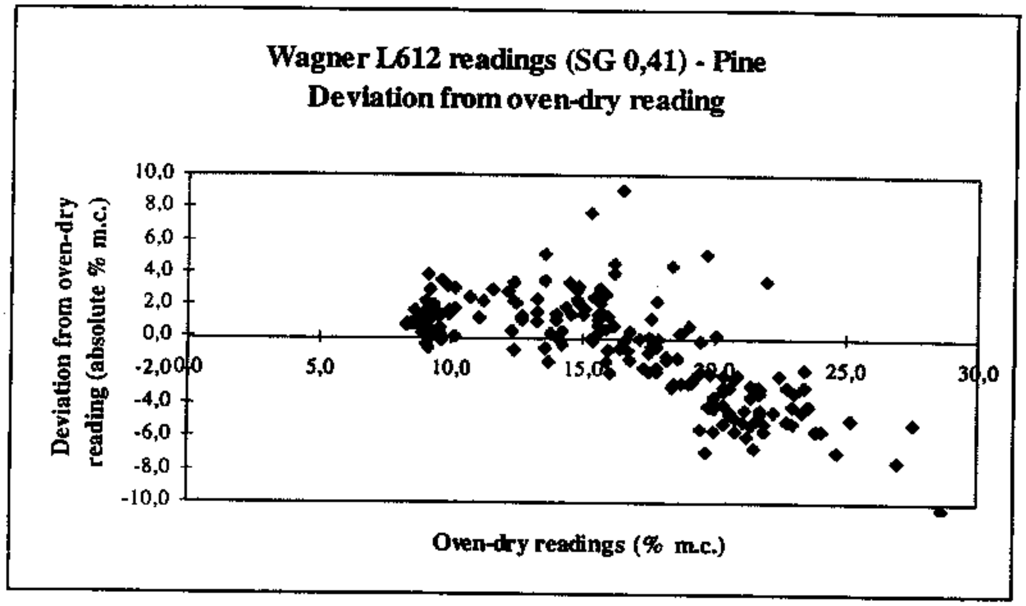

Figure 10 Wagner L612 meter readings (SG 0,41) for pine - deviation from oven-dry readings

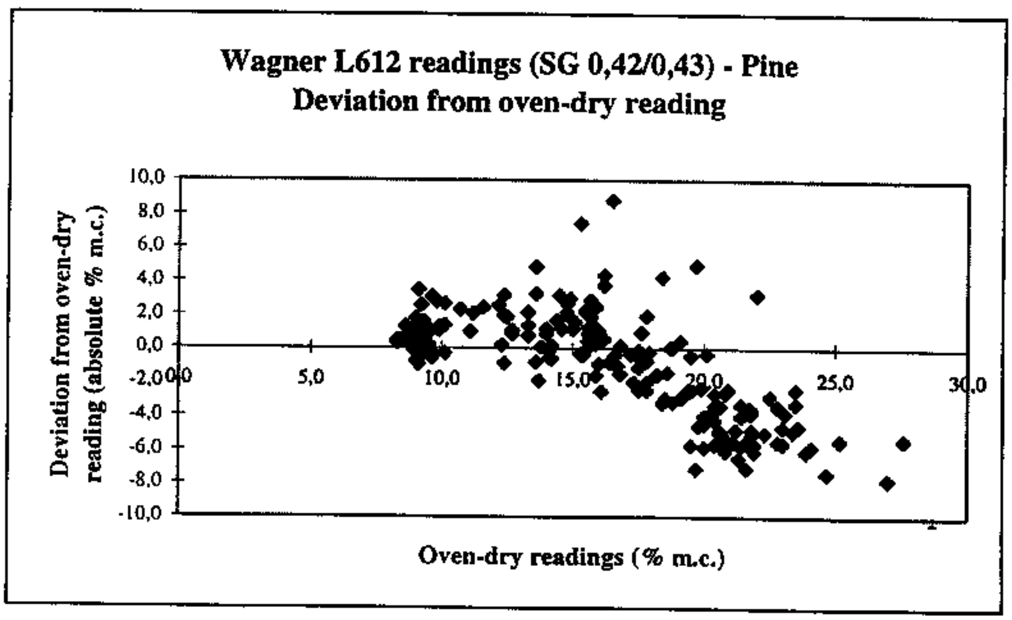

Figure 11 Wagner L612 meter readings (SG 0,42/SG 0,43) for pine - deviation from oven-dry readings

For spruce:

- Mill resistance meter readings generally overestimated the oven-dry m.c. over the whole moisture content range (see Figure 4), and had a large spread of values.
- SP resistance meter readings slightly overestimated the true moisture content over the whole m.c. range (see Figure 5), but were very close to the oven-dry values. They provided the best results for spruce.
- For the Wagner L612 readings (see Figures 6 and 7), the close fit was valid for the 7-15 % m.c. range; from the m.c. range of 15-18 % results fanned out; in the > 17 % m.c. range the meter tended to underestimate the oven-dry m.c. considerably.

For pine:

- Mill resistance meter readings had a tighter fit around the x-axis than those in spruce readings (see Figure 8), and seemed more evenly spread around the oven-dry m.c. over the whole m.c. range. The estimate was slightly low in the 8-10 % m.c. range, slightly higher in the 10-17 % m.c. range, and slightly lower in the > 17 % m.c. range.
- The fit for the SP calibrated resistance meter readings were very similar to those of mill resistance meter readings (see Figure 9): the prediction was slightly low in the 8-10 % m.c. range, slightly higher in the 10-17 % m.c. range, and slightly lower in the > 17 % m.c. range. Both resistance meters (mill and SP calibrated) provided the better fit over the whole m.c. range.
- Wagner L612 readings (see Figures 10 and 11) somewhat overestimated the oven-dry m.c. in the 7-17 % m.c. range. In the > 17 % m.c. range the readings underestimated the oven-dry m.c. considerably.

The SP calibrated resistance meter readings presented the best overall estimate for the oven-dry m.c. over the whole m.c. range, for both spruce and pine.

4 Comments and summary

On average the Wagner L612 Electronic Wave meter performed better than resistance meters under normal operating mill conditions. The wood m.c. estimate provided by the Wagner L612 meter was better for spruce than for pine.

The study also shows that a considerable difference in wood m.c. estimates can be achieved with electrical resistance meters, depending whether the meter is used properly or improperly. The best estimates in this study were shown by the use of resistance meters when used under controlled conditions at the SP.

The two most common mistakes thought to be the cause of these disparaging results when using electrical resistance meters are:

1. it must be ensured that the pins are driven in a certain thickness into the board (0,2 X the thickness of the board in Sweden, or 0,3 X the thickness of the board according to the European norm draft), something which is not always practical or easy to follow in a consequent manner under field conditions. Often an experienced estimate at the correct pin depth is carried out by the mill operator.

2. that the meter be adjusted to the wood temperature, and not to the air temperature. The wood temperature was controlled after the mill operator had carried out his

measurements, an overestimate in the wood temperature by up to 10 °C being noted. This situation can be especially misleading in areas of the country and during seasons where temperatures vary strongly.

Despite the m.c. underestimate shown by the Wagner L612 meter at m.c.'s ≥ 17 %, for the combined mean results for spruce and pine the Wagner L612 meter showed 50 % more readings within 0,5% of oven-dry m.c., and 12 % more readings within 1 % of oven-dry m.c. as compared to the resistance meters used by operators in mill conditions (see Figure 3).

The Wagner L612 meter was easy to handle, and in this study was capable of taking approximately four measurements within the same time that one measurement could be registered with a resistance meter. Unlike resistance meters, the Wagner L612 meter required no air or wood temperature adjustment, nor did board thickness - in the sampled thickness range - have to be taken into consideration. This made the Wagner L612 meter practical to use in operational conditions, with less likelihood of operator induced bias.

It is, however, important that the SG settings in Wagner L612 be carefully selected and programmed to the species in question, as recommended by the manufacturer. It is furthermore recommended that the SG setting be specific to the material available in the region the wood comes from. Based on the data collected in this study, the SG settings for Swedish Scots pine (*Pinus sylvestris*) are recommended be 0,42 in southern Sweden and 0,43 in northern Sweden; and that SG settings for Swedish Norway spruce (*Abies picea*) are recommended to be 0,36.

SP - Swedish National Testing and Research Institute
Wood Structures and Materials

Carl-Johan Johansson
Technical manager

Martin Kemmsies
Technical officer

Accompanying this report are:
Appendix 1 - Results for Norway spruce
Appendix 2 - Results for Scots pine