

THE DEVELOPMENT OF A "MOISTURE GRADIENT" METER FOR PENCIL SLATS

John Rhemrev, Richard Rhemrev, Harvey Smith
California Cedar Products Co. Research Dept.
Stockton, CA

ABSTRACT

Moisture meters are used in the dry kilns to see how drying has progressed. It is in the last days of drying that the instrument becomes critical in its use as the operator needs to decide when to pull the charge based on the average moisture content of a sample of slats. The "moisture gradient" moisture meter shows the average moisture gradient of the slat sample presented on a monitor. A spot decision can be made by the operator to either continue the drying (and how much) or to equalize and condition.

INTRODUCTION

Hand-held moisture meters of various types have been in use as quality control instruments for a long time (1). In the quality control department these instruments are used to measure the average moisture content of packed slats. Noncontracting, capacitive-type moisture meters have been installed as quality control devices to kick out "wet" slats on the factory's line of reassort machines. Incoming lumber is often checked for moisture content and short blocks ready to be sawn into slats are often also checked for their average moisture content. In the dry kilns moisture meters are used to see how far drying has progressed. It is in the last days of drying that these instruments become critical in their use as the operator needs to decide when to pull the dry kiln charge based on the average moisture content of a sample of slats. The "moisture gradient" moisture meter goes beyond measuring just the average moisture content in the slat since the instrument will also sample multiple areas on the slat as the slat is transported under the capacitive type sensor. The result of the batch of slats sampled is seen on the computer monitor as an average "moisture gradient" showing moisture content versus distance for the sampled slats. Thus the dry kiln operator has a much better idea of how the slats have dried and he can decide to dry the slats more or he can decide whether the slats need equalizing or decide whether the charge should be pulled earlier and thereby "save" on drying time.

THEORY

The water in the pencil slat appears in three different forms, free water, bound water, and water vapor. Intermixed with this are stain and wax molecules introduced as part of the staining process. It is well known that the transport mechanisms for these forms vary widely but it is not the purpose of this paper to fully expose this. It is sufficient to say that for the purpose of measuring moisture gradients in pencil slats we can accept the diffusion model under isothermal conditions as a good approximation. The moisture gradients can be reasonably well detected for the range of 6 to 25% moisture content in the slat. A constant diffusivity is assumed and the moisture content is the driving force. The one dimensional diffusion model is assumed and only one half of the slat is measured for this moisture gradient. It is generally accepted that at moisture contents below the fiber saturation point, the moisture moves in the vapor phase through the wood

by diffusion. Thus the fundamental law of diffusion can still be expressed as Fickian movement (2)

$$F = k \cdot A \cdot du/dx \quad (1)$$

where: F = moisture flow per unit time per unit area
 A = section of area A
 K = coefficient of diffusion
 du/dx = the moisture content gradient

A method can thus be devised to measure this moisture concentration along narrow strips of pencil slat starting at the end of the slat and ending at the middle of the slat. A capacitance probe can sample the moisture content of each of these small strips of pencil slat. A computer program displays these moisture contents on a monitor showing the x-axis as distance in inches from the end of the slat toward the center and the y-axis as moisture content from 6 to 25%. The resulting graph screen displays the measured moisture contents of each of the strips of pencil slat as bar graphs of varying height. These heights represent the moisture content of each individual strip of pencil slat. The connected bar graphs show the drying efforts of the slats sampled from the kilns as a "moisture gradient." If this gradient is too steep then the load requires more drying. After the conditioning cycle, the operator sees the gradient as nearly flat and the drying of the kiln load of slats is thus completed.

WHAT IS THE BEST MOISTURE CONTENT FOR PENCIL WOOD

It appears logical that the pencil slat should theoretically be conditioned to a moisture content somewhere near that which it will reach in the pencil factories of the customer. We think that 8% is better than 5% because it is closer to the average moisture content of the pencil slat exposed to varying natural and indoor artificial climatic variations. We worry about dimensional changes of the pencil slat when the humidity changes. Thus even if the two halves of the pencil sandwich are of equal moisture content there is a possibility that each half may shrink unevenly because of structural differences in the slat. If the wood is too dry then it becomes harder and more brittle and it is more likely to chip during the shaping part of the woodworking operation especially when the cutting angle of the knife is too large, or the knife is dull and the feed speed is too large. If the moisture content is too high then there can be a condition such as "fuzzy grain" especially when the knives have a too low a cutting angle and are dull. The hold down mechanism can also crush the soft wood and later, after manufacturing of the pencil, the wood restores itself to show a condition called "raised grain." Incorrect drying can produce "collapse" in the slat or produce uneven stress which is bad for the pencil producing operation. Another question that can be raised is about the rate of change of moisture content in the slats in packaged boxes. As you can see the question of quality control of moisture content of even a small piece of wood such as the pencil slat is extremely important in our business. In the past, measuring the average moisture content of a sample of slats was slow and provided the operator with insufficient data. A fast moisture gradient moisture meter was needed to even further improve the quality control of the kiln drying process.

THE MOISTURE GRADIENT METER

Forrer et al. (3,4) have developed a moisture meter recognizing the requirements with respect to accuracy, temperature compensation and continuous mode operation for dry kiln control. The instrument can also be connected to a

host micro processor system. The system can be equipped with pin-type electrodes or other specially designed electrodes which permit the measurements of moisture content gradients as well as average values of moisture content. The measured parameter was DC electrical resistance. In the California Cedar Product's moisture meter, the moisture in the slat is sensed by a change in the frequency of a Colpitts oscillator. The meter is thus a capacitance type meter which uses the relationship between moisture content and dielectric constant. The wood (pencil slat) is penetrated by the electric field associated with the capacitor of the frequency of the oscillator is changed according to the effect of the wood in between the platen of the capacitor. The dielectric constant essentially consists of a layer of air, a dielectric constant of the wood which varies depending on wood density and the water molecules. The meter can thus be calibrated to read moisture content which can be made to be proportional to a frequency change.

$$C = D \cdot A / 4 \pi Y \quad (2)$$

where:

- K = dielective constant
- A = area of capacitor plates
- Y = distance between plates

A voltage E applied to the plates relates current and capacitive reactance by

$$I_c = E / X_c \quad (3)$$

where:

- E = applied voltage
- X_c = capacitive reactance

Capacitive reactance, in turn, is determined by applied frequency

$$X_c = 1 / 2 \pi f C \quad (4)$$

of voltage E. combining the equations (2) (3) and (4) yields

$$f = 1 / K \cdot 2 I_c Y / A E$$

Thus if I_c , Y, A, and E are held constant then a variation of K will vary f.

There will be a layer of air since the plates of the capacitors do not touch the pencil slat and there is the slat variability since different slats can have different densities (4, 6, 7). Since wood is anisotropic, the dielectric constant is bigger or smaller depending on whether the electric field is parallel or perpendicular to the grain direction. For very high frequencies the dielectric constant also varies to a lesser degree with temperature variations, and is influenced strongly by density and moisture content. In fact, the dielectric constant of wood describes its ability to absorb and store electrical potential energy. Polarization results as soon as an electric potential is applied to wood. Energy is thus absorbed or dissipated with the application or removal of the electric field. The dielectric constant is expressed in terms of capacitance (8). These effects are lumped together and show up as "scatter" around the regression line (Fig. 1). The regression line is created by sampling a large number of slats and recording the instrument frequency reading (Y axis) and correlating these with the moisture content of the slats. The slats were oven dried according to

$$MC = (M1 - M2) / M2 \times 100$$

where:

- MC = moisture content (%)
- M1 = mass of water + wood (kg), and
- M2 = mass of oven dried wood

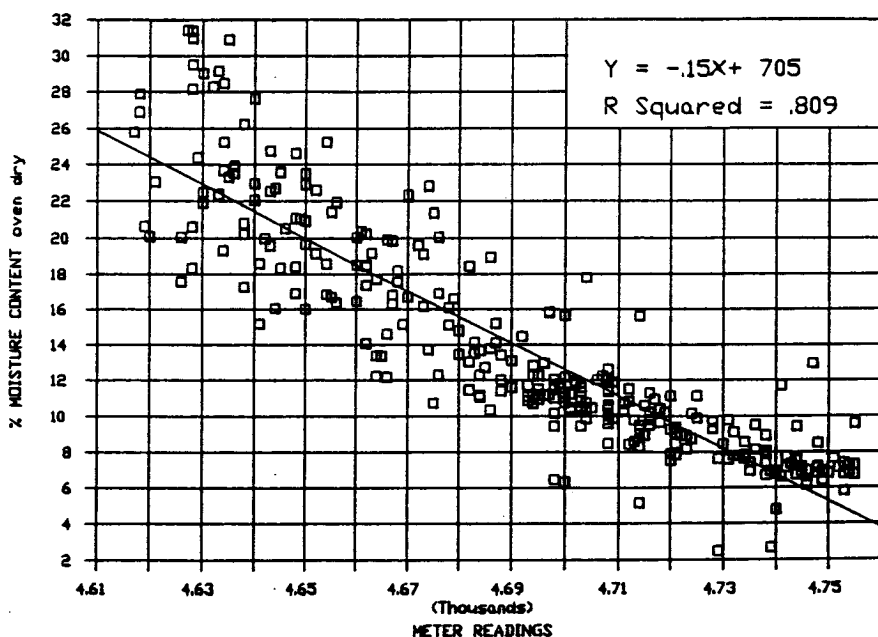


Figure 1. Relationship between instrument frequency and moisture content.

The regression equation is shown as

$$Y = -0.14726X + 704.73$$

where:

$$r^2 = 0.809$$

Points of the regression line are then stored in a look up table (LUT) in memory so that each frequency reading directly corresponds with a moisture content. The instrument is shown in Fig. 2. The drive mechanism allows the slat to move at constant speed between the plates of the capacitor. Half of the slat is divided into known increments or strips of wood which will be sensed by photocells as the slats move between the plates. Samples are taken at a rate of 1000 samples per second and then an average is determined. The slat sensors incrementally detect the position of the slat under the moisture detector so that the computer can correlate a moisture content with the portion of slat under the moisture detector. Fig. 3 shows how the slat is divided up into strips to be detected by the moisture sensor. The input data is then compared to regression analysis data in the look up tables to determine the moisture content. Fig. 4 shows how this output is displayed on the monitor as bar graphs where the height of the bar graph or the Y axis shows the moisture content of each strip of wood scanned. The X axis shows the distance of each strip of wood (bar graph) from the end of the slat. The over all effect is thus "seen" as a moisture gradient within the slat. A multiple sample can be entered in this fashion and the monitor shows the average, high and low moisture gradient as well as the average moisture content of the sample. Fig. 5 shows a plastic slat with a number of steel screws fastened into the plastic for each of the strips as well as a number of holes. This represents a known simulated moisture gradient and can be used by the operator in lieu of a pencil slat for calibration purposes. Fig. 6 shows the block diagram of the instrument. An XT PC compatible on a STD bus and Forth software was selected for the programming.



Figure 2. Moisture gradient meter.

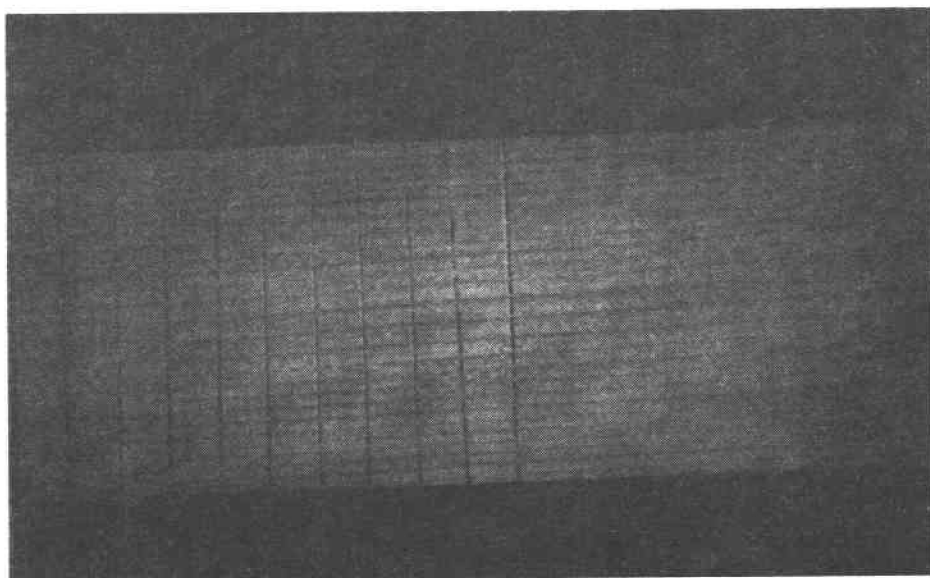


Figure 3. Pencil slat divided into strips.

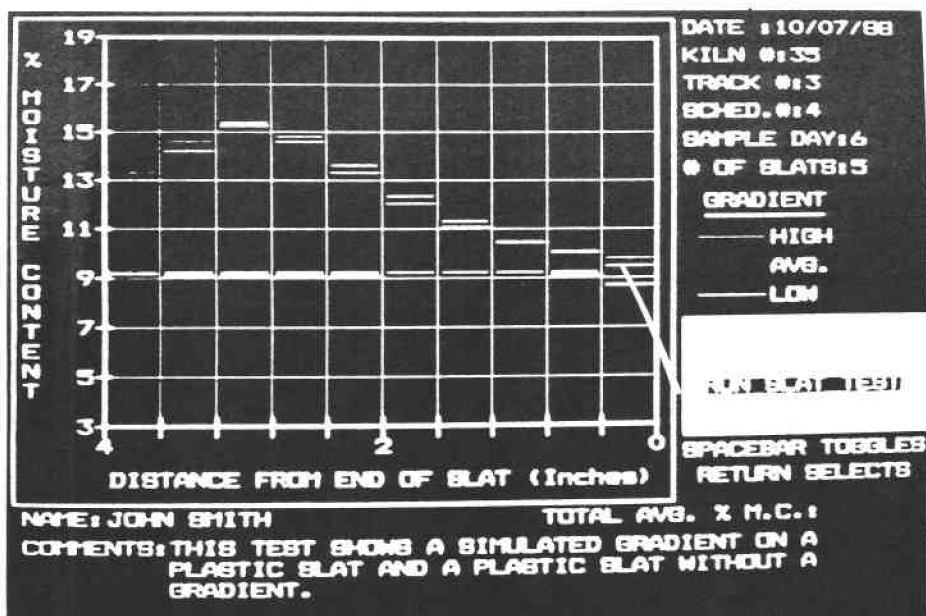


Figure 4. Meter output displayed on monitor.

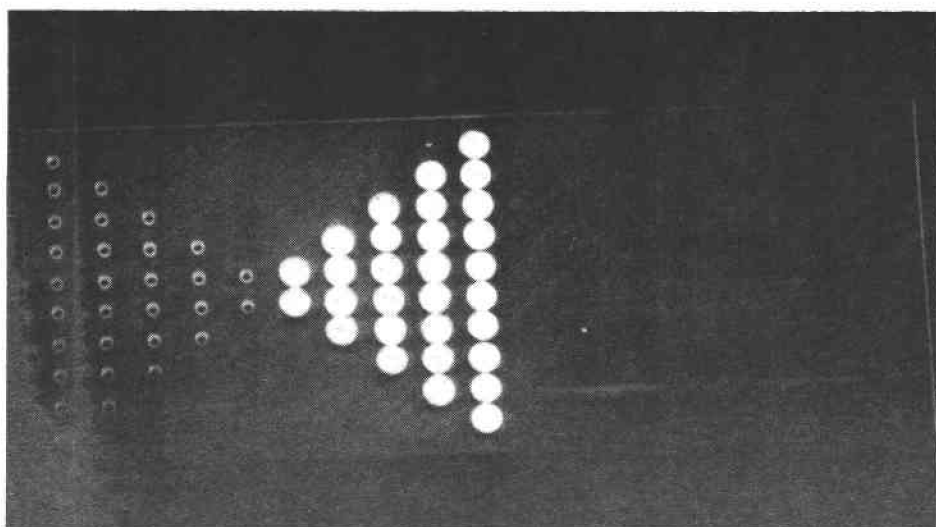


Figure 5. Plastic slab with steel screws. This is used for meter calibration.

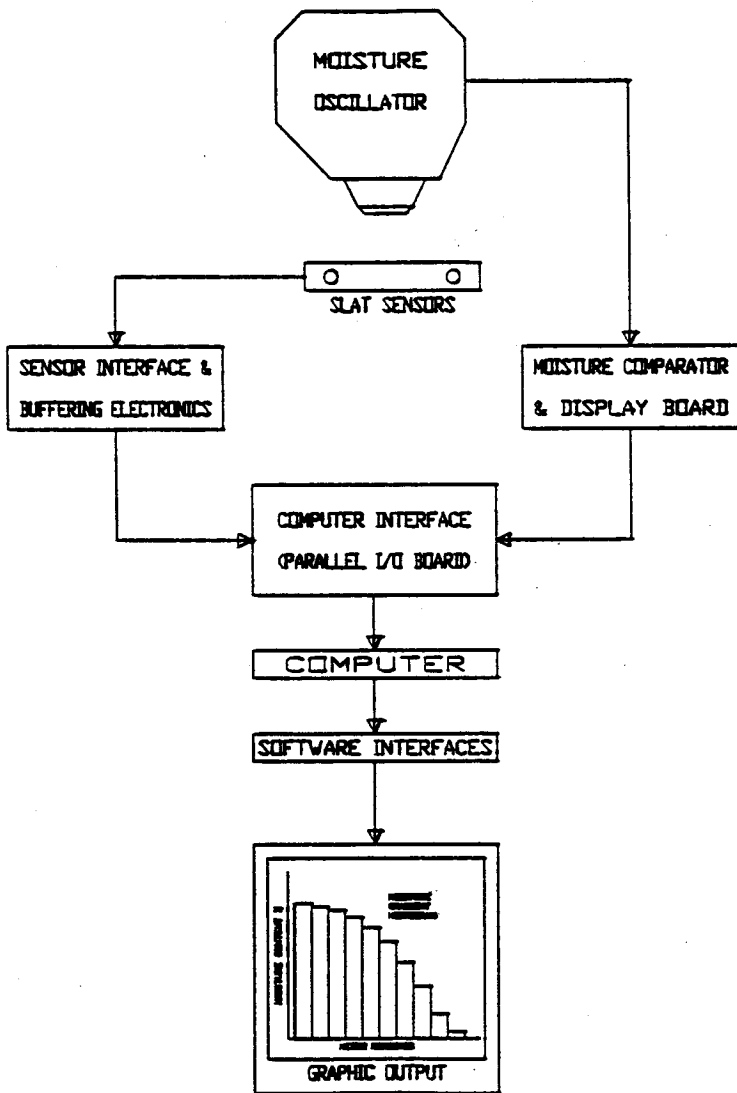


Figure 6. Block diagram of moisture gradient meter.

CONCLUSION

The instrument has proven to be very useful in the kiln quality control drying efforts. It is easy to use and the kiln operator has a much better idea of how well the slats are drying.

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