Improving Quality of Dried Hardwood

by

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I hereby declare that, except as stated herein, this thesis contains no material which has been accepted for the award of any other degree or diploma in any university and that, to the best of my knowledge or belief, this thesis contains no copy or paraphrase of material previously published or written by any other person, except where due reference is made in the text of the thesis.

A.L. Redman

Abstract

This thesis contains three sections of work. The first section of this work is principally aimed at producing resistance and capacitance type meter species correction data for a commercially popular species of Tasmanian Eaucalypt, *Eaucalyptus delegatensis*. The resistance type meter correction data obtained deviate from those values given in the Australian Standard. Differences in resistance meter electrode placement are assumed to be the cause of the deviations. Regression trendlines obtained for the capacitance-type moisture meters were shown to have a lesser degree of accuracy than those for the resistance-type moisture meters due to the effects of density. The practice of measuring the average moisture content at a depth of 1/5th of the thickness of a board using insulated probes in conjunction with resistance-type moisture meters was reinforced.

The second part of this project involved work on a solar kiln situated at Kelly's Timber - Dunally. The purpose of the work was to try and improve the drying efficiency of the kiln and monitor it's progress throughout the drying process. Three drying trials were performed. A full schedule was provided for one of the trials where green sawn timber was fully dried to EMC. The success of the schedule was tainted by the poor quality of the timber before the drying process began. Air flow was improved throughout the kiln by the use of appropriate baffling and racking of the timber as recommended by the author. The temperature distribution and humidity control inside the kiln was found to be satisfactory.

The final section of this research involved improving the drying efficiency of three Tasmanian industrial timber drying kilns. This work is still currently underway at the time of writing this thesis. Written reports have been submitted to the appropriate personnel regarding recommendations made from initial investigations. These reports are appended to this thesis.

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Chapter 1. Moisture Content Determination

1.1 Moisture Content of Wood

The moisture content (MC) of wood is measured as the ratio of the weight of water in a given piece of wood, to the weight of wood when it is completely dry (or 'oven dry') and is usually expressed as a percentage. The 'green' wood of a freshly felled tree may have a MC anywhere in the range of 30% to 200% depending on the species.

For most practical applications almost all of this water must be removed from the wood before it is fit to be used. The desired MC depends upon the intended use, and the average relative humidity at the place where the wood is to be used. The equilibrium moisture content (EMC) of wood is the MC which will eventually be attained by any piece of wood, when stored indefinitely at a particular relative humidity and dry bulb temperature. The EMC of timber varies between different global areas depending on climate and is usually the desired final MC.

Wood is a cellulose material which behaves somewhat like a sponge, so that even wood which has been 'kiln dried' down to EMC may in fact later reabsorb water from the atmosphere. Actually all wood is constantly gaining or losing water to or from the environment because the MC of wood changes as the relative humidity changes. Coats of varnish or paint may greatly slow down this process, but can generally not stop it completely.

As wood dries its MC decreases, however the rate of decreasing MC varies between pieces of timber of the same species and between different species, given the same drying conditions. These inherent differences in timber mean that it is important to measure and hence control the MC of timber during the drying process.

There are several ways of measuring MC including moisture meters, hydrometers, solvent distillation and oven drying. The most common methods used in the Tasmanian timber drying industry are by either the use of an electrical resistance-type moisture meter or by the oven dry method.

1.2 Determination of Moisture Content Using the Oven Drying Method

When using the oven drying method (also known as the gravimetric method) to determine MC it is important to closely follow the Australian/New Zealand Standard 1080, Part1 - 1997, 'Timber -Methods of Test. Method 1 : Moisture Content.' This is a new standard which supersedes AS 1080.1 - 1972. The new standard places more emphasis on using apparatus which is not highly elaborate and includes the correct use of resistance type moisture meters. Appendices for sampling of timber lots, species and temperature correction data and standard resistance calibrations for resistance type moisture meters are also new additions to the standard.

Timber samples to be tested should be selected randomly and should not contain a high resin or oil content or other volatile extractives. Timber containing volatile extractives or preservatives may produce inaccurate readings using this method as these substances are likely to evaporate during oven drying, thus becoming a part of the overall weight loss of the material.

Test pieces for the determination of MC should be cut at a distance of no less than 0.4 metres from the end of the piece of timber. The test piece should incorporate the whole cross-sectional area for which the MC is required. After cutting, the test piece needs to be brushed or scraped so as to remove any loose splinters and sawdust that may drop off during drying. The test piece should then be weighed immediately after scraping in order to prevent further drying of the piece. This would result in inaccurate MC readings being obtained. If the test piece can not be weighed immediately it must be securely wrapped in a non permeable material such as plastic timber wrapping or aluminum foil and then stored in a dry, shaded, cool place.

The test pieces must be weighed on a balance with a sensitivity of not less than 1 in 500.

After the initial weight has been obtained, the test pieces need to be dried in a well ventilated oven at a temperature in the range of 103 ± 2° C. The drying takes place until a constant dry mass is obtained. To ensure that a constant mass has been obtained the test pieces are left for approximately 24 hours in the oven. They are weighed and then reweighed after 2 to 5 hours. If the weight recorded is within 0.2 % of the previous weight then the samples are said to be oven dried to a constant mass. If the difference between the first and second weight is greater than or equal to 0.2 %, then a further period of drying is necessary until the last two weighings agree to within 0.2 %.

Once the initial mass and oven dry mass of a test piece have been determined the percentage moisture content of the sample can be calculated using the following formula:

$$MC = \left(\frac{Wi - Wo}{Wo}\right) \times 100 \qquad (1.2.1)$$

Where MC = percentage moisture content of test piece.

Wi = initial mass of test piece.

Wo = final oven dry mass of test piece.

This formula is often expressed as :

$$MC = \left(\frac{Wi}{Wo} - 1\right) \times 100 \qquad (1.2.2)$$

The oven dry method for measuring MC using (1.2.1) only measures the MC at an instant. The oven dry method can also be used to monitor the MC of timber samples during the drying process. This can be done quickly and accurately, at any particular time.

The initial MC of a sample which is to be monitored during drying must first be known. This is achieved by cutting off a test piece from the sample to be monitored and oven drying the test piece to determine its MC as previously described. It is important to weigh both the test piece immediately after cutting and the sample to be monitored. The MC of the test piece is treated as the same initial MC of the monitored sample.

Having calculated the initial MC of the sample board, and knowing its original weight, it is then possible to determine its oven dry weight by a simple manipulation of the MC determination equation (1.2.1), giving:

$$Wo = \left(\frac{Wi}{MC + 100}\right) \times 100 \qquad (1.2.3)$$

Once the oven dry weight of the test piece is known the MC of the sample board can be determined any time thereafter. This is achieved by simply weighing the sample board and applying the MC equation (1.2.1) where Wi is the current weight of the sample.

1.3 Determination of Moisture Content Using Moisture Meters

A moisture meter is an electronic device used to measure the MC of wood by measuring one of the electrical properties of resistance, dielectric loss or capacitance (dielectric constant). Below about 25 to 30 % MC the electrical resistance of wood rapidly increases with decreasing MC whilst the capacitance and dielectric loss both decrease with a fall of MC.

1.3.1 Resistance Type Meters

Hand held electrical resistance type moisture meters are most commonly used commercially. They operate by measuring the electrical resistance between two electrodes which are driven into the wood. The electrical resistance is then converted to a percentage MC and displayed either on an analogue dial or digital display. Three electrode types exist for resistance type moisture meters. They are the blade, uninsulated pin and insulated pin types.

Blade type electrodes (figure 1.1) are strong and durable and are still used in areas of production, however they are not used commonly with hand held moisture meters. They measure only the lowest resistance or highest MC between the electrodes.

Insulated type electrodes on the other hand, can be used to measure moisture gradients throughout the thickness of a piece of timber. As they are normally driven at greater depths into the timber, the MC is measured between the uninsulated tips only. Insulated type electrodes are normally driven into the wood using a slide/hammer assembly (figure 1.1).

Uninsulated electrodes are used to measure approximate average MCs as the MC is read at the point of least resistance or greatest moisture content between them. These electrodes can also be driven in using a slide/hammer assembly. Alternatively two nails can be hammered into a piece of timber at a specified distance and orientation and the MC is read using either a nail contactor (figure 1.1) or a two wire/alligator clip type assembly. Nail electrodes are a convenient way of monitoring MC of timber as it dries in racks as the nails can be left in the timber during drying, thus repeated measurements can be made easily.

For all of the above electrode types the electrodes should be inserted so that the current flows in the direction specified in the instructions supplied with the meter. This is most commonly in the direction parallel to the timber grain.

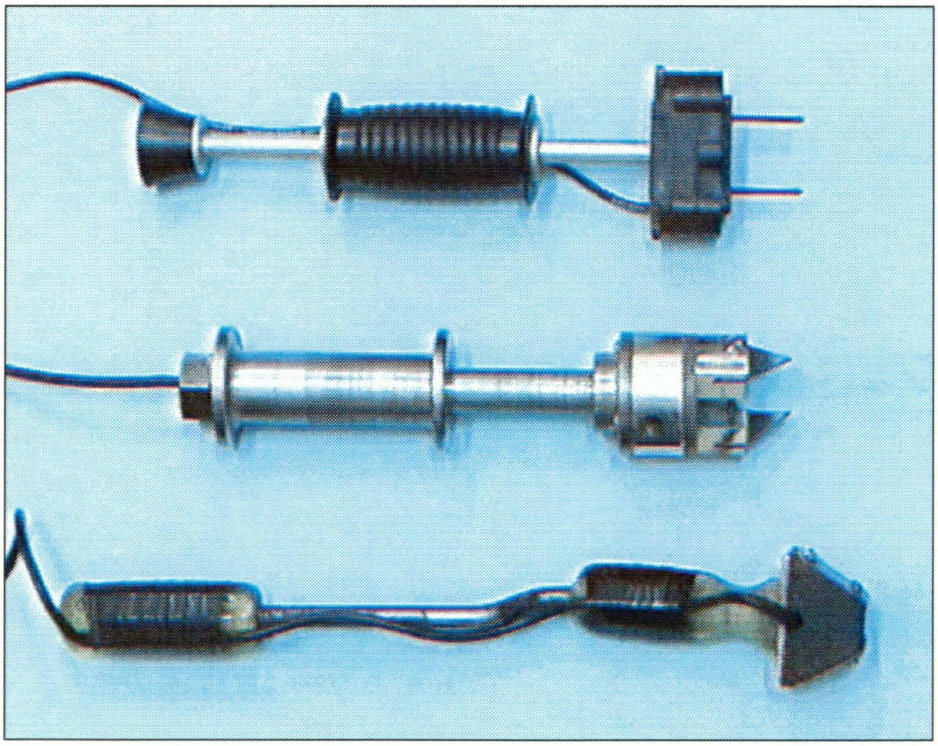

Figure 1.1 - Top to Bottom: Insulated pin slide/hammer electrode, blade slide/hammer electrode, nail contactor electrode.

1.3.2 Dielectric Type - Meters

These type of meters depend upon the change of dielectric properties of a piece of timber with changing MC. A dielectric is defined as a substance or medium that can sustain an electric field. Two different meter measuring techniques are available for measuring the dielectric properties of wood.

Capacitance meters are the most common type of dielectric meter. The electrodes of these type of meters are usually of the form of four or more metal buttons or a metal surface which is pressed against the surface of the timber to be tested. In order to take readings, capacitance meters use either a radio frequency or microwave oscillator to generate a three-dimensional electromagnetic field. This field penetrates through the surface of the timber and measures its dielectric constant.

Microwave capacitance-type moisture meters use a microwave oscillator to generate microwaves which penetrate the wood to determine its dielectric properties. Microwaves are basically a much higher frequency radio wave exhibiting the same electromagnetic properties. These meters are potentially less likely to be affected by resistance and preservative salts than conventional radio frequency capacitance meters. These type of meters are predominantly made as a stationary device.

Stationary meter systems use non contact electrode sensors and are predominantly used in large scale sawmills on timber conveyers. Hand held capacitance meters generally use surface contact electrodes which are non penetrating, giving them the appeal of being a non destructive method of measuring moisture. These meters are able to read MCs below 6% and may be used over painted or polished surfaces (CSIRO, 1974).

The other type of dielectric-type moisture meter is the power loss type. These meters measure the amount of power the timber absorbs from the electromagnetic field, however they are not widely used due to field penetration limitations.

1.4 Factors Affecting Moisture Meter Readings

The following factors must be remembered when using hand held moisture meters in order to obtain the most accurate results possible.

1.4.1 Resistance Type Meters

1.4.1.1 Contact with Timber

Good contact must be made between the wood and the electrodes during measurements in order to avoid artificially high MC results. When using short needle and blade type electrodes sufficient pressure must be applied to the electrode holder in order to achieve good electrical contact. The utilisation of hammer type, or the nails as electrodes usually poses no problems, as the electrodes are driven into the wood ensuring a tight fit.

1.4.1.2 Moisture Gradient

As timber dries the water on the outermost surface of the timber dries first leaving a core of higher moisture content. Thus, a moisture gradient is set up through the thickness of the timber causing lower than average moisture contents near the exterior. Meters with short electrode pins may therefore consistently underestimate the average moisture content of a piece of drying timber. Conversely moisture contents may read inaccurately high if the surface of a piece of timber is wet due to being exposed to unusually wet conditions such as rain. Meters with long insulated probes can be used to overcome these problems. This type of equipment can also give a rough indication of the moisture gradient within a piece. The exposed electrode tips can measure resistance at various depths by driving the electrodes into the board 5mm or more at a time and taking meter readings at each increment until the electrodes reach the center of the board (CSIRO, 1974).

1.4.1.3 Moisture Meter Range

Electrical resistance moisture meters are physically restricted to a range of moisture contents between about 7 and 30% (AS/NZS1080.1, 1997). CSIRO (1974) states that the fibre saturation point which is usually between 25 and 30% MC is a practical upper limit because above this the difference in electrical resistance is small and can not be accurately measured. CSIRO (1974) also states that at very high MCs, errors in the vicinity of 10% can be expected. Some electrical resistance meters have scales above 30% however the accuracy above this is questionable. The lower measurable limit of around 6% is imposed due to increasingly high electrical resistance of drier wood. Below this MC inaccuracies will occur due to the resistance of the timber approaching that of the surrounding air.

1.4.1.4 Species Variations

At any given MC the electrical resistance can vary considerably between different wood species and types. The different electrical resistances come from changes in density and differences in the physical and chemical constitution of different species (Heimerdinger, 1994). Some manufacturers provide moisture meters with a series of different scales providing the corrected reading for common commercial species. As an alternative, correction data is applied to the MC readings to account for variation between species. AS/NZS 1080.1 (1997) contains species correction data for a vast array of timber species. Finding appropriate correction data for Tasmanian *Eucalyptus delegatensis* (R.T.Bak) defines the basis of this research. Most electrical moisture meters are manufactured to be directly calibrated to the American softwood, Douglas-fir (*Pseudottsuga menziesii* (Mirb.) Franco).

1.4.1.5 Temperature

The electrical resistance of wood varies with temperature. MC readings taken with resistance-type moisture meters will be higher for a colder sample and lower for a hotter sample. CSIRO (1974) reported that most moisture meters are normally calibrated for testing at 20°C. A negative correction needs to be made to measurements on wood above this temperature and a positive correction is necessary below 20°C. Temperature correction data for resistance type moisture meters can be observed on the following table obtained from AS/NZS 1080.1, Appendix C (1997).

TEMPERATURE CORRECTION

Meter reading, %	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Wood temperature, °C	Moisture content corrected for temperature, %																						
5	7	8	9	11	12	13	14	15	16	17	19	20	21	22	—	—	—	—	—	—	—	—	
10	7	8	9	10	11	12	13	14	16	17	18	19	20	21	22	—	—	—	—	—	—	—	--
15	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	—	—	—	—	—	—	—	—
20	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	—	—	—	—	—	--
25	—	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	—	—	—	—	—
30	—	6	7	8	9	10	11	12	12	13	14	15	16	17	18	19	20	21	22	—	--	--	—
35	—	—	6	7	8	9	10	11	12	13	14	15	15	16	17	18	19	20	21	22	—	—	—
40	—	—	—	6	7	8	9	10	11	12	13	14	15	16	16	17	18	19	20	21	22	—	—
50	—	—	—	—	6	7	8	9	10	11	11	12	13	14	15	16	17	18	19	19	20	21	22
60	—	—	—	—	—	6	7	8	8	9	10	11	12	13	14	14	15	16	17	18	19	20	20
70	—	—	—	—	—	—	—	3	7	8	9	10	11	11	12	13	14	15	16	16	17	18	19
80	—	—	—	—	—	—	—	—	6	7	8	9	9	10	11	12	13	13	14	15	16	17	18
90	—	—	—	—	—	—	—	—	—	6	7	8	8	9	10	11	11	12	13	14	15	15	16

NOTE: Temperature correction should be applied before species correction.

Figure 1.2 Temperature correction table for solid timber.

As stated on figure 1.2 above, the temperature correction should be applied before species correction. As long as the temperature of the timber is known when it is being measured for MC, temperature corrections can be made. Milota and Quarles (1990) found that the temperature at which the timber has been dried (as distinct from the temperature at which the MC has been measured) has minimal effect on moisture meter readings.

1.4.1.6 Chemicals

The electrical resistance of a piece of timber can be greatly reduced by the presence of certain chemicals. Salt based preservatives and flame retardant treatments are particularly to blame for chemical related inaccuracies when taking MC measurements. Meter readings from timber treated with waterborne preservatives or wood wetted by salt water will give MC readings which are artificially high (CSIRO, 1974). This effect is directly dependent on the amount and type of chemical present. Using resistance type moisture meters to measure MC on chemically treated and glued timbers should be avoided as readings taken are regarded as having limited reliability.

1.4.2 Dielectric Type Meters

1.4.2.1 Density

Dielectric type moisture meters are affected primarily by variation in density between timber. CSIRO (1974) states, 'capacitance-type moisture meter readings are affected mainly by density variations because this meter measures the amount of water per unit volume in the wood, and, as moisture content is proportional to the amount of water per unit weight of the wood, the relationship between weight and volume, in other words, the density, is the property relating capacitance meter readings to moisture content'. Thus correction data should be used, if available, for timbers of different density. This means that the density of each piece measured must also be known, which can cause difficulties if a large number of samples are to be measured.

Quarles and Breiner (1989) concluded that high frequency (microwave) capacitance-type moisture meters were more dependent on density than low frequency (radio) types. They found that by incorporating density information in the regression model of the meter readings versus moisture content, an improved r^2 value and smaller prediction interval was obtained for the high-frequency meter. These improvements were not found for the power-loss capacitance type meter and resistance type meter used.

1.4.2.2 Timber Thickness

Dielectric meters are limited to a range of timber thickness at which they can measure. This is directly related to the depth that the electromagnetic waves are able to penetrate. The field penetration of different meters can range from a few millimetres, in meters designed for testing veneer, to about 50mm in meters for testing thick timber. Different meters have different design specifications, regarding this thickness range, depending on the application of the meter. Most capacitance-type meters read MC to one depth only while some are able to measure MC at incremented depths. Dielectric moisture meters average the MC of a sample to the depth specification. These specifications are usually found in the manufacturer's instructions for each meter.

1.4.2.3 Moisture Gradient

Measuring moisture gradients using a capacitive-type moisture meter is extremely difficult (Waterson 1997) due to the averaging nature of the readings to a specified depth. Quarles (1991) showed that capacitance-type moisture meters are more sensitive to the presence of wet core regions compared to their power loss type counterparts. Neither meter, however, could predict the occurrence of wet cores at a depth of 25 mm, and therefore neither meter could be reliably used to detect wet cores in thicker material. Mackay (1976) showed that the effective penetration of the electric field of power-loss type meters is no more than 2.5mm. Thus these types of meters are only useful in finding the MC of veneers, or that at the surface of a piece of timber.

1.4.2.4 Temperature

No temperature correction data is currently available for capacitance-type moisture meters. The manufacturer's instructions for the Wagner range of meters claim that none are needed between temperatures of 10 and 43°C.

1.4.2.5 Contact

Good contact is needed between electrodes of this type of meter and the board to be measured. Adequate pressure should be applied when taking measurements and more accuracy is obtained on flat machined surfaces (CSIRO 1974) as rough surfaces create small pockets of air between the electrodes and the timber.

1.4.2.6 Preservatives

All readings taken on treated timber are regarded as being unreliable.

1.5 Comparison of Methods

Provided the limitations of each MC determination method are appreciated accurate measurements can be made. For both the oven dry and moisture meter methods repeated measurements and careful interpretation of values measured are required to obtain an accurate estimate of MC. Considering the advantages of each method is a useful way of choosing which one to use.

1.5.1 Oven Dry Method - Advantages

The complete range of moisture contents can be measured via this method whereas moisture meters only have a limited range.

A direct, definitive moisture content can be achieved free from the effects of variable resistance and electrolytic contaminants.

Accurate measurements of moisture gradients throughout the thickness of a piece of timber can be achieved (AS/NZS 1080.1, 1997).

1.5.2 Moisture Meter Method - Advantages

Instant moisture meter readings can be taken frequently with a moisture meter, as opposed to the oven dry method where at least twenty four hours are required.

Many readings can be made at any one time with minimal effort. The oven dry method is restricted by the capacity of the oven used.

Moisture meters (especially capacitance-type) are a non destructive means of measuring moisture content. A loss due to the cutting of samples results when using the oven-dry method.

Chapter 2. Experimental Literature Review

2.1 Introduction

When using moisture meters on timber other than Douglas fir it is recommended that species correction data is used. Species correction data for resistance type moisture meters already exists for a vast number of species (AS/NZS1080.1, 1997). Capacitance-type meter correction data does not exist for any Tasmanian eucalypt species so far as this author is aware.

A number of resistance-type meter species correction data is available for Tasmanian eucalypt species (AS/NZS1080.1, 1997). This data has been taken from Hartley (1995) where each species was 'tested at 20 to 21°C with the current flow perpendicular to the grain'. The resistance of timber is greater across the grain than with the grain. The effect is very small on readings 10% or lower, and can be disregarded. Above 10% the effect becomes more apparent. The resistance-type meters used predominantly in the Tasmanian timber industry specify that measurements should be made parallel to the grain. Thus, it is evident that the species correction data currently available in the standard (AS/NZS1080.1, 1997) may be incorrect when using those meters which specify 'parallel to the grain measurements'. Therefore the basis of this authors work is to create species correction data for Tasmanian commercial eucalypt species using moisture meters which are widely used in the industry today. The three main eucalypt species commercially available in Tasmania are *E. delegatensis* R.T.Bak, *E. regnans* F.Muell and *E. obliqua* L'Herit. They are usually sold together under the standard trade name of Tas. Oak. *E. globulus* (R.T.Bak), another Tasmanian eucalypt species, is also quite prevalent commercially, although not so much as Tas. Oak.

Due to time restrictions *E. delegatensis* is the only species used in this report for correction data generation, however the other three species mentioned above will have moisture meter correction data generated for them at a later date.

2.2 Eucalyptus Delegatensis

Eucalyptus delegatensis is a large hardwood which grows in cold climate areas of Tasmania, Victoria and south-eastern New South Wales (Bootle, 1983). The following map of Tasmania shows the areas of growth of *E. delegatensis* (figure 2.1).

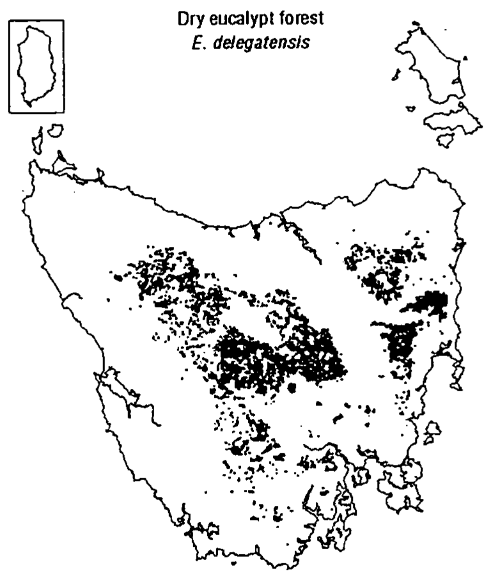

Figure 2.1 - *E. delegatensis* growth in Tasmania

E. delegatensis is a major species in Tasmania and Victoria and is sometimes referred to as alpine ash in Victoria. A generic field name does not appear to have been given to this species.

2.3 Basis for generating species correction data for moisture meters

The basis for generating species correction data for moisture meters is the comparison of measured MCs using a moisture meter with the oven dry method. The oven dry method is considered to be the most accurate method of measuring MC (AS/NZS 1080.1, 1997). It is for this reason that the oven dry method is used as the standard for comparison. In order to obtain the most accurate results possible, factors affecting moisture meter readings (see sections 1.4, 1.5) need to be eliminated. Therefore precautions concerning temperature, moisture meter contact, moisture meter range, chemicals, moisture gradient and timber thickness affecting moisture meter readings must be made.

The following procedures for generating species correction data for electrical moisture meters encompas the above precautions.

2.4 Species correction data generation for electrical moisture meters.

2.4.1 Obtaining Samples

Green samples, free from imperfections such as knots and gum veins, should be taken from mature trees grown in districts where the species occurs in commercial quantities. Edwards (undated) suggests that the amount of material from each log should be sufficient to cut two quartersawn specimens with dressed sizes of 125mm long × 75mm wide × 16mm thick. The samples should be dressed in order to reduce errors in meter readings caused by poor electrode contact. This is especially important when taking measurements with capacitance-type moisture meters.

The following dimensions are generally requested (Edwards) for the cutting of quartersawn flitches from logs: 610mm long × 1016mm wide × 25mm thick. This should give more than sufficient dimensions to dress the sample for the tests whilst being easy to handle. Care must be taken during collection, transport and machining not to allow a reduction in MC of the samples below that of the first test. Edwards states that samples which are allowed to arrive at 20% before the commencement of testing are difficult to raise above this value by conventional methods without soaking in water. Soaking should be avoided as possible leaching of natural timber extractives into the water may occur resulting in changes to the electrical properties of the timber.

This procedure for sample preparation is also used by Foo and Liah (1996) and CSIRO (1974).

Milota and Gupta (1996) and Milota (1996) used sample preparations similar to those of Edwards, however sample sizes were 250mm × 100mm × 50mm and 300mm × random widths × 31mm respectively. Also the samples were only planed or dressed on one face instead of both faces. The samples were considerably thicker than those used by Edwards as correction data was generated using both resistance-type and capacitance-type meters as opposed to only resistance-type meters. The increase in sample thickness is governed by the depth at which capacitance-type meters can measure. Samples used by Milota and Gupta (1996) and Milota (1996) were end coated with an impermeable neoprene seal and air dried to about 30% MC before the commencement of conditioning. End coating was performed to prevent end drying of the samples in order to decrease the possibility of moisture gradients forming along the length of the sample.

2.4.2 Conditioning of Samples

To obtain correction data for resistance-type moisture meters, Edwards suggests that approximately six MCs are sufficient to obtain reliable data. The MCs should be well spaced and in the measurable range of the moisture meter. Edwards suggests between 8 and 24% MC. A set of conditions such as 24, 18, 12 and 8% MC would be typical, but these can be modified to suit available facilities.

Before conditioning commences, the initial green MC of each sample must be known. This is achieved by simply sawing a test piece from each sample and using the oven-dry MC determination method (see section 1.2). Thus, a rough idea can be obtained of the amount of drying required to arrive at the first or highest MC for the commencement of testing. Using the method for measuring the MC of samples as they dry (i.e. weighing the samples periodically during the drying process) allows the samples to arrive at the first MC accurately (see section 1.2).

Drying the samples must be performed in such a way so as not to introduce defects into the samples such as surface checking, collapse and warping of the timber. The process of drying the samples to the first MC for the commencement of testing will introduce a drying gradient across the thickness of each sample. In order to overcome moisture meter reading errors due to moisture gradients Edwards suggests holding the samples at a constant temperature and relative humidity (RH) dependent on the MC chosen for readings to be made. The MC chosen becomes the EMC of timber at these conditions. A psychrometric chart is used to choose the RH and dry bulb temperature to give the appropriate EMC. Figure 2.2 shows a typical psychrometric chart for the EMC of wood as a function of dry bulb temperature, wet bulb depression and RH.

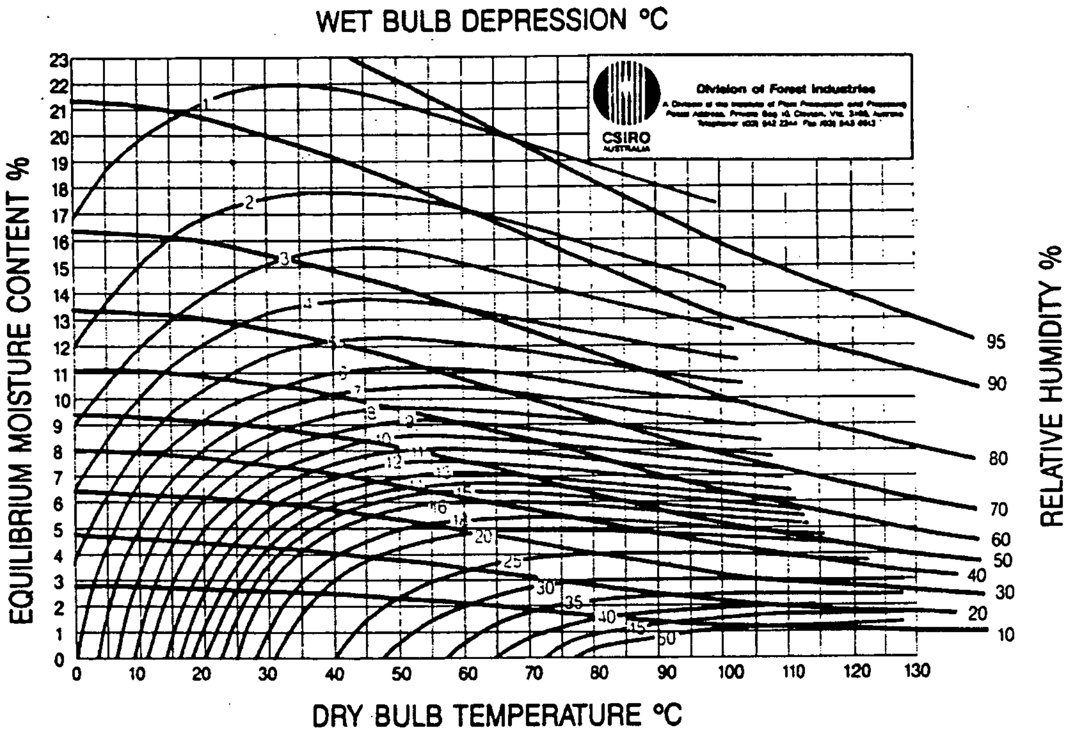

Figure 2.2 - Equilibrium Moisture Content of Wood as a Function of Dry Bulb Temperature, Wet Bulb Depression and Relative Humidity.

Eventually the samples will approach the EMC of the surrounding air and the moisture gradient will 'flatten' until it is practically non-existent. The samples are considered to be at EMC of the surrounding conditions once its weight, measured daily, becomes stable and a moisture gradient is not present through the sample's thickness.

The above process needs to be repeated for each value of MC chosen for calibration. Therefore different drying conditions must be used for the chosen MC values. Equalisation at these MCs should be obtained. Foo and Liah (1996) placed all specimens in the three different conditions, for their calibrations, as listed below:

(1) air-drying at 28°C, 85% RH, 18% EMC

(2) air-conditioned room at 21°C, 65% RH, 12% EMC

(3) conditioning cabinet at 50°C, 35% RH, 6% EMC

Milota and Gupta (1996) and Milota (1996), for their moisture meter correction data generation, placed samples in a conditioning chamber at 38°C. The RH was first held at 90% until practical equilibrium was reached. This procedure was repeated for RHs of 80, 70, and 45%. This process took approximately 3 months for the first condition and 2 months each for the others. The conditions maintained correspond to timber EMCs of approximately 20, 15, 12 and 8%.

Edwards states that 'a more precise, but probably slower, method of conditioning timber specimens to a predetermined MC which also eliminates moisture gradients, uses saturated salt solutions in the cabinet containing the specimens.' Forced air circulation is required to obtain a constant temperature and humidity throughout the cabinet and to improve drying to an equilibrium. A means of controlling the temperature inside the cabinet is also necessary. Values of RH obtained over various saturated salt solutions, at specified temperatures are available from CRC (1980-1981), and Greenspan (1977). When these are used in conjunction with the psychrometric chart shown in figure 2.2, MCs should be predictable within a few percent, provided that sufficient time is allowed for the samples to reach EMC (Edwards).

2.4.3 Meters Used for Testing

Foo and Liah (1996) used two models of electrical resistance-type meters for conducting their calibrations. The models used were the TECHTRON DCR 7T and GANN hydromette HT 75.

Two Delmhorst RDM-1v resistance-type meters and two Wagner L-600 capacitance-type meters were used by Milota and Gupta (1996) and Milota (1996). A calibrated capacitance plate and a calibrated resistance block were used hourly while taking readings to verify that the calibrations did not drift during the experiment.

2.4.4 Taking Readings

Edwards states that all measurements made by moisture meters should be carried out at approximately 21° C. Also measurements should be taken on both sides of the sample and averaged. The sample is then weighed immediately after the reading has been taken to determine its oven dry moisture content (see section 1.2).

Milota and Gupta (1996) and Milota (1996) removed the samples from the chamber and allowed them to cool to 20°C (calibration of resistance-type meters is not needed at 20°C). They were wrapped in a non permeable plastic while not being handled or conditioned. One measurement was taken with each of the four meters on the planed face only, and each sample was then weighed immediately. The location of the capacitance-type meters on the surface of each sample was marked so that the positioning could be repeated at each MC. The resistance probes were drive into the wood at approximately 6mm. At the end of the experiment the samples were oven dried so as to find their exact MC at each MC setting using equation 1.2.1. The oven dry sample volume was also determined for specific gravity corrections.

2.5 Analysis of Results

2.5.1 Linear Regression

Once the oven dry weight and the test weighings for each MC increment are known for all samples, the moisture contents corresponding to each meter reading can be calculated. A visual idea of the spread of the results can be constructed by plotting the corresponding MCs on a graph with oven dry moisture content on the x-axis and moisture meter results on the y-axis. A line of best fit is then drawn between the points plotted. This is known as a linear regression.

The linear regression method for analysing the results for both types of moisture meters was used by Foo and Liah (1996), Milota and Gupta (1996) and Milota (1996). An average of the two readings for each type of meter was calculated for each condition and sample. A linear regression was run for each species and type of meter with average moisture-meter reading as the independent variable.

The specific gravity of a material is simply the ratio of density to the density of water. Milota (1994) developed a multiple regression model based on using specific gravity as a predictor of species correction factors for dielectric-type moisture meters. Two L-600 Wagner meters were used for the study. The regression model was utilised by Milota and Gupta (1996) and Milota (1996). The correction factor CF is given by:

$$CF = 8.77 + 0.249 \times MR - 15.86\ SG - 0.62 \times MR \times SG \qquad (2.4.1)$$

where MR = moisture meter reading

SG = specific gravity

The model is based on samples taken from seven western American softwood species and one hardwood species and Milota suggests that other species can be corrected using this model. However as the timbers tested by Milota are vastly different to the Tasmanian eucalypt species using the above model 2.4.1 in this study is regarded with some skepticism.

2.5.2 R-squared coefficient (r^2) Criterion

The r^2 criterion is an indicator of how well meter readings are correlated with the oven-dry MC. The r^2 coefficient is not a quantitative measure of the accuracy of a meter, it is rather a qualitative criterion which determines whether a meter may/or may not be used in a given application. Meter readings should demonstrate highly significant correlation with the oven dry data.

The r^2 criterion depends on the number of measurements or samples used. Jamroz (1994) suggests using the following table (2.1) as a guide to whether the meter used is satisfactory under the r^2 criterion.

Number of Samples Used	r^2
6	>0.9
9	>0.8
25	>0.5
40	>0.4
70	>0.3
100	>0.25

Table 2.1 - r^2 coefficients corresponding to a highly significant correlation.

Chapter 3. Generation of Moisture Meter Correction Data for *Eucalyptus delegatensis*

3.1 Methodology and Equipment Overview

Using literature cited in section 2.3 and 2.4 as a guide, decisions regarding the methodology and equipment for generation of moisture meter correction data for *E. delegatensis* were made by the author. They are as follows:

Correction data is to be generated for two resistance-type and two capacitance-type meters.

The capacitance-type meters chosen for this study both take measurements to a depth of 19mm. It was decided that sample boards should be dressed to a thickness of 24mm to allow for possible overshoot of the electromagnetic waves at a depth of 19mm. The manufacturer of the resistance-type meters used in this study suggest that readings should be taken at a depth of one fifth of the thickness of a board to obtain a legitimate reading of its average MC. Therefore all resistance-type moisture meter readings were taken with pins driven to a depth of 5mm.

Conditioning of samples was achieved using a sealed, temperature controlled cabinet, with a capacity to store 42 samples. Humidity was controlled using saturated salt solutions in bath in the bottom of the chamber. This method of conditioning was used as Edwards suggests that this is the most accurate method of conditioning samples. The samples were conditioned at 20°C and all moisture meter measurements were made at this temperature to avoid using temperature correction data for the resistance-type moisture meters.

Three EMC values were chosen to take correction data readings. They are 18, 13, and 8%. Thus, three different salt solutions were needed to obtain these conditions. The salts were chosen using Greenspan (1977) and CRC (1980-1981) on the basis of their relative humidities at 20°C to give the EMCs above. The relative humidities corresponding to EMC values of 18, 13 and 8% at 20°C are 85, 75, and 45% respectively. The psychrometric chart, figure 2.2, was used to find these values. Where there existed more than 1 type of salt to achieve the appropriate condition, the salt chosen was the least expensive with respect to the amount needed to produce 5 litres of saturated solution. A salt was not chosen if it was deemed hazardous to a person's health.

The conditioning cabinet was able to hold 42 samples. Enough material was provided to produce 40 samples of the required dimensions. 36 samples were used to take correction data measurements, while the other four samples were used as test samples for measuring moisture gradients during the study.

The moisture gradient samples were sliced with the use of a microtome (see section 3.2.3). Samples 25 × 25 × 24mm were taken from the middle portions of sections cut from the two test samples. The small samples were sliced with the microtome into thin slices (about 1 to 2mm). As soon as a slice was taken, it was numbered and weighed on a top pan balance (sensitivity 0.001g). The process of slicing and weighing was completed as quickly as practicable to minimize the loss of moisture prior to weighing. The thickness of the slice was measured with a micrometer. The MC of the slices were measured using the oven dry method.

Results were analysed using the linear regression technique and r^2 coefficient criterion (see section 2.4).

Oven dry density was measured upon completion of data measurements in order to observe any effects caused by density to moisture meter readings (particularly the capacitance-type). The oven dry density is defined as:

$$\rho(\text{oven dry}) = \frac{W_{dry}}{V_{dry}} \tag{3.1.1}$$

Where W_{dry} = oven dry weight of sample.

V_{dry} = oven dry volume of sample.

The oven dry volume was calculated by the water displacement method with an accurate balance. The oven dry samples were fully immersed in a water filled container. The samples were immersed so that they were just under the surface of the water but not allowed to touch the container in any way. The container was resting on a balance. The difference in balance readings before and after immersion gives the mass of the volume of water displaced. The density of water is taken to be $1000kg/m^3$, therefore the displaced volume of water can be calculated. This volume is equal to the oven dry volume of the test sample.

3.2 Experimental Apparatus

The following equipment was used in this experiment for the preparing, conditioning and measurement processes.

3.2.1 Sample Preparation

An industrial planer and bench saw were used to obtain samples with the appropriate dimensions.

Emastik™ was used to end coat the samples. Emastik™ is a petroleum based, bitumus product exhibiting extremely low permeability. It has been used previously by the Tasmanian Timber Promotion Board and the University of Tasmania.

3.2.2 Conditioning

The most important piece of equipment used in the conditioning process is the conditioning chamber. The purpose of the chamber is to maintain a constant relative humidity at a constant temperature. The chamber itself is basically a hollow rectangular box on wooden legs. Its internal dimensions are 795mm high × 795 wide × 345mm deep. The walls are made from timber paneling followed by a 20mm foam layer and finally a layer of fibre glass. The fibre glass, on the interior side of the chamber, is used because of its impermeability to moisture and resistance to corrosion. The foam layer is used for thermal insulation.

The chamber has hinged doors at the front and top for easy access. Both doors are sealed when shut in order to keep the humidity of the air inside the chamber as constant as possible. Figure 3.1 shows the conditioning chamber with the front door open.

The humidity of the conditioning chamber is controlled using 5 litres of a saturated salt solution placed bath situated towards the bottom of the chamber. The water bath is elevated approximately 200mm from the bottom of the chamber by an aluminium stand. It rests on a 2mm sheet of perforated aluminium allowing for air and heat flow.

The timber samples are racked on two shelves made from perforated aluminium sheeting. The samples stand on their edges and are supported by rivets. Each shelf is able to hold a maximum of 21 samples of the dimensions given in section 3.1. The samples are separated from each other to allow sufficient air flow between them. Figures 3.2 and 3.3 show the water bath and racking shelves viewed from the front door of the chamber, and an example of the racking technique used for racking samples respectively.

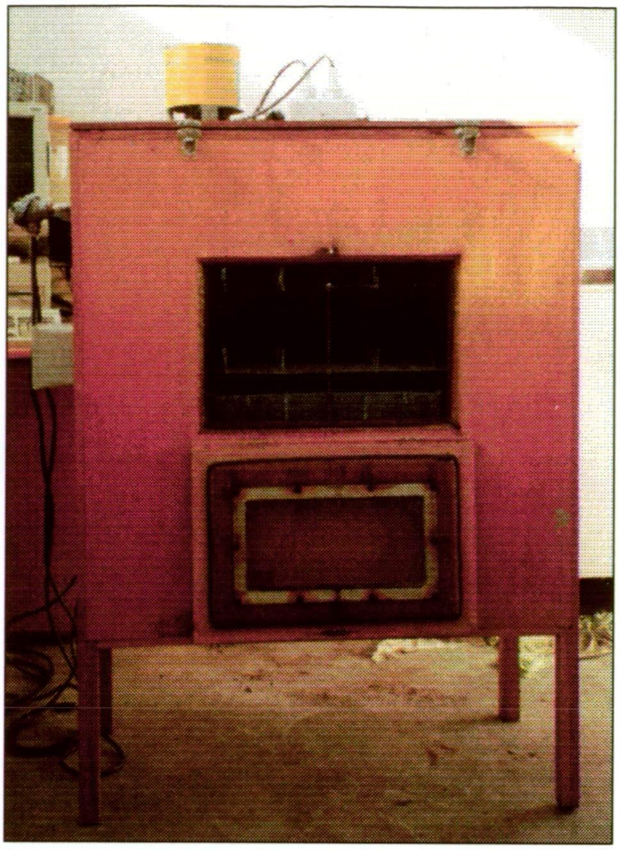

Figure 3.1 - Conditioning chamber.

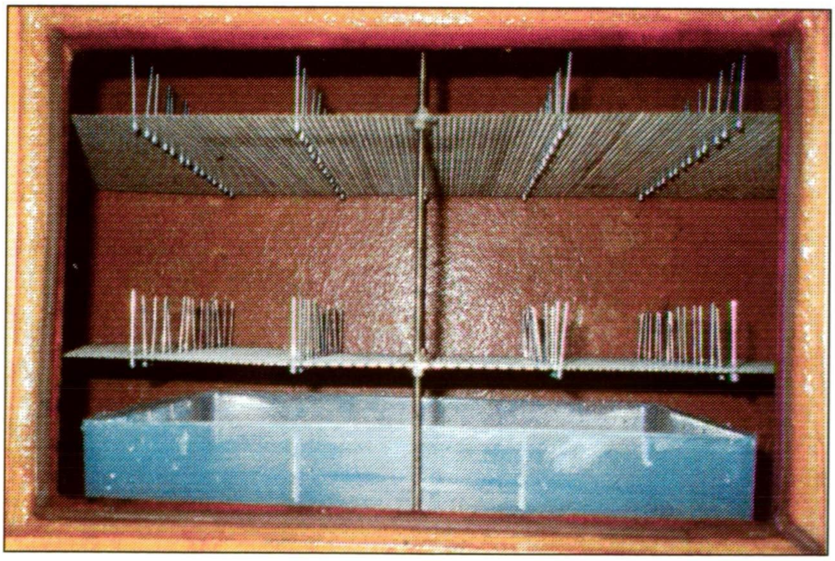

Figure 3.2 - View through the front door of the conditioning chamber showing the salt bath and sample racking shelves.

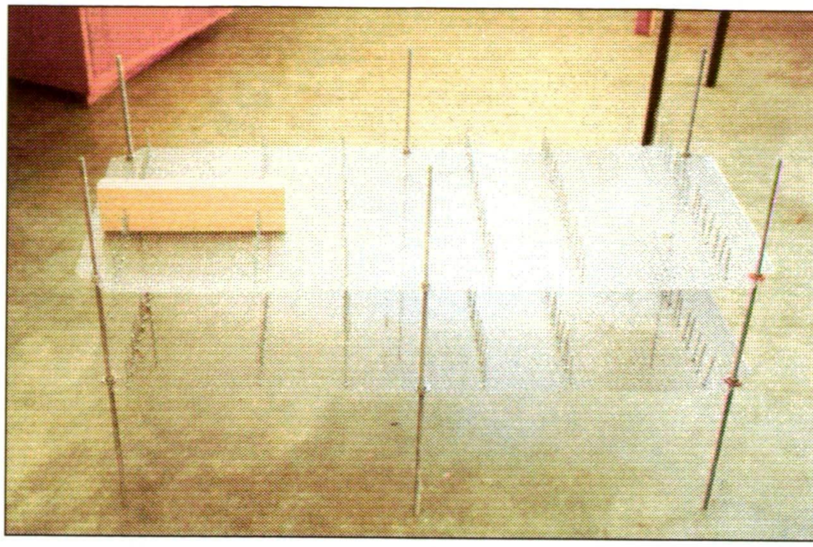

Figure 3.3 - Sample racking shelves.

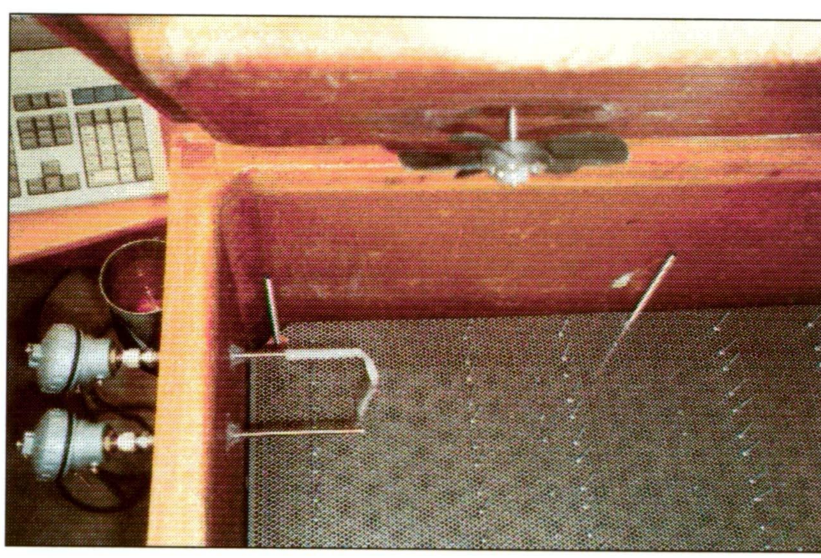

Figure 3.4 - Plan view of the conditioning chamber (open lid) showing the fan, wet and dry bulb RTDs and wet bulb water reservoir.

Heat is supplied to the conditioning chamber via two 65W heating bulbs (similar in appearance to household light bulbs) situated at the bottom of the chamber below the salt bath. Two heating elements are sufficient to hold the temperature of the chamber at 20°C.

A fan is positioned at the top of the chamber. This maintains a constant air flow, humidity and temperature distribution throughout the inside of the chamber.

Two platinum resistance temperature detectors (RTDs) are used to measure the wet bulb and dry bulb temperature of the air inside the conditioning chamber. The wet bulb temperature probe is covered with a wet sheath or wick. The wick is wetted by the use of a hose connected to the wick which leads to a water reservoir, housed on the exterior of the chamber. The probes are situated below the fan blade as air flow is required over the wet bulb probe to measure the wet bulb temperature accurately. Figure 3.4 shows a plan view of the conditioning chamber showing the fan blade, wet and dry bulb RTDs and the wet bulb reservoir.

The temperature values measured by the RTDs are read by a Datataker 100. This is a data acquisition device which converts the analogue output of the RTDs into a digital signal.

The Datataker 100 is programmed using a PC to read the RTD temperatures. The RTD temperature values are fed into the PC via the Datataker 100 and shown on a screen. The datataker 100 is programmed to switch on a relay when the dry bulb temperature falls below 20°C and to switch it off when the dry bulb temperature read above 20°C. The temperature is sampled every second. The relay is directly connected to the heating bulbs and is used to control the heat inside of the conditioning chamber. The heat inside of the chamber is maintained at 20 ± 0.1 °C.

The PC, Datataker 100, fan, and relay switch are all externally powered by a 240V supply. The following diagram shows a flow diagram of the conditioning equipment.

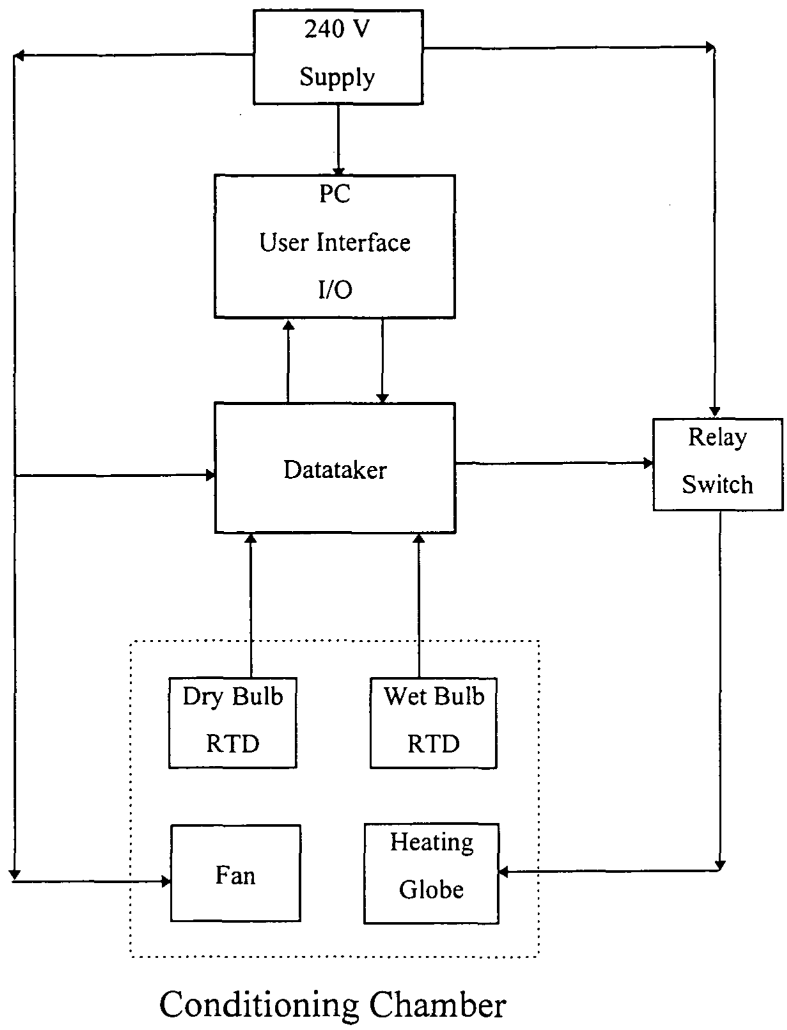

Figure 3.5 - Flow diagram of conditioning apparatus setup.

3.2.3 Measurements

Two capacitance-type and two resistance-type moisture meters were used for calibration measurements. Two Wagner L606 capacitance-type meters, a Delmhorst G-30 and Delmhorst RC-IC resistance-type meters were used. Figures 3.6, 3.7, 3.8 show the meters used for generating the correction data.

Figure 3.6 - Wagner L606 capacitance moisture meter.

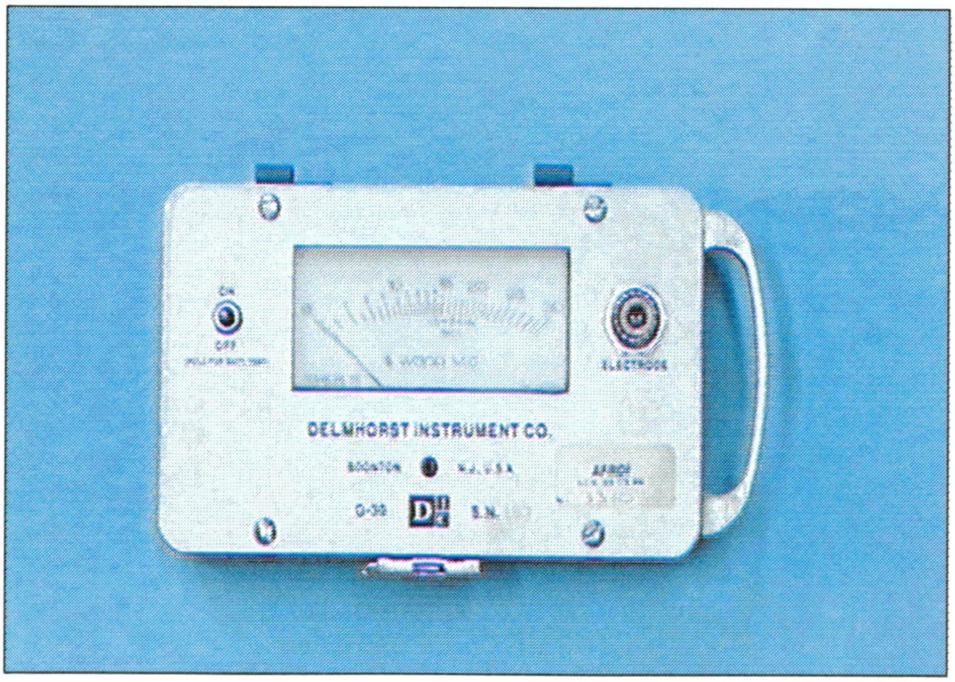

Figure 3.7 - Delmhorst G-30 resistance moisture meter.

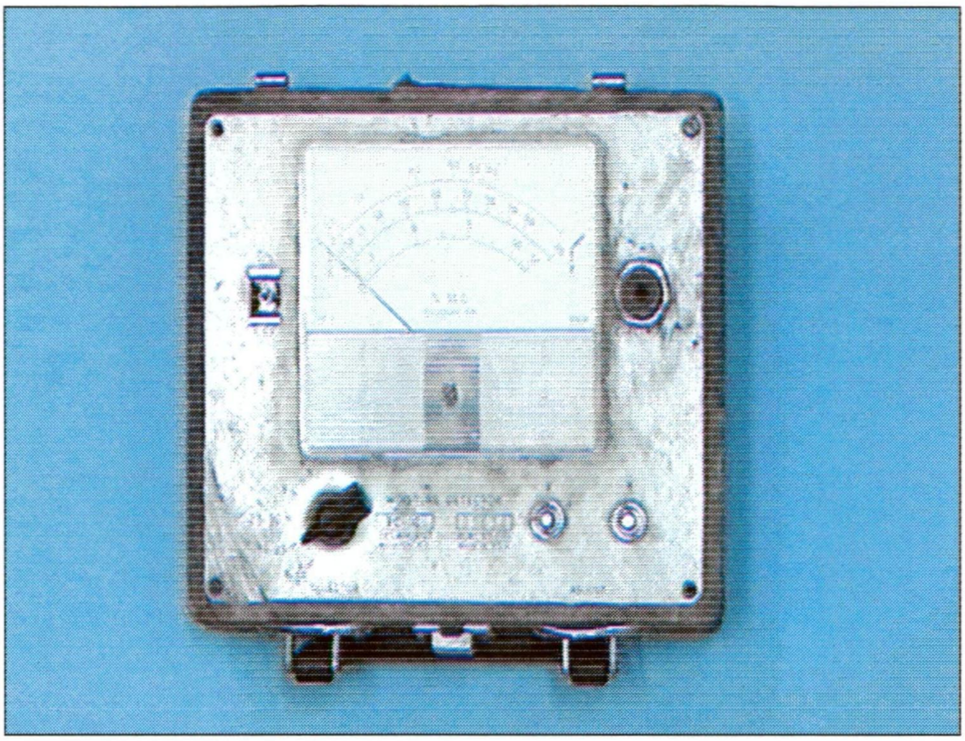

Figure 3.8 - Delmhorst RC-IC resistance moisture meter.

A calibration block was used to calibrate the resistance-type moisture meters at 22 and 12% MC.

For the oven dry method of measuring MC an electrically heated, fan forced, well ventilated oven was used. It was thermostatically controlled to a temperature of 103 ± 2°C as specified by AS/NZS 1080, 1997. An electronic top-loading balance was used to weigh the samples and small test pieces. The balance weighs to a maximum of 300g with an accuracy of 0.001g.

As previously mentioned a microtome was used to determine the moisture distribution of the test samples. A microtome consists of a sharp blade and lever apparatus and was used to slice thin sections off small samples. The microtome used was developed by the University of Tasmania and was first used by Wu (1989).

3.3 Methodology

3.3.1 Sample Preparation

Six randomly selected boards of *E. delegatensis* of length 1.8m were acquired by Boral Timber - southern division. All boards met the select criteria as defined by AS 2796.2: 1985. The boards were partially air seasoned at Boral Timbers Austins Ferry yard. To prevent any further drying, the boards were wrapped in a non permeable plastic sheeting while being transported to Boral Timbers Killafaddy yard.

Using planing and sawing equipment at Boral Timbers - Killafaddy the boards were planed on both sides to a thickness of 24mm. A 400mm length was cut from the ends of each board and discarded as specified by AS/NZS 1080.1: 1997. Then 40 230mm lengths were cut from the remaining timber. A 30mm section was cut from the end of each sample length and its MC was calculated using the oven dry method. The mass of the samples was measured immediately after the 30mm section was cut so that its progressive MC and oven dry weight could be obtained (see section 1.2). Thus the dimensions of each sample were 24mm × 100mm × 200mm as illustrated in figure 3.9.

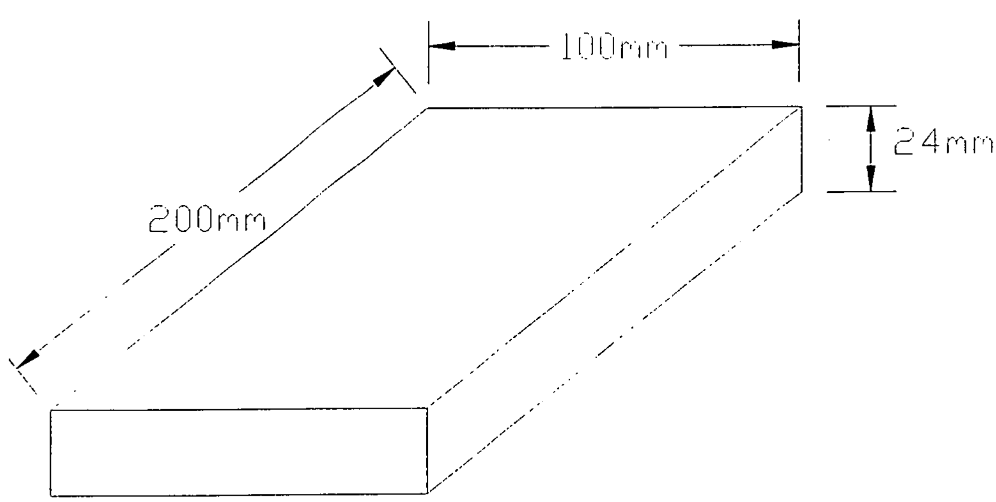

Figure 3.9 Sample size for moisture meter calibration

To avoid end drying, the samples were end coated with Emastik™ .

3.3.2 Conditioning and Measurements

Thirty six samples were used for determining moisture meter correction data, while four samples were used as test pieces for measuring moisture distribution.

The air dried samples were initially racked in the conditioning chamber at 20°C and 85% relative humidity. The humidity was controlled using 5 litres of a potassium chloride saturated salt solution. The samples were held at these conditions until they reached equilibrium. The samples were defined as having reached equilibrium once their weights remained constant to within 0.1% over a period of 48 hours and the moisture distribution measurements of the test pieces were 'flat' to within ± 1% MC. Once equilibrium was achieved at this condition, MC measurements using the moisture meters could be taken.

The samples were individually removed from the conditioning cabinet and the MC was measured on both of the planed faces of the sample, using each of the four meters. This is a total of eight measurements for each sample. The locations of the capacitance-type moisture meters on the surfaces of each sample were marked so that the meters could be repositioned in the same places when the measurements were repeated for other MCs. The weight of each sample was recorded after the moisture meter measurements were made for each sample. When the samples were not being handled or conditioned they were wrapped in an impermeable plastic wrap.

Once the moisture meter MC measurements were made, the samples were dried in a vented oven at approximately 50°C until the average MC of the samples was 13-14 %. The next equilibrium MC to be tested was 13%. 13-14% MC was chosen as the value to dry the samples in order to speed up the equalising process from 18% MC to 13% MC. The value was obtained by weighing the samples periodically during the final drying process. The conditioning and MC measuring process was repeated for relative humidities of 75% and 45%, using saturated salt solutions of sodium bromide and magnesium chloride respectively. The relative humidities correspond to EMCs of approximately 13% and 8% respectively. Final drying between EMCs was repeated between each set of measurements to average MCs corresponding to the next EMC value for conditioning.

Once the measurements were made for the final EMC value (8%), the samples were all oven dried according to AS/NZS 1080.1, 1997 and then weighed. The oven dry volume of the samples was measured using the water displacement method (see section 3.1).

3.4 Results and Analysis

The six sample boards used to obtain the samples were labeled from A to F. Once the samples were obtained they were numbered and labeled according to the board from which they were cut i.e. A1, A2 .. A7, B1 .. B7 etc. Samples A7, B7, C6 and E7 were chosen to be used for moisture profile measurements. They were re-labeled A7S1, B7S2, C6S3, E7S4 so that they could be easily distinguished from the other samples.

The initial MC was found for each sample by following the technique given in section 3.3.1, the results of which can be found in Appendix A1. The initial MC of the samples ranged between 14.1 and 16.3% giving an average initial MC of 15.2%. The predicted oven dry weight was also obtained (see section 1.2) in order to monitor the approximate MC of each sample throughout the calibration process.

The samples were initially placed in the conditioning chamber at the appropriate conditions to give equilibrium to approximately 18% MC. The samples were weighed periodically over the equalisation process, the data is in Appendix A2. After a period of 49 days the samples had an average MC of 18.4 % and were exhibiting changes in weight of less than 0.1% over a period of 48 hours. The samples had MCs ranging from 17.5 to 19.0%. A moisture profile of samples C6S3 and B7S2 were measured, the appropriate data and profile charts are in Appendix A3. The profiles were 'flat' to within ± 1 % MC.

Once the samples were deemed to have reached equilibrium (see section 3.3.2) the MC of each sample was measured using the four moisture meters. A table showing the moisture meter calibration results for sample equalisation at approximately 18% MC are in Appendix A4. The table contains the predicted MC of each sample, the resistance and capacitance type meter measurements on both sides of the samples and the average MC obtained from both types of meters.

After drying the samples for approximately 24 hours in a vented oven at 50°C (see 3.3.2) they were replaced into the conditioning chamber to equilibrate to an EMC of approximately 13%. The samples took 42 days to equilibrate. The average MC of the samples after this period was 13.8% with a MC range from 13.2 to 14.1% (Appendix A5). The moisture profile data for samples A7S1 and E7S4, and the moisture meter calibration results after equilibration to approximately 13% MC are shown in appendices A6 and A7 respectively.

The samples were dried once more in the oven at 50°C until each sample exhibited an average MC of approximately 8%. Equalisiation of the samples in the conditioning chamber was repeated for an equilibrium MC of approximately 8%. After 27 days the samples had sufficiently equalised with samples ranging in MC from 8.0 to 9.1% giving an average MC of 8.7%. Moisture meter data was repeated after equalisation and the results are given in Appendix A10.

Included on the moisture profile charts given in Appendices A3, A6 and A9 are one horizontal and two vertical dashed lines. The horizontal dashed line represents the average MC of the profile and the vertical dashed lines represent a depth of 5mm into the surfaces of the sample. It can be observed that the points at which these lines cross lie very close to the profile itself.

Once the moisture meter readings were completed the samples were oven dried according to the standard (AS/NZS 1080.1, 1997). Their oven dry weight was measured and the oven dry density was calculated (see section 3.1). Oven dry density, weight, adjusted MC and the moisture meter calibration results are shown in Appendix A11. The average oven dry weight and density for the 36 samples was 327.56g and 705 kg/m^3 respectively. It is worth noting that the average MC values taken by the capacitance type meters for samples taken from boards B and C are 2 to 4% higher than the values taken for the remaining boards. This is not the case for the average values obtained using the resistance type meters and the MCs obtained from the oven dry method. The oven dry density of samples taken from boards B and C (Appendix A11) are approximately 100 to 200kg/m^3 greater than the remaining samples. The initial oven dry MC of the samples taken from boards B and C are similar to those values determined for the remaining samples. Therefore the type of capacitance meters used in this work are shown to be highly affected by timber density.

Plots of meter reading versus ovendry MC including regression lines are shown in Figures 3.10 and 3.11 for the resistance- and capacitance-type meters respectively. On each graph the data are in three groups which correspond to the three equilibrium MCs. The r^2 value or correlation factor and regression line equations are shown on figures 3.10 and 3.11. The correlation factors are 0.98 and 0.72 for the resistance- and capacitance-type meter plots respectively.

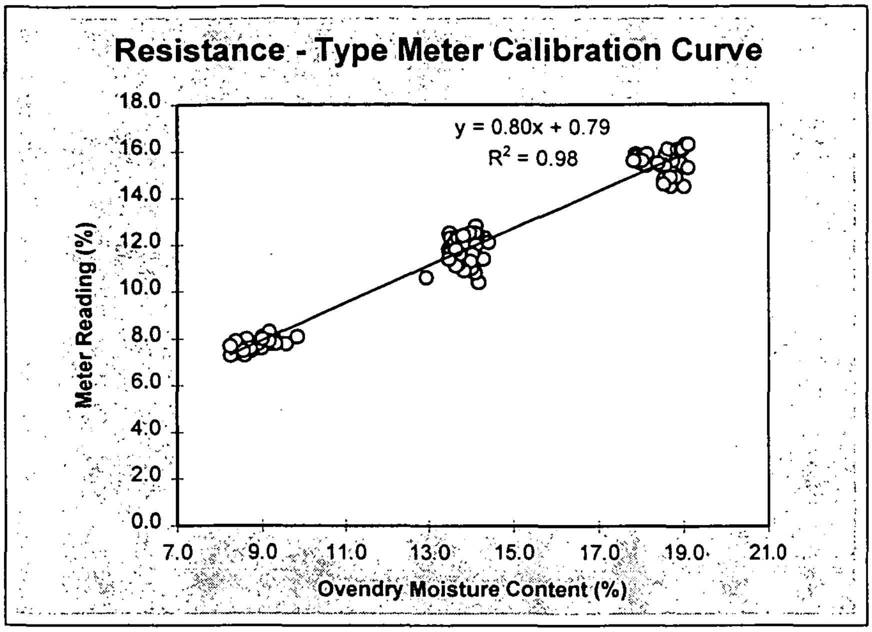

Figure 3.10 - Resistance-type meter regression plot.

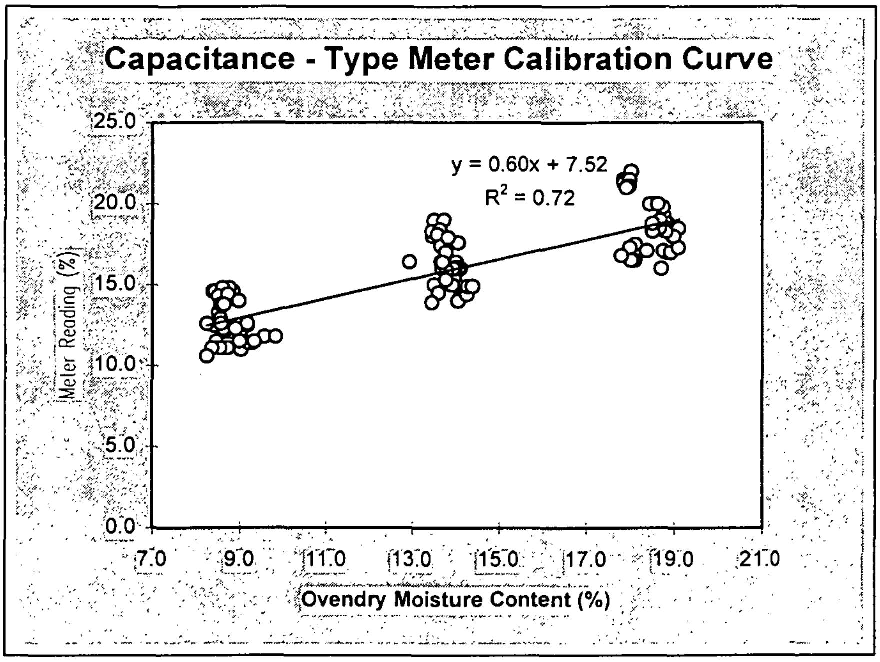

Figure 3.11 - Resistance-type meter regression plot.

The correction factors for the resistance type and capacitance type meters are shown in Table 3.1 for *E. delegatensis*. These values were obtained by using the regression line equations given in Figures 3.10 and 3.11. The correction factors for *E. delegatensis* given in the Australian standard (AS/NZ 1080.1, 1997) are also shown in table 3.1. The resistance-type meter correction data shows that for meter readings from 6 to 9%, 10 to 13%, 14 to 17%, 15 to 21% and 22 to 24% inclusive, positive corrections of 1%, 2%, 3%, 4% and 5% are required according to data obtained by this author. The correction factors used in AS/NZS 1080.1 (1997) show positive corrections of 2% and 1% are required for meter readings from 6 to 16% and 17 to 24% respectively.

Moisture Meter Reading (%)	Authors Correction for resistance-type meter (%)	Aus. Standard Correction for resistance-type meter (%)	Authors Correction for capacitance-type meter (%)
6	7	8	-3
7	8	9	-1
8	9	10	1
9	10	11	2
10	12	12	4
11	13	13	6
12	14	14	7
13	15	15	9
14	17	16	11
15	18	17	12
16	19	18	14
17	20	18	16
18	22	19	17
19	23	20	19
20	24	21	21
21	25	22	22
22	27	23	24
23	28	24	26
24	29	25	27

Table 3.1 - Correction factors for *E. delegatensis*.

3.5 Conclusions

It is evident that this authors correction factors for resistance-type moisture meters used on *E.delegatensis* deviate from those given in the Australian Standard by between ±1% below meter readings of 16.5% MC, and 2% or greater for meter readings above 16.5% MC. The cause of these deviation values are most likely due to the difference in meter electrode placement with respect to the timber grain direction, as described in section 2.1.

The regression trendline for the resistance-type meter indicates a strong fit whereas the capacitance-type meter regression trendline fit is much weaker. This means that the correction factors obtained for the capacitance-type meters used have a lesser degree of accuracy than their resistance-type counterparts.

Samples taken from boards B and C have a higher density than samples taken from the remaining boards. Readings taken from these samples using the capacitance type meters are higher on average compared with the samples taken from the remaining boards. This density difference did not seem to greatly affect readings taken with the resistance type meters. Therefore the change in density has an effect on the accuracy of the capacitance type meters.

The moisture profile charts show that the measurements of moisture content taken at a depth of 1/5 of the total thickness of the sample (approximately 5mm in this case) correlates well with the average MC of the sample. Driving insulated pins to this depth will not always guarantee that the average MC of the sample will be measured however the result reinforces the guidelines set by he manufacturer of the resistance type meters used (see 3.1).

Chapter 4. Solar Kiln Research

4.1 Introduction

The solar kiln used for this section of research is located at Kelly's Timber - Dunalley. The main objective of this section of research was to produce a drying regime for the solar kiln trial and monitor its progress during the drying process. The outcome should provide sufficient data to eventually produce an efficient drying schedule. The quality of air flow and temperature distribution in the kiln were measured. Based on the measurements taken, possible improvements were suggested so that the drying efficiency of the kiln could be improved.

4.2 Design Criteria

The particular kiln researched was designed by the Department of Conservation and Land Management (CALM), Wood Utilisation Research Centre, Western Australia. The CALM solar kilns were originally aimed towards the small hardwood sawmillers of Western Australia (McDonald 1991). Most conventional kilns have large operating and capital costs, and are generally only directed towards companies wishing to produce large quantities of seasoned timber. Thus, there was a perceived need for a drying system suitable for companies involved in sawmilling and drying which do not have the resources to invest in conventional drying equipment.

The design criteria of the CALM solar kiln was to produce an efficient, low cost, dryer for small volumes of timber (McDonald 1991). To achieve this CALM decided to use a low cost structure utilising solar energy and other renewable resources. The kiln was required to have a control system which minimalised labour costs whilst having minimum sophistication for the particular drying requirement. The kiln needed to be easy to erect and readily transportable in kit form.

In the past CALM solar kilns have been successful in Western Australia for drying their timbers (McDonald 1991). The solar kiln at Dunalley is the first of its type to be built in Tasmania.

4.3 Design

The CALM solar kiln design, as the name suggests, utilises energy from the sun. It achieves this by using a translucent, flexible, PVC membrane as an outer cover. This particular fabric is transparent to solar radiation while being resistant to degradation caused by ultra-violet radiation. In effect the cover works on the same principle as a greenhouse, however the fabric has a longer life than most horticultural plastics (5 years as compared to 1-2 years (McDonald 1991). Two layers of plastic are used. The gap between them is inflated using small fans attached to the external membrane to create an air-gap of 100mm. The air-gap acts as an insulation and also makes the overall structure more rigid. The insulation properties of the double layered membrane is beneficial for damping temperature fluctuations and reducing radiation and conduction losses, thus conserving energy.

The outer cover of the kiln is supported by a tubular steel framework. It is relatively inexpensive. Sophisticated handling equipment does not have to be employed to construct the framework. Only a small forklift, which most sawmillers have access to, is necessary for construction.

The floor of the kiln is simply a concrete slab to which the framework is attached via steel footings. This creates a surface which contributes to a clean environment and easy loading.
McDonald (1991) states that, 'a prime innovation of the CALM drying system relates to its control of air circulation'. Air circulation is provided using three fans situated

above the timber charge and air is circulated in one direction only. A tunnel is formed over the timber by using a black plastic blanket which presses against the charge by a pressure differential between the air inside and the air outside of the blanket. This concept is further illustrated by figure 4.1. The blanket is designed to absorb heat radiated from the sun and to baffle the charge and produce a constant air flow across it.

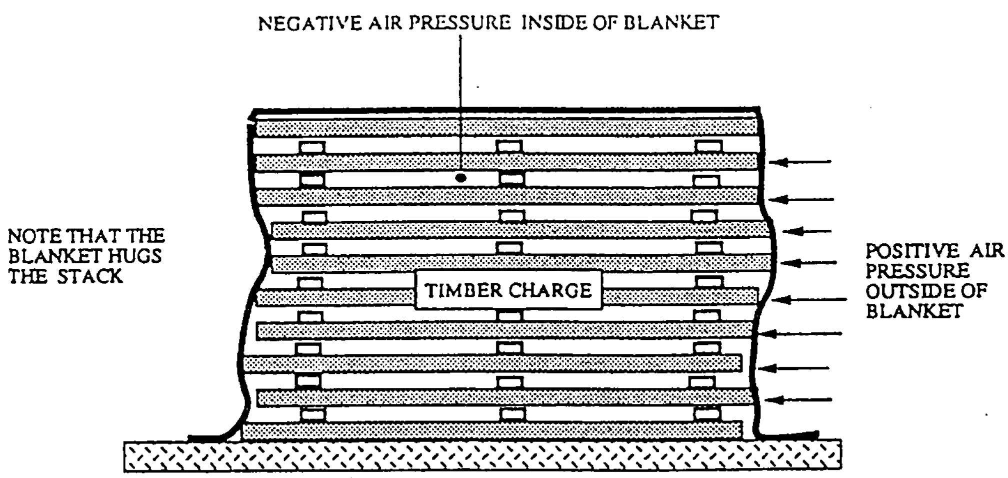

Figure 4.1 - Section through the blanket and charge

Control of the relative humidity inside the kiln is critical for developing drying schedules for particular drying applications. In order to maintain high humidities in the kiln, a fogging system is incorporated into the design. The system consists of laser cut nozzles connected to a hose traversing the width of the kiln near the centre of the timber charge. High pressure water is forced out of the nozzles to produce a fogged environment. The humidification produced by this fogging system is equivalent to the more conventional steam humidification system but uses much less energy as the water is at ambient temperature (McDonald 1991). The humidity is maintained by the use of vents and foggers together.

In order to reduce fluctuations in temperature caused by fluctuations in the solar radiation, which contributes to the heat requirements, an auxiliary heat source is needed. In the case of this kiln, auxiliary heating is produced at the rear of the kiln using an LPG gas burner. Therefore, the humidity and temperature inside the kiln can be controlled to the required levels providing that the ambient conditions outside of the kiln do not conflict with those on the inside.

The kiln is controlled by the use of a Programmable Logic Controller (PLC) unit, mounted in a small shed at the back of the kiln. The unit is used to control the temperature and humidity of the kiln to the required setpoints by switching of the heater, vents and foggers. The PLC unit also logs the kiln conditions over time. The following diagram (figure 4.2) shows the basic skeletal structure of the kiln outlining the main design features.

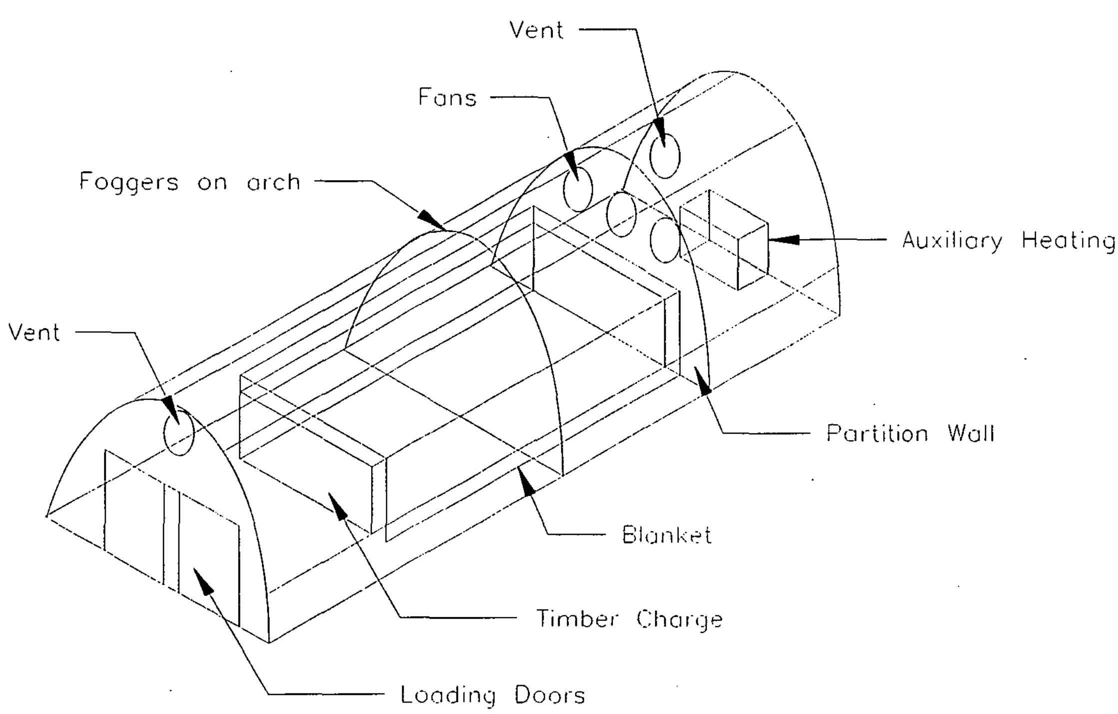

Figure 4.2 - Solar Kiln - Basic Structure.

Photographs of the solar kiln at Dunalley are shown in figures 4.3, 4.4, and 4.5.

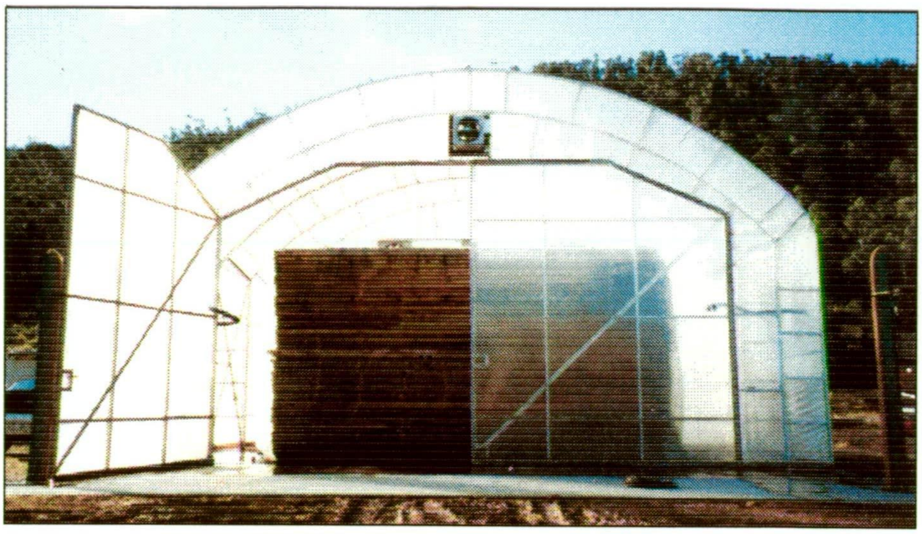

Figure 4.3 - Kiln front with front door open - fully loaded.

Figure 4.4 - Interior of the kiln viewed from the back end (air outlet side). Note the fans at the top and the gas burner at the lower left side of the photo.

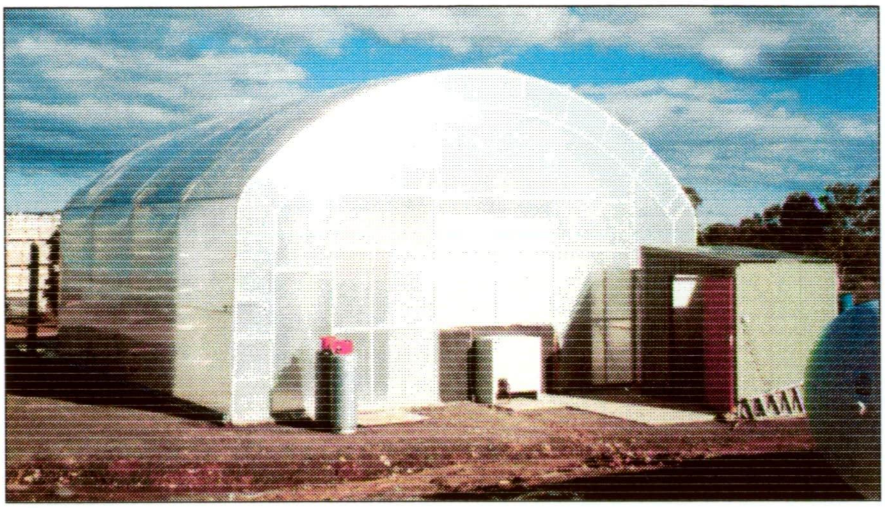

Figure 4.5 - Rear end of kiln (exterior). The control gear for the kiln is housed in the small green shed at the right of the picture.

The air flow inside the kiln is produced by three fans mounted at the top of the partition wall (figure 4.2). The air flow is in one direction only and moves across the blanket covering the timber stack, towards the front loading doors, and then flows through the length of the stack exiting at the gas burner end.

The timber racks are stacked so that their length traverses the width of the kiln. The entire stack consists of a total of sixteen racks, orientated four racks high and four racks deep. This gives a kiln capacity of approximately 35 m^3 of timber.

4.4 Solar Kiln Drying Trials

Two trials have been completed at the time of writing this thesis. A third trial was still being performed.

4.4.1 Trial 1

The first solar kiln drying trial was performed on a full load of partially air seasoned stock. The stock was at a MC of approximately 17%. The main purpose of this trial was to test the air flow characteristics in the kiln, particularly through the timber charge.

4.4.1.1 Air Flow Measurements

The air flow inside the kiln is produced by the use of three fans mounted horizontally and equally spaced at the top of the partition wall (figure 4.2). The fans are not variable speed controlled or reversible. They can be individually switched on or off.

Air flow measurements were taken using a 72mm diameter vane probe anemometer at the air inlet face of the racks with only the centre fan on, both outside fans on and all three working. The air inlet side of the stack is that face closest to the front loading doors (figure 4.2). Readings were taken at the horizontal center of each of the four racks, and above the top of the plastic blanket. The average lengths of the racks measured was 5.4m and the readings began 0.2m from the side edge of the rack and continued at 1m intervals along the length of each rack. This is more clearly illustrated by figure 4.6.

The racks were labelled from A to D for the bottom to top racks respectively. Air flow measurements performed on the air inlet side of the stack for the three fan positions are given in tables 4.1, 4.2 and 4.3.

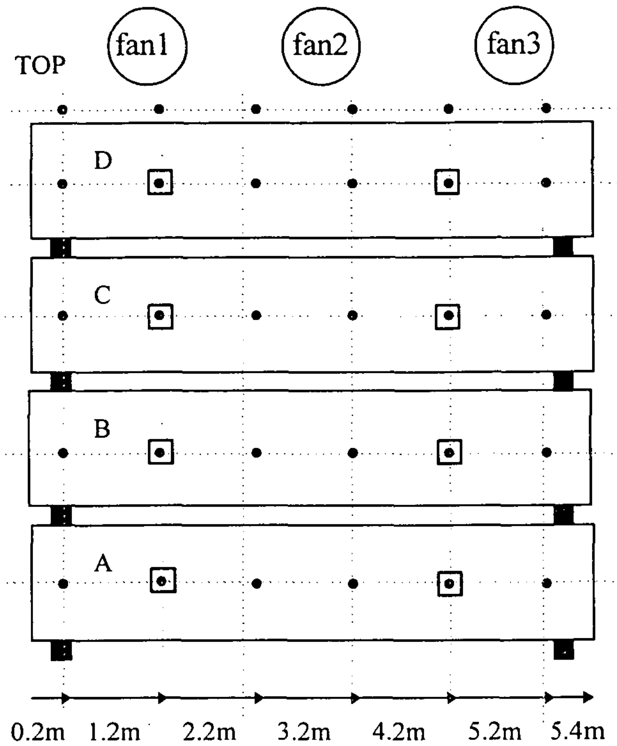

Figure 4.6 - Air flow reading positions taken at positions marked with a • .
Temperature readings were taken at positions marked with a □ .

	Distance From Rack End (m)					
Rack No.	0.2	1.2	2.2	3.2	4.2	5.2
TOP	1.3	2.2	3.2	3.0	1.7	1.6
D	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0	0.0	0.1
A	0.1	0.0	0.0	0.0	0.0	0.2

Table 4.1 - Inlet air flow measurements (m/s) - centre fan2.

	Distance From Rack End (m)					
Rack No.	0.2	1.2	2.2	3.2	4.2	5.2
TOP	3.0	5.0	4.6	4.2	5.0	5.0
D	0.0	0.0	0.1	0.1	0.1	0.1
C	0.4	0.1	0.1	0.2	0.2	0.2
B	0.1	0.2	0.2	0.2	0.4	0.2
A	0.2	0.2	0.3	0.3	0.5	0.2

Table 4.2 - Inlet air flow measurements (m/s) - outside fans 1 & 3.

	Distance From Rack End (m)					
Rack No.	0.2	1.2	2.2	3.2	4.2	5.2
TOP	2.5	2.8	3.0	5.0	4.8	2.6
D	0.6	0.2	0.1	0.2	0.1	0.3
C	0.7	0.4	0.2	0.2	0.3	0.7
B	0.6	0.4	0.4	0.3	0.5	0.6
A	0.7	0.5	0.6	0.5	0.8	0.7

Table 4.3 - Inlet air flow measurements (m/s) - all fans 1,2 & 3.

Waterson (1997, p53) suggests that the air flow rates through the timber stack of solar and predrying kilns should be 0.5 and 1 m/s respectively. As the solar kiln is to be used as a predrier it is recommended that the air flow lies between these values.

Table 4.1 shows the inlet air flow (m/s) through the stack with only the centre fan running. Even though measurable air flows were recorded across the top of the stack, insufficient air flows were measured at the stack face. The air flow data with fan1 and fan 3 running (table 4.2) also shows an overall deficiency in air flow (i.e. below 0.5 m/s) throughout the stack face.

The inlet air flow data with all three fans running was measured (table 4.3). The air flow values for racks A, B, C, and D are higher on average compared with the previous measurements for the other fan conditions. It can be noted that the air flows are substantially higher around the outside of the stack and at the lower rack (rack A). This is highlighted by the shaded area in table 4.3. The racks placed in the kiln did not contain boards of even length and hence the rack edges were 'staggered' causing larger gaps for the air to flow at the rack ends. Air flow, by nature, tends to the path of least resistance. The path of least resistance in this case was the large air gaps at the rack ends, thus the air flow was greater at these positions.

Measurable air flows were present at the air outlet side (gas burner end) of the stack with all three fans operating. The data measured is in table 4.4.

	Distance From Rack End (m)					
Rack No.	0.2	1.2	2.2	3.2	4.2	5.2
D	0.1	0.1	0.2	0.3	0.2	0.3
C	0.2	0.1	0.3	0.3	0.3	0.3
B	0.2	0.3	0.3	0.5	0.3	0.2
A	0.2	0.4	0.2	0.2	0.2	0.3

Table 4.4 - Outlet air flow data (m/s) - all fans 1,2 & 3.

Comparing the air inlet and air outlet sides of the stack with three fans running (tables 4.3 and 4.4) it can be observed that the air flow has decreased at the air outlet side. The decrease in air flow from the air inlet side of the stack to the air outlet side was predicted to be due to insufficient baffling. It was noted that the air inlet side of the stack had baffling in place between the racks, in the form of timber planks, nailed to the bearers. It was suggested that for the second trial, baffling be placed between all racks for the following three rows in the stack. This should reduce air flow losses. As insufficient air flows were recorded with only one and two fans operating the author recommended operating the kiln with all three fans on for the following trial.

4.4.1.2 Humidity Measurements

The PLC controller is used to control the humidity and dry bulb temperature of the kiln via manual setpoints. With the kiln controlling at setpoints of 50% relative humidity and 28°C dry bulb temperature two humidity readings were measured using a sling psychrometer in order to check the accuracy of the humidity and temperature probes used by the kiln controller. The psychrometer measurements were made close to the same location as the controller probes. The readings were made three hours apart and can be observed in table 4.5.

	Controller Reading		Psychrometer reading	
Reading No.	Humidity	Dry Bulb Temp.	Humidity	Dry Bulb Temp.
1.	49.50%	26.5 deg	52%	27 deg
2.	44%	28.5 deg	46%	28.5 deg

Table 4.5 - Humidity and dry bulb temp. comparisons.

The psychrometer readings compare to within a maximum of 3% RH and 1°C dry bulb temperature, of the controller readings. Thus the humidity and temperature probes used to control the kiln were deemed accurate at this setpoint.

4.4.2 Trial 2

The main objective for trial 2 was to initiate a drying regime for a green sawn charge of timber and monitor its progress during the drying process. The progress of the kiln was monitored by periodically measuring the moisture content of samples cut from the racks. The timber was racked in the same 4 × 4 formation as for the first trial. The timber was sawn from the same species of logs, taken from the same location. The boards were predominantly quarter sawn to a nominal thickness of 38mm with widths ranging from 100 - 225mm. The quality of air flow and temperature distribution were also recorded in this trial.

4.4.2.1 Air Flow Measurements

Air flow measurements were produced for trial 2 as for the first trial using an anemometer. The measurements were taken along the same grid reference as for the first trial (figure 4.6). Measurements were taken at the air inlet and outlet sides of the stack with all three fans operating.. This data is shown in tables 4.6 and 4.7.

	Distance From Rack End (m)					
Rack No.	0.2	1.2	2.2	3.2	4.2	5.2
D	0.5	0.4	0.3	0.3	0.3	0.5
C	0.5	0.5	0.7	0.5	0.5	0.8
B	0.6	0.6	0.6	0.6	0.5	0.9
A	0.6	0.6	0.6	0.5	0.5	0.7

Table 4.6 - Inlet air flow measurements (m/s) - trial 2.

	Distance From Rack End (m)					
Rack No.	0.2	1.2	2.2	3.2	4.2	5.2
D	0.3	0.3	0.2	0.2	0.1	0.1
C	0.1	0.0	0.1	0.1	0.1	0.1
B	0.3	0.2	0.2	0.2	0.2	0.3
A	0.1	0.1	0.0	0.0	0.1	0.2

Table 4.7 - Outlet air flow measurements (m/s) - trial 2.

For this trial the racks were made up of boards as close to equal lengths as possible. This reduced the large air gaps at the rack ends which were present in the first trial. This change in racking technique is reflected in the air flow measurements taken at the air inlet side of the stack (table 4.6). Compared to those taken in the first trial (table 4.3) the equality of air flow has been enhanced across the stack face. Excluding the center of the top rack (D) the air flow meets the requirements of Waterson (1997) for a solar, predrying kiln (between 0.5 and 1 m/s).

Air flow measurements were also taken at the air outlet side of the stack (table 4.7). As with the first trial, air outlet flow values exhibited a loss compared with those on the air inlet side of the stack. Again this was thought to be due insufficient bearer baffling between the second, third and fourth set of racks (see 4.3.1.1). The kiln operator was reminded to put the baffling in place however this did not eventuate.

Air flows were recorded between the racks A-B, B-C and C-D at the air outlet side. This data is shown in table 4.8. From this data it is obvious that a significant flow of air is escaping between the racks producing poor air flows through the racks themselves as predicted in the first trial. It is imperative that these bearer spaces be covered on the front face of each row of racks for following trials to help improve the air flow through the entire stack.

	Distance From Rack End (m)					
Rack No.	0.2	1.2	2.2	3.2	4.2	5.2
C - D	2.0	1.2	1.2	1.1	1.1	0.8
B - C	1.0	1.8	2.5	1.5	1.2	0.7
A - B	1.1	1.4	1.6	1.4	1.2	1

Table 4.8 - Air flow between racks (m/s) - air outlet side.

4.4.2.2 Temperature Distribution

The temperature distribution across the air inlet or front face of the timber stack was measured at a setpoint temperature of 22 °C. The measurements were taken at the front face because of its close proximity to the temperature probe which controls the kiln. Eight RTD temperature probes were used to measure the temperature. A Datataker 500 (similar to that described in 3.1.2) was programmed using a PC to read the RTD temperatures. Two RTD's were placed at the horzontal centre of each rack level (A, B, C, and D) at the 1.2m and 4.2m positions as shown on diagram 4.6. Temperature measurements were recorded every 20 seconds for approximately 50 minutes. The values measured for each probe over the allotted time can be found in appendix B1. Over the time period the temperature for each probe only changes by a maximum of 0.2 °C. As the temperature variation is very small the average value for each probe is considered static over the time period. The average values are given in appendix B1 however they are easier to visualise by arranging them into a tabulated form similar to the measurement orientation (table 4.9).

	Temperature (deg C)	
Position	1.2m (1)	4.2m (2)
D	21.9	22.3
C	21.8	22.4
B	21.8	22.2
A	21.7	22.1

Table 4.9 - Average temperature distribution - air inlet side.

The values given in table 4.9 indicate that the vertical and horizontal temperature distribution throughout the kiln varies by a maximum as 0.3 °C and 0.6 °C respectively. These variations are acceptable for a kiln of this size. These values also confirm the accuracy of the kiln temperature probe and the kilns ability to control to the setpoint.

4.4.2.3 Moisture Content and Scheduling.

In order monitor the progress of the timber during drying the average initial and progressive average moisture content of the stack was required. This was achieved by taking samples from the stack for both initial and progressive measurements.

Samples were obtained from the ends of the racks so that they could be easily removed and replaced whilst drying. Two sample boards of comparatively standard size were chosen from the ends of each rack so that uniformity of drying throughout the kiln is covered. The boards chosen were free of end splits, gum veins and knots. They were taken from at least three boards in from the outside of the rack as boards on the outside dry faster and do not represent the average moisture content of the rack (Waterson).

After a suitable board was selected 800 - 900mm was docked from the end. A further 25 mm was cut from the freshly docked end to be used for initial MC determination. The weight of the 25mm and 800 - 900mm sections were determined immediately after removal from the stack. The 800 - 900mm samples were end coated with a non permeable grease to reduce possible end drying and replaced back into its original position in the stack.

This was repeated for 32 samples (one sample from each end of sixteen racks). The rack ends were labelled as depicted by figure 4.7 which shows a plan view of the rack layout in the kiln. The samples were labeled according to the rack end they were situated where the lowest level was numbered level 1 and the top level was level 4. Therefore the samples were labeled A1, A2, A3, A4, B1, B2, B3, B4, C1, etc.

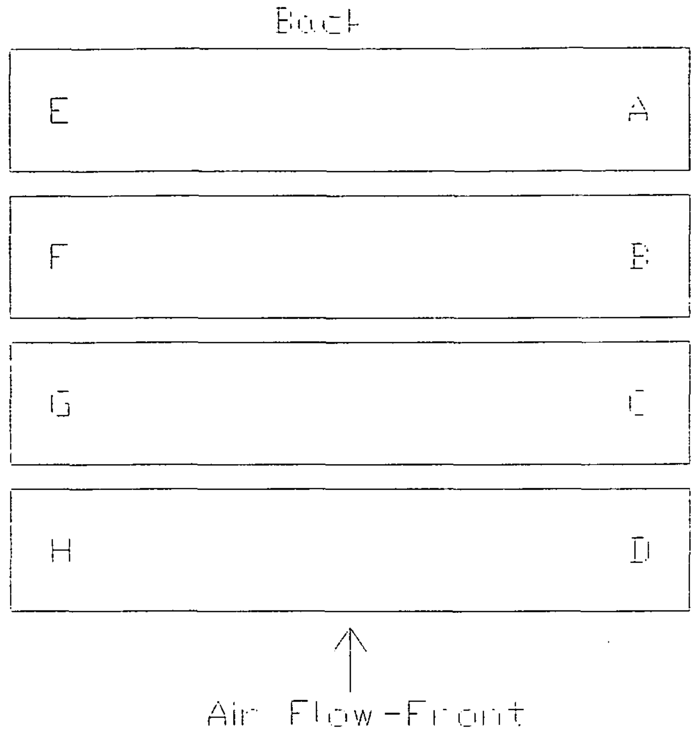

Figure 4.7 - Plan view of rack layout.

The 25mm sections were plastic wrapped and sent to the author at the University of Tasmania for determined of initial MC. The MC was determined via AS/NZS1080.1, 1997 using equation 1.2.1. For reasons unknown to the author 29 samples were delivered instead of 32. The average initial MC of the 29 samples was 53.8 %. The initial weight, oven dry weight and MC of the 25mm sections is give in appendix B2. The initial weight of the 800 - 900mm sample board is also given.

Upon initial inspection of the 25mm green samples, 21 of the 29 samples were collapsed, 10 of which exhibited internal checking. It is interesting to note that the samples which did not show any collapse or internal checking contained very narrow growth rings as compared with the collapsed samples. Figures 4.8 and 4.9 show examples of, a severely internally checked/collapsed sample and a comparison between a narrow growth ring/non collapsed sample with a wide growth ring/collapsed sample, respectively.

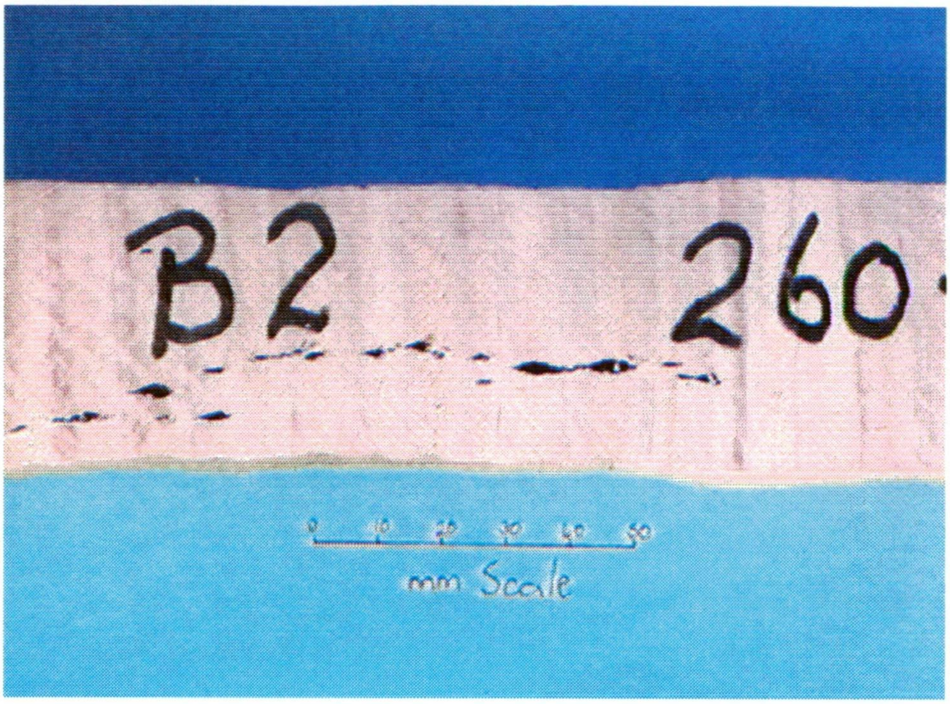

Figure 4.8 - Green sample exhibiting severe collapse and internal checking.

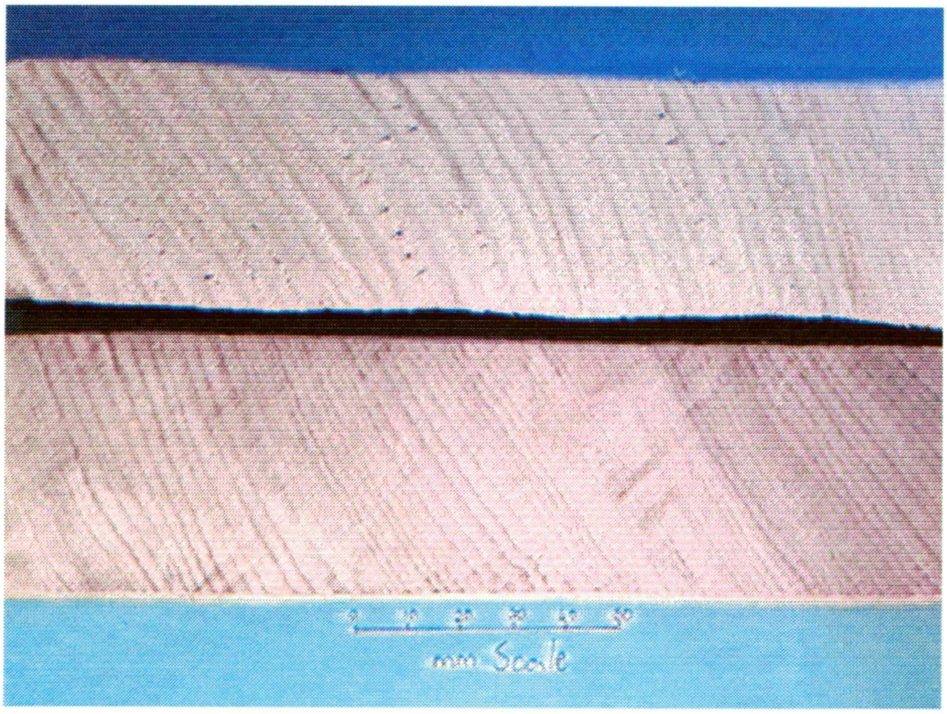

Figure 4.9 - Comparison of wide growth ring/collapsed sample (top) with thin growth ring/non collapsed sample (bottom).

As approximately one third of the samples were initially collapsed before any kiln drying took place it was difficult to provide a predrying schedule which did not induce collapse and checking in the timber. The schedule provided was given on the basis of the average moisture content of the 800-900mm samples whilst drying, and common industry practice. The method for monitoring MC whilst drying is given in chapter 1, section 1.2.

Days of drying	Dry Bulb Temp.	Humidity
0	22	90
9	24	83
22	24	80
31	26	78
45	28	78

Table 4.10 - Predrying Schedule

The progressive MC data for the 29 samples is given in appendixB3. Table 4.10 shows the predrying schedule used, based on the average MC of the kiln samples. The last line of setpoints given on after 45 days were held until a sufficient number of the samples had average MC's below 25%. This was achieved after 65 days. The average MC of the progressive kiln samples dropped from 53.8% to 19.1%. The maximum and minimum MC range that these averages were derived from were 35.7 to 72.9 % and 10.0 to 27.2% respectvely.

After 65 days the timber was reconditioned at 90°C in a reconditioning chamber saturated with steam for 8 hours. These conditions are commonly used in the Tasmanian industry for reconditioning Tas. Oak. The purpose of reconditioning is to recover collapse and relieve stresses in the timber caused by predrying.

Once the timber had been reconditioned it was final dried in the kiln for 10 days at a relative humidity of 55% and dry bulb temperature of 50°C. The final average MC of the progressive samples was 11 %. This value lies within the 10 - 15% final dried E.M.C range for hardwoods as required by AS 2796 - 1985.

4.4.3 Trial 3

The third trial contained a full load of timber which has been air seasoned to below fibre saturation point. As for the previous trial samples were taken from the timber to monitor the progressive MC of the stack. The average initial MC of the samples was 16.6 %. The relevant data measured to obtain this value is in Appendix B4.

As recommended from the previous trial baffling was placed across all of the bearer spaces. Air flow measurements were produced at the same positions on the air inlet and outlet sides of the stack as for to trial 2. All three fans were operating as recommended. The air flow data is shown in tables 4.11 and 4.12.

	Distance From Rack End (m)					
Rack No	0.2	1.2	2.2	3.2	4.2	5.2
D	0.7	0.4	0.4	0.3	0.3	0.3
C	0.4	0.4	0.3	0.3	0.5	0.4
B	0.4	0.5	0.4	0.5	0.6	0.4
A	0.3	0.3	0.5	0.5	0.6	0.4

Table 4.11 - Inlet air flow measurements (m/s) - trial 3.

	Distance From Rack End (m)					
Rack No	0.2	1.2	2.2	3.2	4.2	5.2
D	0.2	0.2	0.3	0.3	0.2	0.2
C	0.2	0.2	0.3	0.3	0.4	0.3
B	0.3	0.4	0.4	0.4	0.4	0.3
A	0.3	0.5	0.5	0.6	0.4	0.4

Table 4.12 - Outlet air flow measurements (m/s) - trial 3.

Similar air flows were measured for this trial and the second trial at the air inlet side of the stack (c.f. tables 4.6 and 4.11). The air flow was evenly distributed except for the measurement of 0.7m/s on the end of the top rack D (shaded). This was expected as this rack was approximately 0.6m shorter at this end compared with the other racks creating a large air gap.

Compared with the previous trial the air flow on the air outlet side of the stack (c.f. tables 4.7 and 4.12) had increased to a more acceptable level. The increased volume of air exiting the stack was achieved by the introduction of baffling between the rack bearers.

4.5 Conclusions

It was concluded from the first trial that to maintain sufficient air flow through the timber charge in the kiln, all three fans should be operating.

Poor distribution of air flow across the front face of the timber charge was recorded in the first trial. This was found to be due to racks in the first trial containing uneven board lengths. An improvement was made regarding the air flow distribution in the second trial by having racks containing boards of even length.

A large loss of air flow was recorded from the air inlet side of the timber charge to the air outlet side for trials 1 and 2. This was found to be due to insufficient baffling at the rack bearers of the second, third and fourth row of racks. Air flow improvements were found in the third trial due to the addition of appropriate baffling as suggested by this author.

At a setpoint of 22°C, the temperature inside the kiln on the front face of the stack was evenly distributed.

The relative humidity was measured inside the kiln, and was found to be within a maximum of 3% RH and 1°C dry bulb temperature of the controller setpoint.

The average initial moisture content of the samples used to monitor the timber in the second trial was 53.8%. Using the schedule suggested the timber was predried to 19.1% in 65 days. After reconditioning and final drying for 10 days the final average MC of the stack represented by the samples was 11%.

Due to the initial poor quality of the timber it is difficult to come to a definitive conclusion regarding the success of the schedule provided. The final product of the timber from the second trial was of very poor quality. This result was expected due to the amount of degrade in the timber initially. Inspection of some of the partially air seasoned stock sawn from the same timber as for the second trial showed similar levels of degrade when observed in the yard at various stages of drying.

Further scheduling and monitoring work is planned for the solar kiln at Dunalley in the future. In order to obtain more definitive results it is recommended that a better quality initial product of known species be used for future trials.

Chapter 5. Industry Liaison Work

5.1 Introduction

The objective of this section of research is to investigate and offer recommendations to improve the drying efficiency of three Tasmanian industrial timber drying kilns. Each of these kilns is predominantly used to season the commercial Tasmanian eucalypt species. The three predriers are situated at Boral Tas. Board Mills - Launceston, Gunns Timber - Launceston and Clennett Timber - Glenorchy. The work involved air flow, temperature and humidity distribution measurements. The investigations were performed by this author and fellow colleagues Mr. Dean Chatwin and Mr. Michael Lee.

Written reports were submitted to the appropriate timber personnel at each timber mill. The reports are provided in full in Appendix C. The following sections of this chapter are summaries of the measurements, recommendations and outcomes from these reports.

5.2 Boral Predrier

Preliminary investigations into the air flow characteristics throughout the predrier at Boral Tas. Board Mills at Killafaddy was conducted. The full report on the findings from this investigation are in Appendix C1.

The predrier, at the time of investigation, housed 318 racks of timber orientated 7 racks wide by 8 racks deep by 3 racks high. Air flow by 20 fans arranged as 10 sets of two. The air flow is forced across the top of the stack along a partition wall and is then allowed to flow through the front face of the stack (figure 5.1). Baffling was placed between the rack rows in the kiln to prevent air flowing around the row edges.

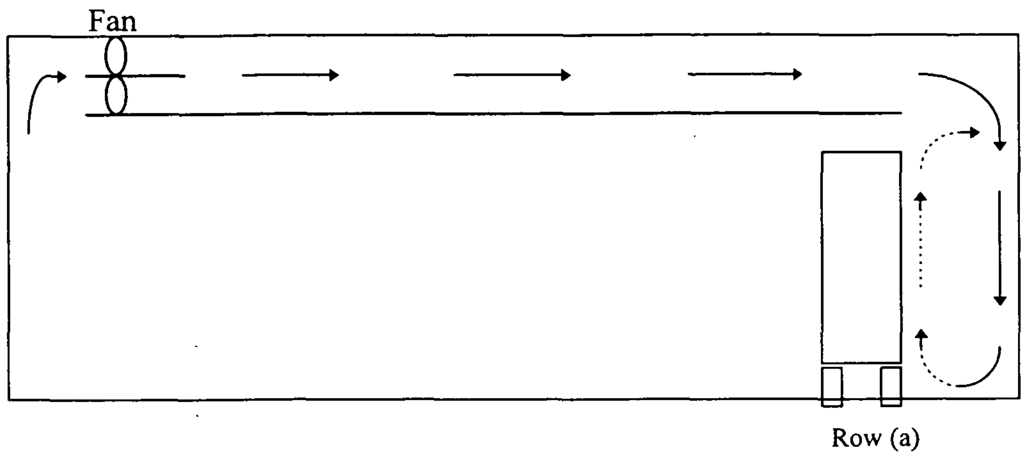

Figure 5.1 - Apparent air flow near row (a).

A uniform air flow of 0.5 m/s throughout the stack was the recommended specification for the predrier. From the investigations it was found that this specification was not met. It became apparent from the measurements taken that an eddy was being set up at the air inlet face of the stack producing much larger air flows at the bottom of the stack compared with the top of the stack (figure 5.1).

Air flows recorded between the rack bearers were found to be much larger than the air flowing through the racks themselves. This was thought to be a cause of air flow deficiencies through the racks.

Some of the baffles between rack rows were missing at the time of investigation. The measurements reflected larger than average air flows at the rack ends which were not baffled. It was concluded that the missing baffles were a cause of this non uniformity.

Three recommendations were proposed to improve air flows through the predrier. The first recommendation was to place an angled baffle at the corner of the predrier above the air inlet row. It was thought that this would reduce the eddy effect at the air inlet face. The second recommendation was to replace the missing baffles so as to improve air flow uniformity through the stack. Lastly it was recommended that baffles be placed over all of the bearer gluts to increase the amount of air flowing through the racks.

Since this investigation has been made, each recommendation has been followed. The control equipment in the predrier has also been recently upgraded. New humidity sensors and RTD's have been added to compare their efficiency. The predrier is now fully feedback controlled via the Honeywell SCAN 3000™ software. Further investigations are planned.

5.2 Clennett Kiln

Preliminary investigations into the air flow characteristics through the Clennetts Timber kiln at Glenorchy were conducted. The full report on the findings from this investigation are in Appendix C2. Follow up air flow and temperature distribution characteristics were taken after initial recommendations were made. Appendix C3 contains the full report of these findings.

The kiln has a design air speed of 2m/s which is supplied by eight fans located above a false roof that run between two rows. The air flow direction is reversible. At the time that the preliminary air flow measurements were made the kiln was filled to capacity housing 18 racks of timber orientated 3 racks wide by 2 racks deep by 3 racks high. Corrugated iron baffles were in place at the ends of each row of racks.

The preliminary investigations showed that the air flow through the stack was not acceptable. Air was escaping around the rack ends and air flow deficiencies were found at the ground level racks on the air outlet row. This occurred for air flows in both directions.

It was observed that air was escaping through the area between the false roof and the top of the stack due to insufficient baffling. Other investigations showed that racking sticks were of uneven widths and the stack consisted of mixed timber from Dover and Bridgewater.

From the preliminary investigations it was recommended that the corrugated iron baffling at the rack ends be replaced by a more suitable material such as canvas curtains. It was thought that this would allow for better controlled air flow between the racks as well as easier access for personnel. Placing a baffle between the top of the stack and the false roof was recommended in order to prevent air loss through this area.

It was recommended that the rack sticks be replaced with those of equal thickness. Doing so should improve the uniformity of air flow through the racks and reduce the possibility of boards bending and warping.

The final recommendation from this investigation was to dry timber from logs felled from the same area. It is common knowledge throughout the industry that logs from different areas have different drying characteristics. Thus the kiln conditions which are adequate to dry timber from one region may not be appropriate for other types due to such differences as density and initial MC values.

Follow up investigations were conducted in the kiln however the recommendations from the preliminary investigations had not been followed. An attempt had been made to provide some of the baffling suggested however it was found to be insufficient. The temperature inside the kiln was 65°C as opposed to 35°C for the initial investigations. Rack orientation was also different. This could have had some effect on the results and hence direct comparison between the preliminary and follow up investigations cannot be made.

The temperature distribution throughout the kiln was measured in the follow up investigation. Wet and dry bulb temperatures were taken using RTD's, a Datataker 500 and a PC. Measurements were taken at six equally spaced distances along the top and bottom level of racks on the air inlet face. The distribution was found to be adequate with the maximum change in wet and dry bulb temperature over the length of the stack being ± 2°C.

Uneven width racking sticks were again being used and the timber in the kiln was from different locations.

5.3 Gunns Kiln

Preliminary air flow and temperature distribution measurements have been made in the progressive kilns at Gunns - Launceston. Due to circumstances beyond the control of this author the results from this investigation are currently incomplete. Insufficient data has been gathered at the time of writing this report to make recommendations regarding the efficiency of the kilns. The measurements will be completed as soon as practicably possible. A full report will be forwarded to the appropriate personnel upon completion.

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Appendix A. Moisture Meter Species Correction Data

A1. Initial MC and oven dry weight of samples

	Initial MC -Small Sample			Oven Dry Weight -large sample	
Sample #	M_w (g)	M_d (g)	MC (%)	$M_{initial}$ (g)	O.D.W (g)
A1	41.268	36.042	14.5	341.12	297.92
A2	37.188	32.438	14.6	339.52	296.15
A3	36.819	32.082	14.8	348.92	304.03
A4	36.869	32.075	14.9	353.44	307.48
A5	40.731	35.397	15.1	348.04	302.46
A6	38.915	33.824	15.1	341.95	297.21
A7S1	32.284	28.026	15.2	328.90	285.52
B1	48.153	41.739	15.4	453.77	393.33
B2	52.245	45.291	15.4	453.23	392.90
B3	53.679	46.624	15.1	447.10	388.34
B4	52.156	45.358	15.0	448.95	390.43
B5	52.092	45.294	15.0	450.50	391.71
B6	53.259	46.138	15.4	446.10	386.45
B7S2	51.919	45.054	15.2	439.94	381.77
C1	48.836	42.522	14.8	393.87	342.95
C2	42.760	37.200	14.9	402.04	349.76
C3	47.082	40.925	15.0	415.38	361.06
C4	50.518	43.936	15.0	406.67	353.68
C5	47.190	40.980	15.2	407.52	353.89
C6S3	45.621	39.702	14.9	389.56	339.02
D1	40.171	34.533	16.3	336.00	288.84
D2	40.378	34.715	16.3	345.94	297.42
D3	40.322	34.695	16.2	348.50	299.87
D4	41.715	35.971	16.0	357.23	308.04
D5	40.580	35.026	15.9	356.33	307.56
D6	40.540	34.990	15.9	340.00	293.45
D7	41.585	35.889	15.9	346.67	299.19
E1	40.925	35.387	15.6	374.82	324.10
E2	43.459	37.636	15.5	375.37	325.07
E3	42.284	36.582	15.6	382.07	330.55
E4	44.974	38.953	15.5	382.61	331.39
E5	48.072	41.625	15.5	383.43	332.01
E6	42.123	36.418	15.7	385.79	333.54
E7S4	42.792	36.981	15.7	395.58	341.86
F1	40.344	35.253	14.4	335.54	293.20
F2	37.926	33.173	14.3	344.35	301.20
F3	38.883	33.989	14.4	349.75	305.73
F4	38.325	33.539	14.3	356.26	311.77
F5	42.363	37.025	14.4	351.23	306.97
F6	39.454	34.582	14.1	344.77	302.20

Average MC (%)	15.2

A2. Equalisation data to approximately 18% MC

Sample #	O.D.W (g)	Date: 3/9/97 $M_{current}$ (g)	M.C (%)	Date: 9/9/97 $M_{current}$ (g)	M.C (%)	Date: 16/9/97 $M_{current}$ (g)	M.C (%)
A1	297.92	344.06	15.5	346.86	16.4	349.41	17.3
A2	296.15	342.56	15.7	345.32	16.6	347.88	17.5
A3	304.03	351.77	15.7	354.25	16.5	356.67	17.3
A4	307.48	356.23	15.9	358.28	16.5	360.23	17.2
A5	302.46	350.99	16.0	353.37	16.8	355.62	17.6
A6	297.21	345.03	16.1	347.71	17.0	350.17	17.8
A7S1	285.52	331.40	16.1	333.58	16.8	335.62	17.5
B1	393.33	456.26	16.0	458.51	16.6	460.67	17.1
B2	392.90	455.67	16.0	458.01	16.6	460.33	17.2
B3	388.34	449.50	15.7	451.87	16.4	454.21	17.0
B4	390.43	451.28	15.6	453.59	16.2	455.98	16.8
B5	391.71	452.72	15.6	454.68	16.1	456.81	16.6
B6	386.45	448.39	16.0	450.46	16.6	452.74	17.2
B7S2	381.77	441.56	15.7	443.10	16.1	444.57	16.5
C1	342.95	397.78	16.0	400.84	16.9	403.19	17.6
C2	349.76	406.24	16.1	409.03	16.9	411.65	17.7
C3	361.06	419.06	16.1	421.12	16.6	423.36	17.3
C4	353.68	410.31	16.0	412.17	16.5	414.11	17.1
C5	353.89	411.26	16.2	413.84	16.9	416.3	17.6
C6S3	339.02	393.85	16.2	396.69	17.0	399.46	17.8
D1	288.84	338.17	17.1	339.57	17.6	340.9	18.0
D2	297.42	348.73	17.3	350.39	17.8	352.05	18.4
D3	299.87	351.46	17.2	353.50	17.9	355.27	18.5
D4	308.04	360.31	17.0	362.14	17.6	363.93	18.1
D5	307.56	359.45	16.9	361.48	17.5	363.36	18.1
D6	293.45	343.19	16.9	345.25	17.7	347.13	18.3
D7	299.19	349.77	16.9	351.79	17.6	353.72	18.2
E1	324.10	377.96	16.6	380.64	17.4	383.29	18.3
E2	325.07	378.36	16.4	380.90	17.2	383.51	18.0
E3	330.55	385.04	16.5	387.9	17.4	390.52	18.1
E4	331.39	385.06	16.2	387.18	16.8	389.03	17.4
E5	332.01	386.19	16.3	388.97	17.2	391.66	18.0
E6	333.54	388.48	16.5	391.15	17.3	393.79	18.1
E7S4	341.86	398.15	16.5	400.10	17.0	402.02	17.6
F1	293.20	338.99	15.6	341.45	16.5	343.86	17.3
F2	301.20	347.43	15.4	350.35	16.3	352.83	17.1
F3	305.73	353.48	15.6	356.57	16.6	359.2	17.5
F4	311.77	359.52	15.3	362.39	16.2	365.1	17.1
F5	306.97	354.55	15.5	357.05	16.3	359.46	17.1
F6	302.20	347.71	15.1	350.19	15.9	352.72	16.7

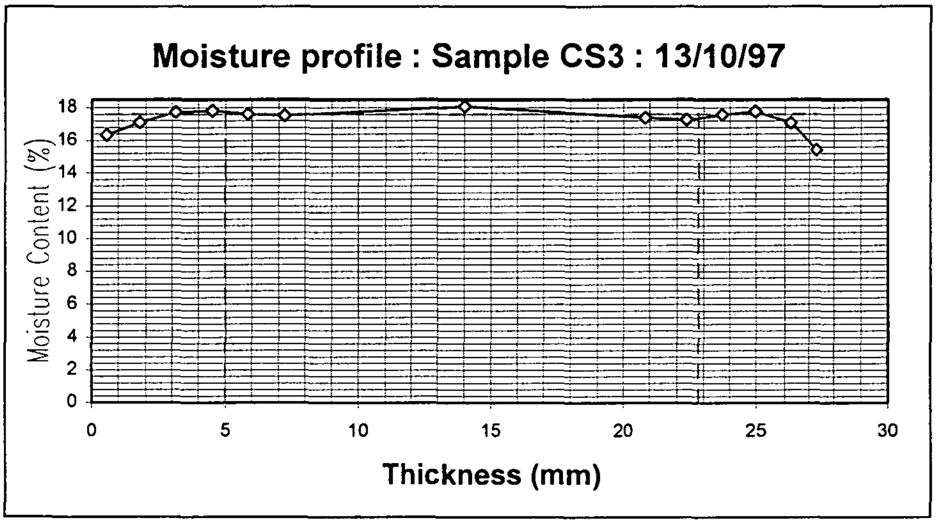
		Date:23/9/97		Date:1/10/97		Date:6/10/97	
Sample #	O.D.W (g)	$M_{current}$ (g)	M.C (%)	$M_{current}$ (g)	M.C (%)	$M_{current}$ (g)	M.C (%)
A1	297.92	350.46	17.6	351.31	17.9	351.69	18.0
A2	296.15	348.73	17.8	349.53	18.0	349.91	18.2
A3	304.03	357.77	17.7	358.66	18.0	359.04	18.1
A4	307.48	361.73	17.6	362.89	18.0	363.36	18.2
A5	302.46	356.74	17.9	357.60	18.2	358.00	18.4
A6	297.21	350.93	18.1	351.58	18.3	351.91	18.4
A7S1	285.52	336.39	17.8	337.15	18.1	337.52	18.2
B1	393.33	461.89	17.4	463.15	17.8	463.64	17.9
B2	392.90	461.47	17.5	462.64	17.8	463.22	17.9
B3	388.34	455.35	17.3	456.52	17.6	457.07	17.7
B4	390.43	457.12	17.1	458.34	17.4	458.94	17.5
B5	391.71	458.21	17.0	459.49	17.3	460.08	17.5
B6	386.45	453.80	17.4	454.84	17.7	455.35	17.8
B7S2	381.77	445.82	16.8	447.02	17.1	447.54	17.2
C1	342.95	404.29	17.9	405.21	18.2	405.62	18.3
C2	349.76	412.78	18.0	413.74	18.3	414.20	18.4
C3	361.06	424.77	17.6	426.01	18.0	426.58	18.1
C4	353.68	415.62	17.5	416.93	17.9	417.50	18.0
C5	353.89	417.17	17.9	418.14	18.2	418.60	18.3
C6S3	339.02	400.22	18.1	401.06	18.3	401.40	18.4
D1	288.84	341.19	18.1	341.74	18.3	341.98	18.4
D2	297.42	352.35	18.5	353.06	18.7	353.39	18.8
D3	299.87	355.65	18.6	356.31	18.8	356.66	18.9
D4	308.04	364.60	18.4	365.39	18.6	365.81	18.8
D5	307.56	363.86	18.3	364.57	18.5	364.94	18.7
D6	293.45	347.62	18.5	348.33	18.7	348.68	18.8
D7	299.19	354.22	18.4	354.81	18.6	355.06	18.7
E1	324.10	384.06	18.5	384.84	18.7	385.15	18.8
E2	325.07	384.43	18.3	385.19	18.5	385.57	18.6
E3	330.55	391.35	18.4	392.25	18.7	392.71	18.8
E4	331.39	390.57	17.9	391.80	18.2	392.29	18.4
E5	332.01	392.50	18.2	393.44	18.5	393.83	18.6
E6	333.54	394.65	18.3	395.59	18.6	395.98	18.7
E7S4	341.86	402.78	17.8	403.65	18.1	404.02	18.2
F1	293.20	344.95	17.7	345.85	18.0	346.25	18.1
F2	301.20	353.70	17.4	354.53	17.7	354.89	17.8
F3	305.73	360.05	17.8	360.90	18.0	361.30	18.2
F4	311.77	366.00	17.4	366.82	17.7	367.15	17.8
F5	306.97	360.56	17.5	361.41	17.7	361.83	17.9
F6	302.20	353.57	17.0	354.37	17.3	354.68	17.4

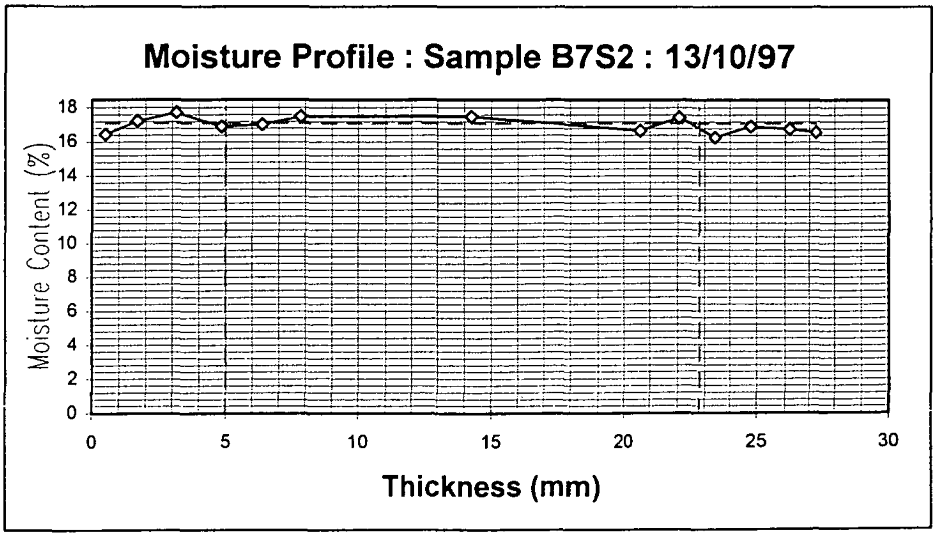
Sample #	O.D.W (g)	Date:13/10/97 $M_{current}$ (g)	M.C (%)	Date: 20/10/97 $M_{current}$ (g)	M.C (%)	Date:22/10/97 $M_{current}$ (g)	M.C (%)
A1	297.92	351.92	18.1	352.35	18.3	352.11	18.2
A2	296.15	350.37	18.3	350.88	18.5	350.55	18.4
A3	304.03	359.37	18.2	359.82	18.4	359.52	18.3
A4	307.48	363.89	18.3	363.93	18.4	363.92	18.4
A5	302.46	358.25	18.4	358.67	18.6	358.41	18.5
A6	297.21	352.19	18.5	352.61	18.6	352.34	18.5
A7S1	285.52	337.82	18.3	338.22	18.5	337.98	18.4
B1	393.33	464.43	18.1	465.04	18.2	465.01	18.2
B2	392.90	463.73	18.0	464.35	18.2	464.27	18.2
B3	388.34	457.68	17.9	458.34	18.0	458.16	18.0
B4	390.43	459.53	17.7	460.31	17.9	460.20	17.9
B5	391.71	460.67	17.6	461.32	17.8	461.22	17.7
B6	386.45	455.9	18.0	456.57	18.1	456.45	18.1
B7S2	381.77	448.35	17.4	-	-	-	-
C1	342.95	405.94	18.4	406.48	18.5	406.12	18.4
C2	349.76	414.5	18.5	415.00	18.7	414.66	18.6
C3	361.06	427.08	18.3	427.14	18.3	427.09	18.3
C4	353.68	418.09	18.2	418.19	18.2	418.12	18.2
C5	353.89	418.95	18.4	419.54	18.6	419.23	18.5
C6S3	339.02	401.65	18.5	-	-	-	-
D1	288.84	342.15	18.5	342.54	18.6	342.30	18.5
D2	297.42	353.66	18.9	354.03	19.0	353.74	18.9
D3	299.87	356.91	19.0	357.18	19.1	357.02	19.1
D4	308.04	366.12	18.9	366.10	18.8	366.04	18.8
D5	307.56	365.24	18.8	365.52	18.8	365.28	18.8
D6	293.45	348.84	18.9	349.07	19.0	348.86	18.9
D7	299.19	355.26	18.7	355.64	18.9	355.39	18.8
E1	324.10	385.38	18.9	385.91	19.1	385.62	19.0
E2	325.07	385.88	18.7	386.33	18.8	386.07	18.8
E3	330.55	393.01	18.9	393.21	19.0	392.90	18.9
E4	331.39	392.92	18.6	392.97	18.6	392.96	18.6
E5	332.01	394.21	18.7	394.76	18.9	394.39	18.8
E6	333.54	396.26	18.8	396.77	19.0	396.45	18.9
E7S4	341.86	404.31	18.3	404.79	18.4	404.51	18.3
F1	293.20	346.54	18.2	346.91	18.3	346.71	18.3
F2	301.20	355.23	17.9	355.62	18.1	355.29	18.0
F3	305.73	361.53	18.3	361.90	18.4	361.71	18.3
F4	311.77	367.4	17.8	367.89	18.0	367.65	17.9
F5	306.97	362.17	18.0	362.63	18.1	362.26	18.0
F6	302.20	354.96	17.5	355.40	17.6	355.18	17.5

Average MC (%)	18.4

A3. Moisture Profile data at approximately 18% EMC

13/10/97	Sample: C6S3 Initial Thickness: 25.39				Sample:B7S2 Initial Thickness: 24.48			
Slice #	Thick (mm)	Mwet (g)	Mdry (g)	M.C. (%)	Thick (mm)	Mwet (g)	Mdry (g)	M.C. (%)
1 top	1.11	0.420	0.361	16.3	1.02	0.453	0.389	16.5
2	1.33	0.486	0.415	17.1	1.33	0.673	0.574	17.2
3	1.40	0.591	0.502	17.7	1.62	0.823	0.699	17.7
4	1.33	0.575	0.488	17.8	1.73	0.802	0.686	16.9
5	1.33	0.574	0.488	17.6	1.35	0.660	0.564	17.0
6	1.45	0.550	0.468	17.5	1.54	0.712	0.606	17.5
7	12.11	6.058	5.13	18.1	11.34	6.994	5.952	17.5
8	1.55	0.594	0.506	17.4	1.39	0.749	0.642	16.7
9	1.44	0.625	0.533	17.3	1.47	0.720	0.613	17.5
10	1.30	0.662	0.563	17.6	1.22	0.693	0.596	16.3
11	1.24	0.656	0.557	17.8	1.56	0.870	0.744	16.9
12	1.25	0.651	0.556	17.1	1.20	0.661	0.566	16.8
13bot	0.96	0.494	0.428	15.4	1.04	0.436	0.374	16.6





A4. Meter calibration results at approximately 18% MC

		Resistance Type-meter					Capacitance Type-meter				
		G-30 MC(%)		RC-IC MC(%)			M10-1 MC(%)		M10-2 MC(%)		
Sample #	Approx. MC(%)	Side 1	Side 2	Side 1	Side 2	AVE.	Side 1	Side 2	Side 1	Side 2	AVE.
A1	18.2	15.5	15.5	15.5	15.5	15.5	17.0	17.0	17.0	17.0	17.0
A2	18.4	15.5	15.3	15.5	15.3	15.4	17.0	17.0	17.0	17.0	17.0
A3	18.3	15.3	15.3	15.3	15.3	15.3	17.0	17.0	17.5	17.0	17.1
A4	18.4	15.3	15.3	15.3	15.3	15.3	16.0	16.0	16.0	16.0	16.0
A5	18.5	15.5	15.5	15.5	15.5	15.5	17.0	17.0	17.0	17.0	17.0
A6	18.5	15.3	15.3	15.3	15.3	15.3	17.5	17.0	17.5	17.0	17.3
A7S1	18.4	15.8	15.5	15.8	15.5	15.6	17.5	17.5	17.5	17.5	17.5
B1	18.2	15.5	15.8	15.5	15.8	15.6	22.0	22.0	22.0	22.0	22.0
B2	18.2	15.5	15.8	15.5	15.8	15.6	21.5	21.5	21.5	21.5	21.5
B3	18.0	16.0	15.8	16.0	15.8	15.9	21.0	21.5	21.0	21.5	21.3
B4	17.9	15.8	15.5	15.8	15.5	15.6	21.5	21.5	21.5	21.5	21.5
B5	17.7	15.5	15.5	15.5	15.5	15.5	21.0	21.5	21.0	21.0	21.1
B6	18.1	16.0	15.8	15.8	15.8	15.8	21.0	21.0	21.0	21.0	21.0
C1	18.4	16.3	15.5	16.3	15.5	15.9	19.0	19.5	19.0	19.5	19.3
C2	18.6	15.8	15.5	15.8	15.5	15.6	20.0	19.5	20.0	19.5	19.8
C3	18.3	16.5	15.3	16.5	15.3	15.9	20.0	20.0	20.0	20.0	20.0
C4	18.2	15.8	15.0	15.8	15.0	15.4	20.0	20.0	20.0	20.0	20.0
C5	18.5	16.5	15.8	16.5	15.8	16.1	19.5	20.5	19.5	20.5	20.0
D1	18.5	15.0	15.8	15.0	15.8	15.4	18.5	18.5	18.5	18.5	18.5
D2	18.9	16.3	16.3	16.3	16.3	16.3	18.5	18.5	18.5	18.5	18.5
D3	18.3	16.3	16.0	16.3	16.0	16.1	18.5	18.5	18.5	18.5	18.5
D4	18.8	16.3	16.0	16.3	16.0	16.1	18.5	19.0	18.5	19.0	18.8
D5	18.8	16.3	16.0	16.3	16.0	16.1	18.5	18.0	18.5	18.5	18.4
D6	18.9	16.0	16.3	16.0	16.3	16.1	18.0	18.0	18.0	18.0	18.0
D7	18.8	16.3	16.3	16.3	16.3	16.3	18.5	18.5	18.5	18.5	18.5
E1	19.0	14.5	14.5	14.5	14.5	14.5	18.0	18.0	18.0	18.0	18.0
E2	18.8	14.5	14.8	14.5	15.8	14.9	18.0	18.5	18.0	18.5	18.3
E3	18.9	14.5	14.5	14.5	14.5	14.5	18.5	18.5	18.5	18.5	18.5
E4	18.6	14.8	14.8	14.8	14.8	14.8	18.0	18.5	18.0	18.5	18.3
E5	18.8	14.8	15.0	14.8	15.0	14.9	19.0	19.0	19.0	19.0	19.0
E6	18.9	14.5	14.8	14.5	14.8	14.6	18.5	19.0	18.5	19.0	18.8
E7S4	18.3	14.8	14.8	14.8	14.8	14.8	19.0	19.0	19.0	19.0	19.0
F1	18.3	15.5	15.3	15.5	15.3	15.4	16.5	16.5	16.5	16.5	16.5
F2	18.0	15.8	15.8	15.8	15.8	15.8	16.5	16.5	16.5	16.5	16.5
F3	19.1	15.5	15.3	15.5	15.8	15.5	17.5	17.0	17.0	17.0	17.1
F4	17.9	16.0	15.8	16.0	15.8	15.9	17.5	17.5	17.5	17.5	17.5
F5	18.0	15.5	15.8	15.5	15.8	15.6	17.0	17.5	17.0	17.5	17.3
F6	17.5	15.5	15.8	15.5	15.8	15.6	16.5	17.0	16.5	17.0	16.8

A5. Equalisation data to approximately 13% MC

		Date: 5/11/97		Date: 10/11/97		Date: 13/11/97	
Sample #	O.D.W (g)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)
A1	297.92	338.13	13.5	339.54	14.0	339.56	14.0
A2	296.15	335.79	13.4	337.55	14.0	337.63	14.0
A3	304.03	344.62	13.4	345.56	13.7	345.82	13.7
A4	307.48	350.01	13.8	351.49	14.3	351.49	14.3
A5	302.46	344.20	13.8	345.52	14.2	345.57	14.3
A6	297.21	337.92	13.7	339.55	14.2	339.61	14.3
A7S1	285.52	325.39	14.0	326.38	14.3	326.36	14.3
B1	393.33	447.36	13.7	448.20	14.0	448.37	14.0
B2	392.90	447.58	13.9	448.29	14.1	448.41	14.1
B3	388.34	441.47	13.7	442.23	13.9	442.38	13.9
B4	390.43	443.75	13.7	444.61	13.9	444.77	13.9
B5	391.71	444.56	13.5	445.40	13.7	445.56	13.7
B6	386.45	439.86	13.8	440.84	14.1	441.00	14.1
B7S2	381.77	-	-	-	-	-	-
C1	342.95	381.38	11.2	384.66	12.2	385.61	12.4
C2	349.76	396.72	13.4	397.73	13.7	397.99	13.8
C3	361.06	411.06	13.8	411.85	14.1	412.05	14.1
C4	353.68	402.15	13.7	402.83	13.9	403.01	13.9
C5	353.89	402.30	13.7	403.08	13.9	403.31	14.0
C6S3	339.02	-	-	-	-	-	-
D1	288.84	329.06	13.9	330.65	14.5	330.7	14.5
D2	297.42	337.76	13.6	340.06	14.3	340.12	14.4
D3	299.87	341.55	13.9	343.32	14.5	343.31	14.5
D4	308.04	350.81	13.9	352.87	14.6	352.92	14.6
D5	307.56	350.25	13.9	351.95	14.4	351.92	14.4
D6	293.45	334.04	13.8	335.56	14.3	335.61	14.4
D7	299.19	340.86	13.9	342.23	14.4	342.14	14.4
E1	324.10	368.58	13.7	370.90	14.4	370.94	14.5
E2	325.07	370.59	14.0	371.92	14.4	371.91	14.4
E3	330.55	375.74	13.7	377.87	14.3	377.93	14.3
E4	331.39	376.86	13.7	378.96	14.4	378.94	14.3
E5	332.01	377.74	13.8	379.52	14.3	379.49	14.3
E6	333.54	379.97	13.9	382.04	14.5	382.06	14.5
E7S4	341.86	388.99	13.8	390.41	14.2	390.39	14.2
F1	293.20	334.24	14.0	334.52	14.1	334.57	14.1
F2	301.20	341.84	13.5	342.33	13.7	342.46	13.7
F3	305.73	348.01	13.8	348.75	14.1	348.97	14.1
F4	311.77	355.05	13.9	355.21	13.9	355.32	14.0
F5	306.97	349.55	13.9	349.89	14.0	349.98	14.0
F6	302.20	342.90	13.5	343.10	13.5	343.21	13.6

		Date: 18/11/97		Date: 20/11/97		Date: 24/11/97	
Sample #	O.D.W (g)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)
A1	297.92	338.81	13.7	338.66	13.7	338.39	13.6
A2	296.15	336.89	13.8	336.77	13.7	336.47	13.6
A3	304.03	345.35	13.6	345.26	13.6	345.10	13.5
A4	307.48	350.83	14.1	350.64	14.0	350.38	14.0
A5	302.46	344.86	14.0	344.71	14.0	344.42	13.9
A6	297.21	338.84	14.0	338.68	14.0	338.38	13.9
A7S1	285.52	325.66	14.1	325.50	14.0	325.23	13.9
B1	393.33	447.87	13.9	447.71	13.8	447.44	13.8
B2	392.90	448.00	14.0	447.87	14.0	447.59	13.9
B3	388.34	441.90	13.8	441.77	13.8	441.44	13.7
B4	390.43	444.38	13.8	444.21	13.8	443.97	13.7
B5	391.71	445.07	13.6	444.94	13.6	444.71	13.5
B6	386.45	440.51	14.0	440.36	14.0	440.08	13.9
B7S2	381.77	-	-	-	-	-	-
C1	342.95	385.67	12.5	385.72	12.5	385.72	12.5
C2	349.76	397.26	13.6	397.20	13.6	396.98	13.5
C3	361.06	411.40	13.9	411.24	13.9	411.01	13.8
C4	353.68	402.35	13.8	402.24	13.7	402.00	13.7
C5	353.89	402.66	13.8	402.49	13.7	402.24	13.7
C6S3	339.02			-	-	-	-
D1	288.84	329.89	14.2	329.75	14.2	329.44	14.1
D2	297.42	339.30	14.1	339.19	14.0	338.89	13.9
D3	299.87	342.49	14.2	342.34	14.2	342.01	14.1
D4	308.04	352.08	14.3	351.97	14.3	351.61	14.1
D5	307.56	351.15	14.2	350.94	14.1	350.62	14.0
D6	293.45	334.88	14.1	334.69	14.1	334.42	14.0
D7	299.19	341.26	14.1	341.05	14.0	340.73	13.9
E1	324.10	370.06	14.2	369.85	14.1	369.50	14.0
E2	325.07	371.07	14.2	370.84	14.1	370.50	14.0
E3	330.55	377.03	14.1	376.86	14.0	376.54	13.9
E4	331.39	378.06	14.1	377.88	14.0	377.53	13.9
E5	332.01	378.57	14.0	378.40	14.0	378.00	13.9
E6	333.54	381.24	14.3	381.04	14.2	380.73	14.1
E7S4	341.86	389.53	13.9	389.34	13.9	388.98	13.8
F1	293.20	334.84	14.2	333.72	13.8	333.48	13.7
F2	301.20	341.90	13.5	341.84	13.5	341.67	13.4
F3	305.73	348.25	13.9	348.19	13.9	347.98	13.8
F4	311.77	354.50	13.7	354.37	13.7	354.20	13.6
F5	306.97	349.31	13.8	349.14	13.7	348.89	13.7
F6	302.20	342.40	13.3	342.30	13.3	342.03	13.2

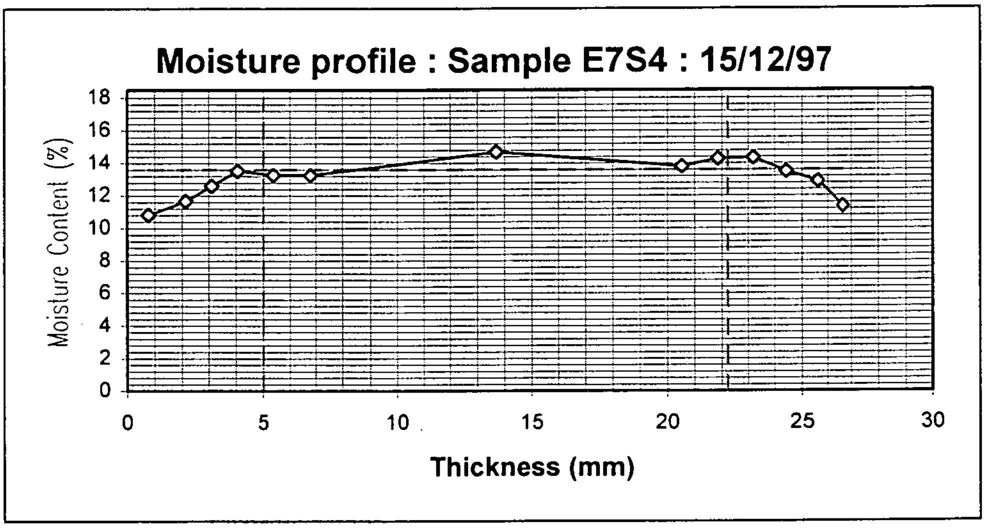
		Date: 2/12/97		Date: 8/12/97		Date: 10/12/97	
Sample #	O.D.W (g)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)
A1	297.92	338.86	13.7	337.91	13.4	337.84	13.4
A2	296.15	336.95	13.8	336.07	13.5	335.95	13.4
A3	304.03	345.63	13.7	344.92	13.4	344.84	13.4
A4	307.48	350.77	14.1	349.93	13.8	349.88	13.8
A5	302.46	344.92	14.0	344.09	13.8	343.97	13.7
A6	297.21	338.89	14.0	337.96	13.7	337.85	13.7
A7S1	285.52	-	-	-	-	-	-
B1	393.33	447.71	13.8	446.93	13.6	446.80	13.6
B2	392.90	447.80	14.0	447.16	13.8	447.02	13.8
B3	388.34	441.73	13.7	441.02	13.6	440.90	13.5
B4	390.43	444.18	13.8	443.49	13.6	443.32	13.5
B5	391.71	444.95	13.6	444.21	13.4	444.07	13.4
B6	386.45	440.38	14.0	439.61	13.8	439.50	13.7
B7S2	381.77	-	-	-	-	-	-
C1	342.95	386.48	12.7	385.73	12.5	385.68	12.5
C2	349.76	397.59	13.7	396.46	13.4	396.41	13.3
C3	361.06	411.47	14.0	410.46	13.7	410.31	13.6
C4	353.68	402.51	13.8	401.42	13.5	401.35	13.5
C5	353.89	402.82	13.8	401.76	13.5	401.64	13.5
C6S3	339.02	-	-	-	-	-	-
D1	288.84	329.95	14.2	329.11	13.9	329.00	13.9
D2	297.42	339.37	14.1	338.46	13.8	338.37	13.8
D3	299.87	342.45	14.2	341.55	13.9	341.44	13.9
D4	308.04	352.07	14.3	351.11	14.0	350.98	13.9
D5	307.56	350.93	14.1	350.13	13.8	350.01	13.8
D6	293.45	334.88	14.1	333.96	13.8	333.85	13.8
D7	299.19	341.11	14.0	340.10	13.7	340.01	13.6
E1	324.10	370.01	14.2	369.10	13.9	369.01	13.9
E2	325.07	370.97	14.1	370.07	13.8	369.94	13.8
E3	330.55	377.12	14.1	376.09	13.8	375.97	13.7
E4	331.39	378.02	14.1	376.98	13.8	376.85	13.7
E5	332.01	378.52	14.0	377.47	13.7	377.39	13.7
E6	333.54	381.07	14.3	380.11	14.0	379.98	13.9
E7S4	341.86	-	-	-	-	-	-
F1	293.20	334.05	13.9	333.07	13.6	332.98	13.6
F2	301.20	342.14	13.6	341.34	13.3	341.23	13.3
F3	305.73	348.57	14.0	347.63	13.7	347.54	13.7
F4	311.77	354.73	13.8	353.78	13.5	353.67	13.4
F5	306.97	349.37	13.8	348.52	13.5	348.40	13.5
F6	302.20	342.60	13.4	341.60	13.0	341.49	13.0

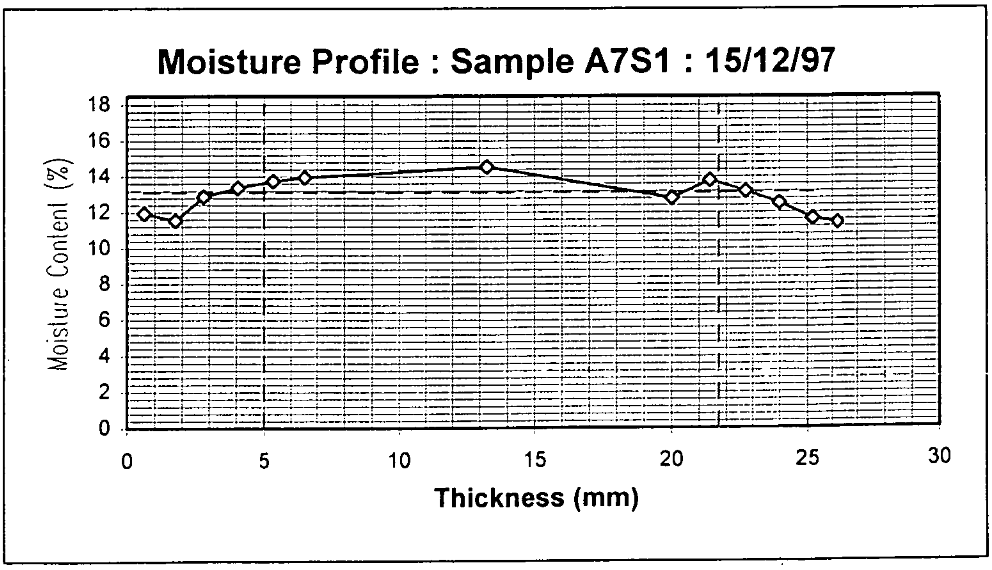
		Date: 12/12/97		Date: 15/12/97		Date: 16/12/97	
Sample #	O.D.W (g)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)
A1	297.92	338.04	13.5	338.28	13.5	338.31	13.6
A2	296.15	336.16	13.5	336.39	13.6	336.48	13.6
A3	304.03	345.00	13.5	345.2	13.5	345.22	13.5
A4	307.48	350.00	13.8	350.25	13.9	350.31	13.9
A5	302.46	344.16	13.8	344.38	13.9	344.43	13.9
A6	297.21	338.09	13.8	338.31	13.8	338.41	13.9
A7S1	285.52	-	-	-	-	-	-
B1	393.33	446.90	13.6	447.05	13.7	447.10	13.7
B2	392.90	447.11	13.8	447.22	13.8	447.22	13.8
B3	388.34	440.98	13.6	441.13	13.6	441.12	13.6
B4	390.43	443.50	13.6	443.61	13.6	443.64	13.6
B5	391.71	444.16	13.4	444.33	13.4	444.38	13.4
B6	386.45	439.60	13.8	439.74	13.8	439.79	13.8
B7S2	381.77	-	-	-	-	-	-
C1	342.95	385.93	12.5	386.15	12.6	386.23	12.6
C2	349.76	396.66	13.4	396.97	13.5	397.04	13.5
C3	361.06	410.61	13.7	410.84	13.8	410.91	13.8
C4	353.68	401.59	13.5	401.86	13.6	401.91	13.6
C5	353.89	401.88	13.6	402.14	13.6	402.19	13.6
C6S3	339.02	-	-	-	-	-	-
D1	288.84	329.18	14.0	329.37	14.0	329.39	14.0
D2	297.42	338.58	13.8	338.82	13.9	338.88	13.9
D3	299.87	341.61	13.9	341.84	14.0	341.87	14.0
D4	308.04	351.23	14.0	351.46	14.1	351.48	14.1
D5	307.56	350.14	13.8	350.28	13.9	350.32	13.9
D6	293.45	334.05	13.8	334.25	13.9	334.27	13.9
D7	299.19	340.19	13.7	340.42	13.8	340.43	13.8
E1	324.10	369.21	13.9	369.42	14.0	369.44	14.0
E2	325.07	370.11	13.9	370.3	13.9	370.32	13.9
E3	330.55	376.2	13.8	376.44	13.9	376.48	13.9
E4	331.39	377.07	13.8	377.32	13.9	377.38	13.9
E5	332.01	377.58	13.7	377.83	13.8	377.84	13.8
E6	333.54	380.18	14.0	380.43	14.1	380.44	14.1
E7S4	341.86	-	-	-	-	-	-
F1	293.20	333.25	13.7	333.51	13.7	333.57	13.8
F2	301.20	341.43	13.4	341.65	13.4	341.71	13.4
F3	305.73	347.85	13.8	348.1	13.9	348.13	13.9
F4	311.77	353.92	13.5	354.13	13.6	354.20	13.6
F5	306.97	348.61	13.6	348.79	13.6	348.83	13.6
F6	302.20	341.74	13.1	341.99	13.2	342.09	13.2

Average MC (%)	13.8

A6. Moisture Profile data at approximately 13% EMC

15/12/97	Sample: E7S4 Initial Thickness: 24.82				Sample:A7S1 Initial Thickness: 24.83			
Slice #	Thick. (mm)	Mwet (g)	Mdry (g)	M.C. (%)	Thick. (mm)	Mwet (g)	Mdry (g)	M.C. (%)
1 top	1.53	0.522	0.471	10.8	1.24	0.300	0.268	11.9
2	1.21	0.469	0.420	11.7	1.01	0.396	0.355	11.5
3	0.74	0.268	0.238	12.6	1.08	0.464	0.411	12.9
4	1.17	0.503	0.443	13.5	1.44	0.466	0.411	13.4
5	1.46	0.529	0.467	13.3	1.14	0.463	0.407	13.8
6	1.37	0.555	0.490	13.3	1.25	0.449	0.394	14.0
7	12.44	6.158	5.369	14.7	12.20	5.029	4.390	14.6
8	1.23	0.552	0.485	13.8	1.31	0.476	0.422	12.8
9	1.40	0.528	0.462	14.3	1.45	0.487	0.428	13.8
10	1.28	0.534	0.467	14.3	1.22	0.498	0.440	13.2
11	1.20	0.513	0.452	13.5	1.28	0.486	0.432	12.5
12	1.09	0.499	0.442	12.9	1.14	0.470	0.421	11.6
13bot	1.10	0.529	0.475	11.4	0.97	0.430	0.386	11.4





A7. Meter calibration results at approximately 13% MC

		Resistance Type-model					Capacitance Type-model				
		G-30 MC(%)		RC-IC MC(%)			M10-1 MC(%)		M10-2 MC(%)		
Sample #	Approx. MC(%)	Side 1	Side 2	Side 1	Side 2	AVE.	Side 1	Side 2	Side 1	Side 2	AVE.
A1	13.6	10.5	10.3	10.5	10.3	10.4	14.5	14.5	14.5	14.5	14.5
A2	13.6	10.8	10.8	11.0	10.8	10.8	14.0	14.0	14.0	14.0	14.0
A3	13.5	12.0	12.0	12.0	12.0	12.0	15.0	15.0	15.0	15.0	15.0
A4	13.9	11.5	11.5	11.5	11.3	11.4	14.5	14.3	14.5	14.3	14.4
A5	13.9	12.3	12.3	12.3	12.3	12.3	15.0	15.0	14.5	15.0	14.9
A6	13.9	12.0	12.3	12.0	12.3	12.1	15.0	15.0	14.5	15.0	14.9
B1	13.7	12.5	12.5	12.5	12.5	12.5	18.0	18.0	18.0	18.0	18.0
B2	13.8	12.3	12.3	12.3	12.3	12.3	19.0	19.0	19.0	19.0	19.0
B3	13.6	12.0	11.5	12.0	11.5	11.8	18.5	18.0	18.5	18.0	18.3
B4	13.6	12.3	12.3	12.3	12.3	12.3	19.0	19.0	19.0	19.0	19.0
B5	13.4	12.3	12.3	12.3	12.5	12.3	18.5	18.3	18.5	18.3	18.4
B6	13.8	12.0	12.0	12.3	12.0	12.1	18.0	18.0	18.5	18.0	18.1
C1	12.6	10.5	10.8	10.5	10.8	10.6	16.5	16.5	16.0	16.5	16.4
C2	13.5	12.3	12.3	12.3	12.3	12.3	17.5	17.5	17.0	17.5	17.4
C3	13.8	12.3	12.3	12.3	12.3	12.3	17.5	17.8	17.5	17.8	17.6
C4	13.6	12.0	12.0	12.0	12.0	12.0	18.0	18.0	18.0	17.5	17.9
C5	13.6	12.3	12.3	12.3	12.3	12.3	17.0	17.0	17.0	17.0	17.0
D1	14.0	12.8	12.8	12.8	12.8	12.8	16.0	16.0	16.0	15.8	15.9
D2	13.9	12.5	12.5	12.5	12.5	12.5	16.5	16.5	16.0	16.5	16.4
D3	14.0	12.0	12.0	12.0	12.0	12.0	16.0	16.0	16.0	16.0	16.0
D4	14.1	12.3	12.3	12.5	12.8	12.4	16.0	16.0	16.0	16.0	16.0
D5	13.9	12.5	12.5	12.5	12.5	12.5	16.0	16.0	16.0	16.3	16.1
D6	13.9	11.5	12.0	11.5	12.0	11.8	15.5	15.5	15.5	15.5	15.5
D7	13.8	12.0	12.0	12.0	12.0	12.0	16.0	16.0	16.0	16.0	16.0
E1	14.0	11.5	11.5	11.8	11.5	11.6	16.0	16.0	16.0	16.0	16.0
E2	13.9	11.3	11.3	11.3	11.3	11.3	16.0	16.0	16.0	16.0	16.0
E3	13.9	11.0	11.0	11.0	11.3	11.1	16.0	16.0	16.0	16.0	16.0
E4	13.9	10.8	10.8	11.3	10.8	10.9	16.0	16.0	15.5	16.0	15.9
E5	13.8	11.3	11.3	11.0	11.3	11.2	16.5	16.5	16.0	16.5	16.4
E6	14.1	11.5	11.5	12.0	11.5	11.6	16.5	16.5	16.0	16.5	16.4
F1	13.8	11.0	11.0	11.5	11.0	11.1	14.5	15.0	14.5	15.0	14.8
F2	13.4	11.5	11.8	11.8	11.8	11.7	15.0	15.0	15.0	15.0	15.0
F3	13.9	12.5	12.5	12.5	12.5	12.5	15.0	15.0	15.0	15.0	15.0
F4	13.6	12.5	12.3	12.5	12.3	12.4	15.5	15.0	15.5	15.0	15.3
F5	13.6	11.8	11.8	11.8	11.8	11.8	14.5	14.5	14.5	14.5	14.5
F6	13.2	11.5	11.5	11.5	11.3	11.4	14.0	14.0	13.5	14.0	13.9

A8. Equalisation data to approximately 8% MC

Sample #	O.D.W (g)	Date: 21/01/98 Mcurrent (g)	M.C (%)	Date: 27/01/98 Mcurrent (g)	M.C (%)	Date: 29/01/98 Mcurrent (g)	M.C (%)
A1	297.92	321.33	7.9	322.80	8.4	323.46	8.6
A2	296.15	319.83	8.0	321.19	8.5	321.78	8.7
A3	304.03	328.49	8.0	329.97	8.5	330.5	8.7
A4	307.48	332.85	8.3	334.25	8.7	334.84	8.9
A5	302.46	326.99	8.1	328.65	8.7	329.24	8.9
A6	297.21	321.28	8.1	322.83	8.6	323.45	8.8
A7S1	285.52	-	-	-	-		-
B1	393.33	424.37	7.9	426.64	8.5	427.13	8.6
B2	392.90	424.63	8.1	426.71	8.6	427.17	8.7
B3	388.34	418.66	7.8	420.83	8.4	421.32	8.5
B4	390.43	420.99	7.8	423.09	8.4	423.55	8.5
B5	391.71	421.74	7.7	423.99	8.2	424.48	8.4
B6	386.45	417.06	7.9	419.34	8.5	419.85	8.6
B7S2	381.77	-	-	-	-		-
C1	342.95	370.92	8.2	371.90	8.4	372.45	8.6
C2	349.76	377.98	8.1	379.32	8.5	379.99	8.6
C3	361.06	390.13	8.1	391.28	8.4	391.85	8.5
C4	353.68	382.21	8.1	383.38	8.4	383.94	8.6
C5	353.89	382.89	8.2	383.93	8.5	384.53	8.7
C6S3	339.02	-	-	-	-		-
D1	288.84	312.26	8.1	313.67	8.6	314.27	8.8
D2	297.42	321.60	8.1	323.00	8.6	323.65	8.8
D3	299.87	324.34	8.2	325.87	8.7	326.45	8.9
D4	308.04	333.09	8.1	334.45	8.6	335.06	8.8
D5	307.56	332.33	8.1	333.64	8.5	334.19	8.7
D6	293.45	317.11	8.1	318.53	8.5	319.12	8.7
D7	299.19	323.28	8.1	324.70	8.5	325.17	8.7
E1	324.10	350.62	8.2	351.97	8.6	352.64	8.8
E2	325.07	351.52	8.1	352.82	8.5	353.39	8.7
E3	330.55	356.86	8.0	358.48	8.4	359.17	8.7
E4	331.39	358.32	8.1	359.57	8.5	360.14	8.7
E5	332.01	358.80	8.1	360.23	8.5	360.82	8.7
E6	333.54	360.58	8.1	361.90	8.5	362.55	8.7
E7S4	341.86	-	-	-	-		-
F1	293.20	316.98	8.1	318.07	8.5	318.62	8.7
F2	301.20	325.28	8.0	326.27	8.3	326.8	8.5
F3	305.73	330.99	8.3	332.35	8.7	332.99	8.9
F4	311.77	336.03	7.8	337.26	8.2	337.94	8.4
F5	306.97	331.64	8.0	332.86	8.4	333.54	8.7
F6	302.20	325.00	7.5	326.21	7.9	326.84	8.2

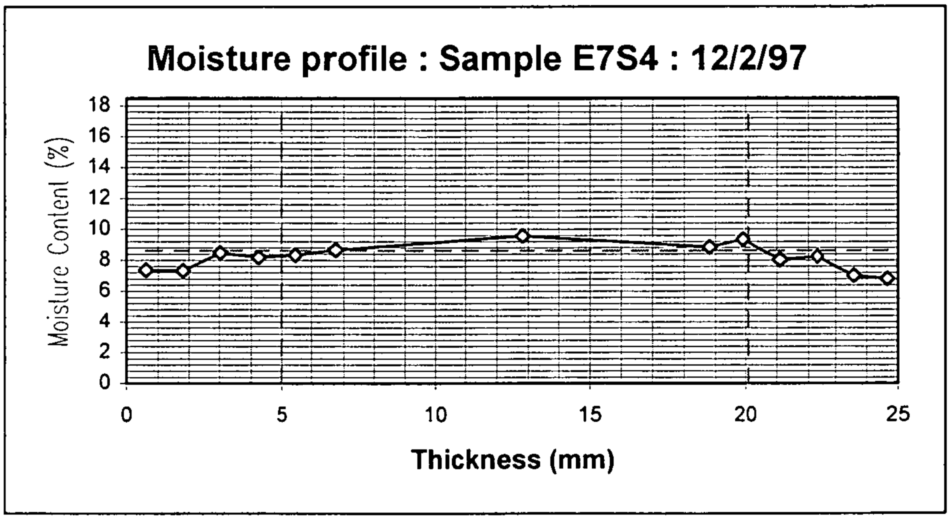
		Date: 5/02/98		Date: 9/02/98		Date: 11/02/98	
Sample #	O.D.W (g)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)
A1	297.92	323.47	8.6	323.98	8.7	323.53	8.6
A2	296.15	322.66	9.0	323.35	9.2	323.11	9.1
A3	304.03	331.53	9.0	332.41	9.3	332.06	9.2
A4	307.48	335.09	9.0	335.59	9.1	335.18	9.0
A5	302.46	329.91	9.1	331.58	9.6	331.31	9.5
A6	297.21	323.72	8.9	324.21	9.1	323.72	8.9
A7S1	285.52	-	-	-	-	-	-
B1	393.33	428.00	8.8	429.11	9.1	429.05	9.1
B2	392.90	427.34	8.8	427.74	8.9	427.44	8.8
B3	388.34	421.57	8.6	422.06	8.7	421.83	8.6
B4	390.43	424.50	8.7	424.77	8.8	424.87	8.8
B5	391.71	424.80	8.4	425.40	8.6	425.15	8.5
B6	386.45	420.22	8.7	420.75	8.9	420.45	8.8
B7S2	381.77	-	-	-	-	-	-
C1	342.95	372.69	8.7	372.96	8.8	372.42	8.6
C2	349.76	379.81	8.6	380.32	8.7	379.73	8.6
C3	361.06	392.21	8.6	393.79	9.1	392.92	8.8
C4	353.68	383.88	8.5	384.44	8.7	383.92	8.6
C5	353.89	384.49	8.6	384.90	8.8	384.52	8.7
C6S3	339.02	-	-	-	-	-	-
D1	288.84	314.45	8.9	314.85	9.0	314.62	8.9
D2	297.42	323.67	8.8	324.56	9.1	324.15	9.0
D3	299.87	326.46	8.9	327.05	9.1	326.57	8.9
D4	308.04	335.16	8.8	335.48	8.9	335.10	8.8
D5	307.56	334.11	8.6	334.79	8.9	334.17	8.7
D6	293.45	319.06	8.7	320.27	9.1	319.88	9.0
D7	299.19	326.18	9.0	326.68	9.2	326.38	9.1
E1	324.10	353.30	9.0	354.35	9.3	353.78	9.2
E2	325.07	354.24	9.0	355.50	9.4	355.29	9.3
E3	330.55	359.33	8.7	360.08	8.9	359.56	8.8
E4	331.39	360.14	8.7	360.86	8.9	360.37	8.7
E5	332.01	361.07	8.8	361.70	8.9	361.34	8.8
E6	333.54	362.60	8.7	363.13	8.9	362.64	8.7
E7S4	341.86	-	-	-	-	-	-
F1	293.20	319.03	8.8	319.54	9.0	319.13	8.8
F2	301.20	326.89	8.5	327.30	8.7	326.94	8.5
F3	305.73	334.04	9.3	334.27	9.3	333.74	9.2
F4	311.77	337.97	8.4	338.73	8.6	338.24	8.5
F5	306.97	333.41	8.6	333.98	8.8	333.33	8.6
F6	302.20	326.76	8.1	327.48	8.4	326.95	8.2

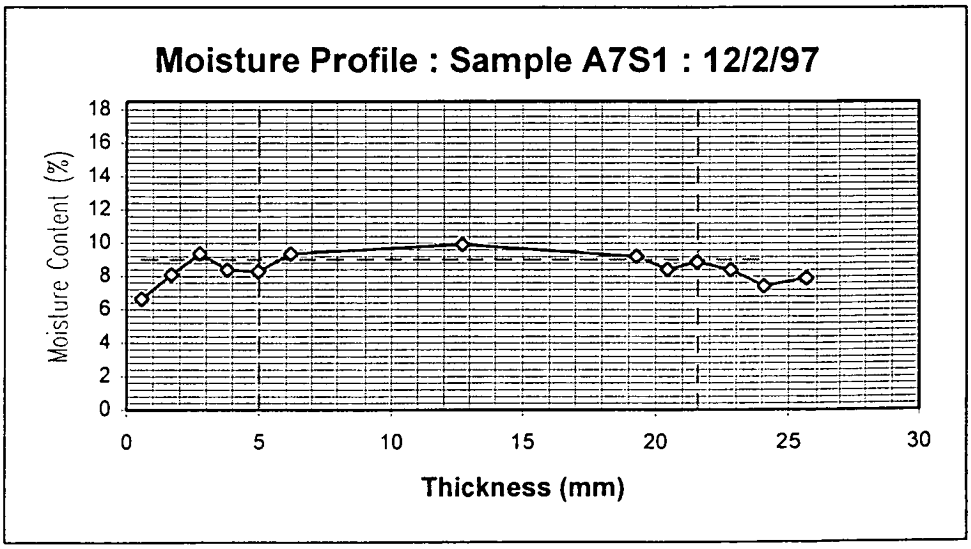
		Date: 15/02/98		Date: 16/02/98	
Sample #	O.D.W (g)	Mcurrent (g)	M.C (%)	Mcurrent (g)	M.C (%)
A1	297.92	323.03	8.4	323.11	8.5
A2	296.15	322.36	8.9	322.36	8.9
A3	304.03	331.71	9.1	331.67	9.1
A4	307.48	334.60	8.8	334.76	8.9
A5	302.46	331.08	9.5	330.98	9.4
A6	297.21	323.41	8.8	323.43	8.8
A7S1	285.52	-	-	-	-
B1	393.33	428.91	9.0	428.85	9.0
B2	392.90	427.02	8.7	427.03	8.7
B3	388.34	421.48	8.5	421.53	8.5
B4	390.43	424.23	8.7	424.22	8.7
B5	391.71	424.58	8.4	424.63	8.4
B6	386.45	420.09	8.7	420.09	8.7
B7S2	381.77	-	-	-	-
C1	342.95	371.74	8.4	371.84	8.4
C2	349.76	378.95	8.3	378.99	8.4
C3	361.06	392.64	8.7	392.55	8.7
C4	353.68	383.23	8.4	383.26	8.4
C5	353.89	383.97	8.5	383.99	8.5
C6S3	339.02	-	-	-	-
D1	288.84	314.19	8.8	314.20	8.8
D2	297.42	323.43	8.7	323.44	8.7
D3	299.87	326.02	8.7	326.09	8.7
D4	308.04	334.47	8.6	334.53	8.6
D5	307.56	333.59	8.5	333.64	8.5
D6	293.45	319.74	9.0	319.67	8.9
D7	299.19	325.75	8.9	325.74	8.9
E1	324.10	352.96	8.9	352.91	8.9
E2	325.07	354.82	9.2	354.75	9.1
E3	330.55	358.90	8.6	358.93	8.6
E4	331.39	359.90	8.6	359.97	8.6
E5	332.01	360.85	8.7	360.85	8.7
E6	333.54	362.04	8.5	362.13	8.6
E7S4	341.86	-	-	-	-
F1	293.20	319.24	8.9	319.14	8.8
F2	301.20	326.42	8.4	326.46	8.4
F3	305.73	333.06	8.9	333.03	8.9
F4	311.77	337.89	8.4	337.86	8.4
F5	306.97	332.60	8.3	332.67	8.4
F6	302.20	326.24	8.0	326.33	8.0

Average MC (%)	8.7

A9. Moisture Profile data at approximately 8% EMC

12/2/98	Sample: E7S4 Initial Thickness: 24.33				Sample:A7S1 Initial Thickness: 2434			
Slice #	Thick. (mm)	Mwet (g)	Mdry (g)	M.C. (%)	Thick. (mm)	Mwet (g)	Mdry (g)	M.C. (%)
1 top	1.23	0.451	0.420	7.4	1.16	0.386	0.362	6.6
2	1.14	0.483	0.450	7.3	1.06	0.400	0.370	8.1
3	1.32	0.486	0.448	8.5	1.03	0.431	0.394	9.4
4	1.12	0.515	0.476	8.2	1.11	0.413	0.381	8.4
5	1.31	0.520	0.480	8.3	1.20	0.444	0.410	8.3
6	1.24	0.489	0.450	8.7	1.21	0.444	0.406	9.4
7	10.90	5.012	4.574	9.6	11.90	5.013	4.560	9.9
8	1.09	0.505	0.464	8.8	1.21	0.522	0.478	9.2
9	1.11	0.550	0.503	9.3	1.12	0.451	0.416	8.4
10	1.25	0.538	0.498	8.0	1.09	0.442	0.406	8.9
11	1.26	0.551	0.509	8.3	1.40	0.490	0.452	8.4
12	1.23	0.594	0.555	7.0	1.17	0.333	0.310	7.4
13bot	0.90	0.392	0.367	6.8	1.90	0.766	0.710	7.9





A10. Meter calibration results at approximately 8% MC

		Resistance Type-model					Capacitance Type-model				
		G-30 MC(%)		RC-IC MC(%)			M10-1 MC(%)		M10-2 MC(%)		
Sample #	Approx. MC(%)	Side 1	Side 2	Side 1	Side 2	AVE.	Side 1	Side 2	Side 1	Side 2	AVE.
A1	8.4	8.0	8.0	7.8	7.8	7.9	11.0	11.0	11.0	11.0	11.0
A2	8.9	8.0	8.0	8.0	8.0	8.0	11.0	12.0	11.0	11.5	11.4
A3	9.1	8.0	7.8	7.8	7.8	7.8	12.0	12.0	11.5	11.5	11.8
A4	8.8	8.0	7.8	8.0	7.5	7.8	11.5	12.0	11.0	11.0	11.4
A5	9.5	8.3	8.0	8.0	8.0	8.1	11.5	12.0	11.5	12.0	11.8
A6	8.8	8.0	7.8	7.8	7.5	7.8	11.5	12.0	11.0	11.5	11.5
B1	9.0	7.8	7.8	7.8	7.8	7.8	14.5	15.0	14.5	14.5	14.6
B2	8.7	7.8	7.8	7.8	7.8	7.8	14.5	15.0	14.5	14.5	14.6
B3	8.5	7.8	7.8	7.8	7.8	7.8	14.5	15.0	14.5	14.5	14.6
B4	8.7	8.0	7.8	7.8	7.8	7.8	15.0	15.0	14.5	14.5	14.8
B5	8.4	8.0	7.8	7.8	7.8	7.8	15.0	15.0	14.5	14.5	14.8
B6	8.7	7.8	7.5	7.8	7.8	7.7	14.5	14.0	14.5	14.0	14.3
C1	8.4	7.5	7.5	7.5	7.5	7.5	13.0	14.0	13.0	13.5	13.4
C2	8.3	7.8	7.3	7.8	7.3	7.5	13.0	14.0	13.0	13.0	13.3
C3	8.7	7.8	7.5	7.5	7.5	7.6	14.0	14.5	13.5	14.0	14.0
C4	8.4	7.8	7.5	7.5	7.5	7.6	13.5	14.0	13.5	14.0	13.8
C5	8.5	7.5	7.5	7.5	7.5	7.5	13.5	14.5	13.0	14.0	13.8
D1	8.8	7.5	8.0	7.5	7.8	7.7	12.5	12.0	12.0	12.0	12.1
D2	8.7	7.8	7.8	8.0	7.8	7.8	12.5	12.5	12.0	12.0	12.3
D3	8.7	7.8	8.0	7.8	8.0	7.9	12.0	12.5	12.0	12.0	12.1
D4	8.6	8.0	7.8	7.8	7.8	7.8	12.0	12.5	12.0	12.5	12.3
D5	8.5	8.0	8.0	8.0	8.0	8.0	12.0	12.5	12.0	12.5	12.3
D6	9.0	8.0	8.3	7.8	8.5	8.1	12.0	12.5	12.0	12.0	12.1
D7	8.9	8.0	8.5	8.0	8.5	8.3	12.5	13.0	12.0	12.5	12.5
E1	8.9	7.8	7.8	7.8	7.8	7.8	12.5	12.5	12.0	12.0	12.3
E2	9.2	7.8	8.0	7.8	8.0	7.9	12.5	13.0	12.5	12.5	12.6
E3	8.6	7.3	7.5	7.3	7.5	7.4	12.0	13.0	12.0	13.0	12.5
E4	8.6	7.5	7.5	7.3	7.5	7.4	13.0	13.0	12.5	13.0	12.9
E5	8.7	7.3	7.5	7.3	7.3	7.3	12.5	12.5	12.5	13.0	12.6
E6	8.5	7.3	7.3	7.3	7.3	7.3	12.5	13.0	12.5	12.5	12.6
F1	8.9	7.5	7.8	7.5	7.8	7.6	11.5	11.0	11.0	11.0	11.1
F2	8.4	7.8	7.8	7.8	7.5	7.7	11.5	11.5	11.5	11.5	11.5
F3	8.9	8.0	8.0	8.0	8.0	8.0	11.5	11.5	11.5	11.5	11.5
F4	8.4	7.5	7.5	7.5	7.5	7.5	11.5	11.0	11.0	11.0	11.1
F5	8.3	7.8	8.0	7.8	8.0	7.9	11.0	11.0	11.0	11.5	11.1
F6	8.0	7.8	7.8	7.8	7.5	7.7	10.5	11.0	10.5	10.5	10.6

A11. Oven dry Density, Oven dry Weight and Moisture Meter Calibration Results

Sample #	O.D.W (g)	Oven dry density (kg/m^3)	MC's at approx 18%			MC's at approx 13%			MC's at approx 8%		
			Oven Dry	Resistance	Capacitance	Oven Dry	Resistance	Capacitance	Oven Dry	Resistance	Capacitance
A1	296.38	624	18.8	15.5	17.0	14.1	10.4	14.5	9.0	7.9	11.0
A2	294.98	634	18.8	15.4	17.0	14.1	10.8	14.0	9.3	8.0	11.4
A3	302.73	631	18.8	15.3	17.1	14.0	12.0	15.0	9.6	7.8	11.8
A4	306.58	632	18.7	15.3	16.0	14.3	11.4	14.4	9.2	7.8	11.4
A5	301.38	628	18.9	15.5	17.0	14.3	12.3	14.9	9.8	8.1	11.8
A6	295.84	629	19.1	15.3	17.3	14.4	12.1	14.9	9.3	7.8	11.5
B1	394.01	866	18.0	15.6	22.0	13.5	12.5	18.0	8.8	7.8	14.6
B2	393.97	856	17.8	15.6	21.5	13.5	12.3	19.0	8.4	7.8	14.6
B3	388.75	845	17.9	15.9	21.3	13.5	11.8	18.3	8.4	7.8	14.6
B4	390.04	857	18.0	15.6	21.5	13.7	12.3	19.0	8.8	7.8	14.8
B5	390.96	850	18.0	15.5	21.1	13.7	12.3	18.4	8.6	7.8	14.8
B6	387.12	851	17.9	15.8	21.0	13.6	12.1	18.1	8.5	7.7	14.3
C1	341.99	752	18.8	15.9	19.3	12.9	10.6	16.4	8.7	7.5	14.4
C2	349.24	759	18.7	15.6	19.8	13.7	12.3	17.4	8.5	7.5	13.3
C3	360.22	783	18.6	15.9	20.0	14.1	12.3	17.6	9.0	7.6	14.0
C4	353.02	776	18.4	15.4	20.0	13.8	12.0	17.9	8.6	7.6	13.8
C5	353.44	777	18.6	16.1	20.0	13.8	12.3	17.0	8.6	7.5	13.8
D1	288.76	649	18.5	15.4	18.5	14.1	12.8	15.9	8.8	7.7	12.1
D2	297.19	646	19.0	16.3	18.5	14.0	12.5	16.4	8.8	7.8	12.3
D3	300.18	653	18.9	16.1	18.5	13.9	12.0	16.0	8.6	7.9	12.1
D4	308.00	662	18.8	16.1	18.8	14.1	12.4	16.0	8.6	7.8	12.3
D5	307.15	654	18.9	16.1	18.4	14.1	12.5	16.1	8.6	8.0	12.3
D6	293.26	631	19.0	16.1	18.0	14.0	11.0	15.5	9.0	8.1	12.1
D7	298.39	649	19.1	16.3	18.5	14.1	12.0	16.0	9.2	8.3	12.5
E1	324.06	704	19.0	14.5	18.0	14.0	11.6	16.0	8.9	7.8	12.3
E2	324.96	706	18.8	14.9	18.3	14.0	11.3	16.0	9.2	7.9	12.6
E3	331.09	712	18.7	14.5	18.5	13.7	11.1	16.0	8.4	7.4	12.5
E4	331.58	713	18.5	14.8	18.3	13.8	10.9	15.9	8.6	7.4	12.9
E5	332.35	723	18.7	14.9	19.0	13.7	11.2	16.4	8.6	7.3	12.6
E6	334.54	719	18.5	14.6	18.8	13.7	11.6	16.4	8.2	7.3	12.6
F1	293.56	618	18.1	15.4	16.5	13.6	11.1	14.8	8.7	7.6	11.1
F2	301.01	634	18.0	15.8	16.5	13.5	11.7	15.0	8.5	7.7	11.5
F3	305.55	637	18.4	15.5	17.1	13.9	12.5	15.0	9.0	8.0	11.5
F4	311.26	642	18.1	15.9	17.5	13.8	12.4	15.3	8.5	7.5	11.1
F5	307.00	646	18.0	15.6	17.3	13.6	11.8	14.5	8.4	7.9	11.1
F6	301.49	635	17.8	15.6	16.8	13.5	11.4	13.9	8.2	7.7	10.6

Average	327.56	705

Appendix B. Solar Kiln Measured Data

B1. Temperature distribution data - Trial 2

Time (14/7)	A1	A2	B1	B2	C1	C2	D1	D2
12:11:40	21.6	22.1	21.7	22.2	21.7	22.4	21.8	22.3
12:12:00	21.6	22.1	21.7	22.2	21.7	22.4	21.8	22.3
12:12:20	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:12:40	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:13:00	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:13:20	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:13:40	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:14:00	21.6	22.1	21.7	22.2	21.7	22.4	21.8	22.3
12:14:20	21.6	22.1	21.7	22.2	21.7	22.3	21.8	22.3
12:14:40	21.6	22.1	21.8	22.2	21.7	22.3	21.8	22.3
12:15:00	21.6	22.1	21.7	22.2	21.7	22.3	21.8	22.3
12:15:20	21.6	22.1	21.7	22.2	21.7	22.3	21.8	22.3
12:15:40	21.5	22.1	21.7	22.2	21.7	22.3	21.8	22.3
12:16:00	21.6	22.1	21.7	22.2	21.7	22.3	21.8	22.3
12:16:20	21.6	22.1	21.7	22.2	21.7	22.3	21.8	22.3
12:16:40	21.6	22.0	21.8	22.2	21.7	22.3	21.8	22.3
12:17:00	21.6	22.0	21.8	22.2	21.7	22.3	21.8	22.3
12:17:20	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:17:40	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:18:00	21.6	22.1	21.8	22.2	21.7	22.3	21.8	22.3
12:18:20	21.6	22.1	21.8	22.2	21.7	22.3	21.8	22.3
12:18:40	21.6	22.1	21.8	22.2	21.7	22.3	21.8	22.3
12:19:00	21.6	22.1	21.8	22.2	21.7	22.3	21.8	22.3
12:19:20	21.6	22.1	21.8	22.2	21.7	22.3	21.8	22.3
12:19:40	21.6	22.1	21.8	22.2	21.7	22.3	21.8	22.3
12:20:00	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:20:20	21.6	22.1	21.7	22.2	21.7	22.4	21.8	22.3
12:20:40	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:21:00	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:21:20	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:21:40	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:22:00	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:22:20	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:22:40	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:23:00	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:23:20	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:23:40	21.6	22.1	21.8	22.2	21.7	22.4	21.8	22.3
12:24:00	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:24:20	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:24:40	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3

12:25:00	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:25:20	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:25:40	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:26:00	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:26:20	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:26:40	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:27:00	21.7	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:27:20	21.6	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:27:40	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:28:00	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:28:20	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:28:40	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:29:00	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:29:20	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:29:40	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:30:00	21.7	22.1	21.9	22.2	21.8	22.4	21.9	22.3
12:30:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:30:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:31:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:31:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:31:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:32:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:32:20	21.7	22.1	21.9	22.2	21.8	22.4	21.9	22.3
12:32:40	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:33:00	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:33:20	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:33:40	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:34:00	21.7	22.1	21.9	22.2	21.8	22.4	21.9	22.3
12:34:20	21.7	22.1	21.8	22.2	21.8	22.4	22.0	22.3
12:34:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:35:00	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:35:20	21.7	22.1	21.8	22.2	21.8	22.4	22.0	22.3
12:35:40	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:36:00	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:36:20	21.6	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:36:40	21.6	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:37:00	21.6	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:37:20	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:37:40	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:38:00	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:38:20	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:38:40	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:39:00	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:39:20	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:39:40	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:40:00	21.6	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:40:20	21.6	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:40:40	21.6	22.1	21.8	22.2	21.7	22.4	21.9	22.3
12:41:00	21.7	22.1	21.8	22.2	21.8	22.3	21.9	22.3

12:41:20	21.7	22.1	21.8	22.2	21.8	22.3	21.9	22.3
12:41:40	21.7	22.1	21.8	22.2	21.8	22.3	21.9	22.3
12:42:00	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3
12:42:20	21.7	22.1	21.9	22.2	21.8	22.4	21.9	22.3
12:42:40	21.7	22.1	21.9	22.2	21.8	22.4	21.9	22.3
12:43:00	21.7	22.1	21.9	22.2	21.8	22.4	21.9	22.3
12:43:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:43:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:44:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:44:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:44:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:45:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:45:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:45:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:46:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:46:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:46:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:47:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:47:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:47:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:48:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:48:20	21.8	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:48:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:49:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:49:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:49:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:50:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:50:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:50:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:51:00	21.7	22.1	21.9	22.2	21.8	22.3	22.0	22.3
12:51:20	21.7	22.1	21.9	22.2	21.8	22.3	22.0	22.3
12:51:40	21.7	22.1	21.9	22.2	21.8	22.3	22.0	22.3
12:52:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:52:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:52:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:53:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:53:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:53:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:54:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:54:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:54:40	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:55:00	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:55:20	21.7	22.1	21.9	22.2	21.8	22.4	22.0	22.3
12:55:40	21.7	22.1	21.9	22.2	21.9	22.4	22.0	22.3
12:56:00	21.8	22.1	21.9	22.2	21.9	22.4	22.0	22.3
12:56:20	21.8	22.1	21.9	22.2	21.9	22.4	22.0	22.3
12:56:40	21.8	22.1	22.0	22.2	21.9	22.4	22.1	22.3
12:57:00	21.8	22.1	22.0	22.2	21.9	22.4	22.1	22.3

12:57:20	21.8	22.1	22.0	22.2	21.9	22.4	22.1	22.3
12:57:40	21.8	22.1	22.0	22.3	21.9	22.4	22.1	22.3
12:58:00	21.8	22.1	22.0	22.2	21.9	22.4	22.1	22.3
12:58:20	21.8	22.1	22.0	22.2	21.9	22.4	22.1	22.3
12:58:40	21.8	22.1	22.0	22.2	21.9	22.4	22.1	22.3
12:59:00	21.8	22.1	21.9	22.2	21.9	22.4	22.0	22.3

Average	21.7	22.1	21.8	22.2	21.8	22.4	21.9	22.3

B2. Initial MC data - Trial 2

Sample No.	25mm Sample Date: 6/7/97 Initial Weight (g)	Oven Dry Weight (g)	Calculated M.C.%	Sample Board Initial Weight (g) Date: 8am 6/797
A1	140.7	95.3	47.6	3552.9
A2	249.7	154.4	61.7	5702.1
A3	152.6	96.5	58.1	3900.0
A4	228.7	149.2	53.3	5718.5
B2	260.5	177.1	47.1	5430.9
B3	304.3	176.0	72.9	6077.3
B4	171.6	107.1	60.2	5537.0
C2	238.8	156.0	53.1	5533.0
C3	229.4	151.9	51.0	5708.2
C4	168.8	103.1	63.7	4107.4
D1	137.0	82.4	66.3	4041.3
D2	225.9	135.0	67.3	5297.6
D3	127.5	88.4	44.2	3507.8
D4	180.6	121.1	49.1	4101.2
E1	149.0	94.2	58.2	3507.6
E2	252.1	161.3	56.3	5711.2
E3	133.3	85.5	55.9	3627.4
E4	227.1	154.1	47.4	5993.0
F1	168.3	111.6	50.8	5356.3
F2	192.3	141.7	35.7	4335.1
F3	287.7	178.6	61.1	5952.2
G1	100.6	73.3	37.2	2724.5
G2	244.0	160.9	51.6	5313.8
G3	218.7	141.7	54.3	5254.4
G4	175.1	114.3	53.2	4611.9
H1	159.0	104.6	52.0	4179.1
H2	191.9	123.4	55.5	4106.5
H3	129.0	92.0	40.2	3093.0
H4	112.6	72.9	54.5	4324.0

Average	53.8

B3. Progressive MC data - Trial 2

Sample No.	Sample Board Oven Dry Weight (g)	Date: 8 am 10/7/97		Date: 2pm 14/7/97		Date: 18/7/97	
		Weight	M.C.% (O.D)	Weight	M.C.% (O.D)	Weight	M.C.% (O.D)
A1	2406.5	3522.4	46.4	3496.7	45.3	3464.4	44.0
A2	3525.8	5586.1	58.4	5702.1	61.7	5355.6	51.9
A3	2466.3	3777.0	53.1	3681.5	49.3	3570.6	44.8
A4	3730.7	5620.0	50.6	5531.5	48.3	5428.4	45.5
B2	3692.2	5341.3	44.7	5260.8	42.5	5164.5	39.9
B3	3515.0	5861.3	66.8	5718.2	62.7	5562.7	58.3
B4	3455.8	5338.3	54.5	5197.6	50.4	5043.5	45.9
C2	3614.5	5355.6	48.2	5245.4	45.1	5125.7	41.8
C3	3779.8	5514.7	45.9	5297.1	40.1	5271.6	39.5
C4	2508.7	3943.1	57.2	3838.6	53.0	3726.6	48.5
D1	2430.7	3786.0	55.8	3671.2	51.0	3558.8	46.4
D2	3165.9	5026.5	58.8	4890.4	54.5	4740.2	49.7
D3	2432.1	3433.3	41.2	3369.5	38.5	3304.6	35.9
D4	2750.0	3995.4	45.3	3934.2	43.1	3854.0	40.1
E1	2217.6	3462.4	56.1	3421.4	54.3	3369.7	52.0
E2	3654.2	5650.2	54.6	5588.4	52.9	5512.6	50.9
E3	2326.7	3576.8	53.7	3522.8	51.4	3464.0	48.9
E4	4066.6	5918.1	45.5	5829.9	43.4	5732.0	41.0
F1	3551.8	5274.8	48.5	5202.8	46.5	5120.0	44.2
F2	3194.4	4289.0	34.3	4253.8	33.2	4204.8	31.6
F3	3695.0	5868.0	58.8	5778.1	56.4	5678.6	53.7
G1	1985.1	2684.4	35.2	2659.1	33.9	2623.3	32.1
G2	3504.1	5215.8	48.9	5141.5	46.7	5053.6	44.2
G3	3404.4	5124.6	50.5	5034.1	47.9	4932.6	44.9
G4	3010.5	4552.0	51.2	4482.6	48.9	4402.2	46.2
H1	2749.3	4010.3	45.9	3922.1	42.7	3822.0	39.0
H2	2640.7	3971.6	50.4	3887.5	47.2	3785.1	43.3
H3	2205.9	3030.0	37.4	2991.9	35.6	2937.2	33.2
H4	2799.5	4324.0	54.5	4219.7	50.7	N/A	N/A

Average MC		50.1		47.5		44.2

Sample No.	Sample Board Oven Dry Weight (g)	Date: 24/7/97		Date: 28/7/97		Date: 1/8/97	
		Weight	M.C.% (O.D)	Weight	M.C.% (O.D)	Weight	M.C.% (O.D)
A1	2406.5	3414.7	41.9	3382.7	40.6	3343.3	38.9
A2	3525.8	5187.1	47.1	5097.4	44.6	4997.3	41.7
A3	2466.3	3418.3	38.6	3334.6	35.2	3242.8	31.5
A4	3730.7	5284.3	41.6	5205.7	39.5	5115.1	37.1
B2	3692.2	5032.5	36.3	4954.0	34.2	4865	31.8
B3	3515.0	5386.5	53.2	5283.2	50.3	5182.4	47.4
B4	3455.8	4870.9	40.9	4781.2	38.4	4688	35.7
C2	3614.5	4979.7	37.8	4902.8	35.6	4821.6	33.4
C3	3779.8	5127.5	35.7	5054.8	33.7	4977.7	31.7
C4	2508.7	3587.3	43.0	3512.6	40.0	3435.9	37.0
D1	2430.7	3427.9	41.0	3357.0	38.1	3285.1	35.2
D2	3165.9	4565.2	44.2	4470.1	41.2	4366.6	37.9
D3	2432.1	3228.5	32.7	3191.3	31.2	3147	29.4
D4	2750.0	3757.1	36.6	3704.5	34.7	3648.3	32.7
E1	2217.6	3290.4	48.4	3241.5	46.2	3182.8	43.5
E2	3654.2	5401.2	47.8	5334.4	46.0	5256	43.8
E3	2326.7	3358.8	44.4	3296.0	41.7	3216.9	38.3
E4	4066.6	5591.0	37.5	5513.1	35.6	5426.2	33.4
F1	3551.8	5003.6	40.9	4935.8	39.0	4860.6	36.9
F2	3194.4	4140.3	29.6	4103.0	28.4	4062	27.2
F3	3695.0	5533.5	49.8	5454.0	47.6	5365.8	45.2
G1	1985.1	2571.7	29.5	2546.9	28.3	2515.7	26.7
G2	3504.1	4931.5	40.7	4869.4	39.0	4797.5	36.9
G3	3404.4	4792.2	40.8	4726.8	38.8	4654.7	36.7
G4	3010.5	4286.8	42.4	4228.2	40.4	4166.5	38.4
H1	2749.3	3707.4	34.9	3645.0	32.6	3579.1	30.2
H2	2640.7	3656.8	38.5	3587.0	35.8	3513.1	33.0
H3	2205.9	2880.0	30.6	2849.4	29.2	2814.3	27.6
H4	2799.5	4021.4	43.6	N/A	N/A	N/A	N/A

Average MC	40.3		38.1		35.7

Sample No.	Sample Board Oven Dry Weight (g)	Date: 20/8/97		Date: 22/8/97		Date: 26/8/97	
		Weight	M.C.% (O.D)	Weight	M.C.% (O.D)	Weight	M.C.% (O.D)
A1	2406.5	3168.0	31.6	3149.3	30.9	3108.7	29.2
A2	3525.8	4665.8	32.3	4637.0	31.5	4577.4	29.8
A3	2466.3	2928.3	18.7	2903.2	17.7	2853.3	15.7
A4	3730.7	4818.6	29.2	4792.4	28.5	4737.6	27.0
B2	3692.2	4507.6	22.1	4473.3	21.2	4402.8	19.2
B3	3515.0	4815.4	37.0	4779.9	36.0	4710.9	34.0
B4	3455.8	4391.8	27.1	4367.0	26.4	4316.6	24.9
C2	3614.5	4536.4	25.5	4510.9	24.8	4459.5	23.4
C3	3779.8	4718.9	24.8	4694.9	24.2	4646.2	22.9
C4	2508.7	3167.5	26.3	3146.1	25.4	3102.6	23.7
D1	2430.7	3055.6	25.7	3039.0	25.0	3004.3	23.6
D2	3165.9	4016.7	26.9	3985.6	25.9	3925.0	24.0
D3	2432.1	3006.0	23.6	2994.5	23.1	2969.6	22.1
D4	2750.0	3416.0	24.2	3393.8	23.4	3347.2	21.7
E1	2217.6	2958.0	33.4	2937.3	32.5	2892.8	30.4
E2	3654.2	4969.8	36.0	4941.4	35.2	4884.3	33.7
E3	2326.7	2924.3	25.7	2895.5	24.4	2840.2	22.1
E4	4066.6	5132.8	26.2	5106.9	25.6	5052.4	24.2
F1	3551.8	4584.5	29.1	4559.0	28.4	4509.0	27.0
F2	3194.4	3901.0	22.1	3886.0	21.7	3853.4	20.6
F3	3695.0	5018.4	35.8	4985.7	34.9	4917.0	33.1
G1	1985.1	2392.0	20.5	2380.5	19.9	2354.4	18.6
G2	3504.1	4521.8	29.0	4495.4	28.3	4439.4	26.7
G3	3404.4	4405.8	29.4	4384.7	28.8	4339.9	27.5
G4	3010.5	3887.4	29.1	3862.4	28.3	3811.8	26.6
H1	2749.3	3372.8	22.7	3358.6	22.2	3328.0	21.1
H2	2640.7	3259.6	23.4	3240.9	22.7	3201.4	21.2
H3	2205.9	2697.3	22.3	2690.5	22.0	2670.0	21.0
H4	2799.5	N/A	N/A	N/A	N/A	N/A	N/A

Average MC	27.1		26.4		24.8

Sample No.	Sample Board - Oven Dry Weight (g)	Date: 29/8/97		Date: 2/9/97		Date: 5/9/97	
		Weight	M.C.% (O.D)	Weight	M.C.% (O.D)	Weight	M.C.% (O.D)
A1	2406.5	3081.0	28.0	3032.8	26.0	2995.3	24.5
A2	3525.8	4540.0	28.8	4475.5	26.9	4427.3	25.6
A3	2466.3	2825.7	14.6	2782.2	12.8	2750.7	11.5
A4	3730.7	4701.5	26.0	4642.4	24.4	4598.1	23.3
B2	3692.2	4355.4	18.0	4281.3	16.0	4220.7	14.3
B3	3515.0	4663.2	32.7	4590.6	30.6	4532.0	28.9
B4	3455.8	4283.4	23.9	4234.0	22.5	4190.0	21.2
C2	3614.5	4426.2	22.5	4371.2	20.9	4323.2	19.6
C3	3779.8	4613.1	22.0	4561.9	20.7	4516.8	19.5
C4	2508.7	3076.8	22.6	3038.8	21.1	3006.1	19.8
D1	2430.7	2985.7	22.8	2954.9	21.6	2926.1	20.4
D2	3165.9	3889.7	22.9	3834.7	21.1	3838.6	21.2
D3	2432.1	2955.9	21.5	2932.2	20.6	2972.9	22.2
D4	2750.0	3316.8	20.6	3272.9	19.0	3267.1	18.8
E1	2217.6	2862.3	29.1	2814.1	26.9	2774.9	25.1
E2	3654.2	4843.6	32.5	4778.5	30.8	4725.5	29.3
E3	2326.7	2805.0	20.6	2753.4	18.3	2715.7	16.7
E4	4066.6	5013.7	23.3	4952.9	21.8	4902.4	20.6
F1	3551.8	4465.7	25.7	4409.7	24.2	4360.5	22.8
F2	3194.4	3833.2	20.0	3800.0	19.0	3766.5	17.9
F3	3695.0	4871.6	31.8	4802.7	30.0	4743.7	28.4
G1	1985.1	2336.6	17.7	2312.2	16.5	2285.0	15.1
G2	3504.1	4400.8	25.6	4344.7	24.0	4291.4	22.5
G3	3404.4	4310.5	26.6	4268.5	25.4	4223.6	24.1
G4	3010.5	3775.6	25.4	3726.2	23.8	3676.6	22.1
H1	2749.3	3307.1	20.3	3280.6	19.3	3244.5	18.0
H2	2640.7	3179.0	20.4	3146.0	19.1	3107.3	17.7
H3	2205.9	2656.2	20.4	2638.5	19.6	2611.1	18.4
H4	2799.5	N/A	N/A	N/A	N/A	N/A	N/A

Average MC		23.8		22.2		21.1

After Reconditioning

Sample No.	Sample Board Oven Dry Weight (g)	Date: 9/9/97		Date: 29/9/97		Date: 3/10/97	
		Weight	M.C.% (O.D)	Weight	M.C.% (O.D)	Weight	M.C.% (O.D)
A1	2406.5	2940.6	22.2	2899.5	20.5	2760.8	14.7
A2	3525.8	4359.0	23.6	4350.5	23.4	4183.7	18.7
A3	2466.3	2711.7	10.0	2774.4	12.5	2646.4	7.3
A4	3730.7	4534.1	21.5	4544.0	21.8	4383.4	17.5
B2	3692.2	4142.0	12.2	4163.1	12.8	4001.2	8.4
B3	3515.0	4454.7	26.7	4451.8	26.7	4263.5	21.3
B4	3455.8	4133.9	19.6	4209.1	21.8	3982.6	15.2
C2	3614.5	4263.0	17.9	4306.0	19.1	4115.7	13.9
C3	3779.8	4458.0	17.9	4512.8	19.4	4347.5	15.0
C4	2508.7	2967.4	18.3	3068.1	22.3	2922.0	16.5
D1	2430.7	2894.5	19.1	3013.7	24.0	2870.3	18.1
D2	3165.9	3769.1	19.1	3870.0	22.2	3685.3	16.4
D3	2432.1	2895.6	19.1	3022.0	24.3	2858.1	17.5
D4	2750.0	3212.0	16.8	3244.9	18.0	3099.2	12.7
E1	2217.6	2717.5	22.5	2695.1	21.5	2585.9	16.6
E2	3654.2	4646.6	27.2	4758.7	30.2	4526.2	23.9
E3	2326.7	2664.4	14.5	2705.9	16.3	2587.9	11.2
E4	4066.6	4826.9	18.7	4816.5	18.4	4640.0	14.1
F1	3551.8	4287.6	20.7	4294.9	20.9	4119.5	16.0
F2	3194.4	3714.3	16.3	3795.9	18.8	3629.5	13.6
F3	3695.0	4658.5	26.1	4666.0	26.3	4474.0	21.1
G1	1985.1	2250.2	13.4	2277.2	14.7	2161.3	8.9
G2	3504.1	4221.0	20.5	4234.3	20.8	4056.1	15.8
G3	3404.4	4163.9	22.3	4231.6	24.3	4036.8	18.6
G4	3010.5	3611.6	20.0	3682.9	22.3	3514.7	16.7
H1	2749.3	3202.3	16.5	3317.0	20.7	3160.3	15.0
H2	2640.7	3065.0	16.1	3194.7	21.0	3018.4	14.3
H3	2205.9	2579.1	16.9	2669.7	21.0	2553.4	15.8
H4	2799.5	N/A	N/A	3431.1	22.6	3280.1	17.2

Average MC	19.1		21.0		15.6

Sample No.	Sample Board Oven Dry Weight (g)	Date: 6/10/97		Date: 8/10/97		Date: 13/10/97	
		Weight	M.C.% (O.D)	Weight	M.C.% (O.D)	Weight	M.C.% (O.D)
A1	2406.5	2699.2	12.2	2658.1	10.5	2631.3	9.3
A2	3525.8	4105.4	16.4	4051.9	14.9	4019.0	14.0
A3	2466.3	2589.3	5.0	2553.6	3.5	2552.4	3.5
A4	3730.7	4300.9	15.3	4243.5	13.7	4219.5	13.1
B2	3692.2	3911.2	5.9	3854.5	4.4	3812.0	3.2
B3	3515.0	4188.6	19.2	4137.5	17.7	4099.4	16.6
B4	3455.8	3895.9	12.7	3840.4	11.1	3823.6	10.6
C2	3614.5	4036.2	11.7	3982.7	10.2	3953.3	9.4
C3	3779.8	4257.7	12.6	4198.6	11.1	4157.8	10.0
C4	2508.7	2863.0	14.1	2824.1	12.6	2804.0	11.8
D1	2430.7	2809.0	15.6	2769.8	14.0	2754.6	13.3
D2	3165.9	3609.5	14.0	3559.6	12.4	3537.2	11.7
D3	2432.1	2796.2	15.0	2756.1	13.3	2736.8	12.5
D4	2750.0	3040.5	10.6	3002.1	9.2	2982.2	8.4
E1	2217.6	2536.4	14.4	2503.1	12.9	2480.6	11.9
E2	3654.2	4421.3	21.0	4351.9	19.1	4301.0	17.7
E3	2326.7	2533.1	8.9	2498.9	7.4	2501.6	7.5
E4	4066.6	4552.8	12.0	4491.6	10.5	4458.0	9.6
F1	3551.8	4048.3	14.0	3999.0	12.6	3970.9	11.8
F2	3194.4	3560.0	11.4	3512.4	10.0	3488.2	9.2
F3	3695.0	4395.5	19.0	4340.2	17.5	4320.4	16.9
G1	1985.1	2118.2	6.7	2091.0	5.3	2092.1	5.4
G2	3504.1	3979.4	13.6	3927.5	12.1	3899.4	11.3
G3	3404.4	3954.2	16.1	3896.1	14.4	3878.5	13.9
G4	3010.5	3441.0	14.3	3390.4	12.6	3365.2	11.8
H1	2749.3	3096.0	12.6	3053.0	11.0	3041.8	10.6
H2	2640.7	2947.1	11.6	2904.6	10.0	2892.0	9.5
H3	2205.9	2500.7	13.4	2465.9	11.8	2452.8	11.2
H4	2799.5	3216.9	14.9	3175.7	13.4	3171.4	13.3

Average MC	13.2		11.7		11.0

B4. Initial MC data - Trial 3

Sample	25mm Sample	Date: 13/11/97	Calculated	Sample Board Initial Weight (g)
No.	Initial Weight (g)	Oven Dry Weight (g)	M.C.%	Date: 13/11/97
A1	51.3	44.4	15.5	1535.0
A2	75.3	63.9	17.8	2005.5
A3	95.3	82.0	16.2	1793.8
A4	92.5	79.8	15.9	2139.4
B1	54.7	46.3	18.1	1203.8
B2	133.8	115.2	16.1	3437.9
B3	60.5	52.1	16.1	1779.8
B4	34.7	30.1	15.3	1054.8
C1	113.3	95.9	18.1	3017.6
C2	84.6	73.8	14.6	1829.2
C3	26.1	22.6	15.5	729.4
C4	94.6	80.9	16.9	2570.3
D1	109.2	93.3	17.0	3045.7
D2	106.4	91.5	16.3	2932.6
D3	91.8	79.1	16.1	2724.1
D4	99.8	85.3	17.0	2539.3
E1	53.6	47.5	12.8	1336.2
E2	94.4	81.6	15.7	2026.1
E3	62.2	53.1	17.1	2259.3
E4	78.7	67.5	16.6	2067.8
F1	64.1	54.4	17.8	879.9
F2	107.8	90.5	19.1	2980.7
F3	55.7	46.9	18.8	1488.0
F4	47.9	41.3	16.0	1317.2
G1	87.4	73.4	19.1	2797.1
G2	101.0	87.3	15.7	2202.4
G3	41.4	35.7	16.0	1254.6
G4	76.0	65.0	16.9	2293.0
H1	93.7	80.3	16.7	2618.0
H2	159.6	136.1	17.3	3349.7
H3	103.6	89.4	15.9	2191.8
H4	101.6	86.9	16.9	2345.6

Average	16.6

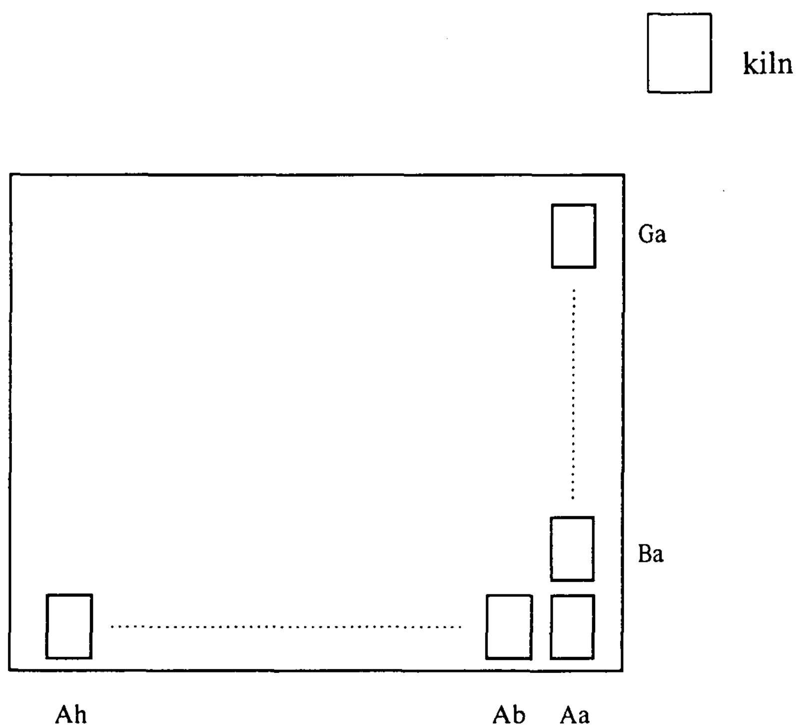
Appendix C. Industry Liaison Reports

C1. Preliminary Report - Boral

Preliminary investigation into air-flow characteristics through pre-drier at Boral board-mill at Killafaddy Conducted between the 31/10/96 and 7/11/96.

Dean Chatwin, Adam Redman and Mike Lee.

The pre-drier was orientated and numbered in the following way so that there would be no confusion as to where readings were taken from for future reference.



Front Doors

fig 1. plan view of drier

Looking at the pre-drier from a plan view the rows were numbered from (a) to (h), second letter ie. vertical, and the columns were numbered (A) to (G), first letter ie. horizontal. It should be noted that each stack contained three levels and for the purposes of this investigation all air velocity readings were taken at level two.

However as a guide initial readings were taken of the air velocity distribution across row (a) at all three levels as well as in the gluts separating levels 1 and 2, levels 2 and 3, and above level 3. These readings can be seen in table 4 as well as graphs 7 and 8. It should be noted that the fan motor speed was set at 645 rpm and each reading was taken roughly in the middle of the face of the relevant stack.

The pre-drier was designed to have a uniform airflow of 0.5 m/s throughout. As can be seen in table 4 this value is only just attained at level 2 with level 1 receiving on average only 84% of the design flow speed. Level 3 had very limited airflow and in fact the flow appeared to be so affected that some readings of negative air flow were recorded indicating the presence of reversed air flow. One good sign was that there was little air flow measured above level 3. This is a plus because any air flow in this area would be largely wasted, but the fact that the air flow was measured to be predominantly negative would expose a weakness in the design of the pre-drier which would need to be looked into. However in the region just above level 3 it is important to have adequate air speed so that the top of level 3 is efficiently dried.

Another important aspect to consider is the amount of air that is lost because it escapes through the gluts. As can be seen from table 4 and graphs 7 and 8 the air velocity through the gluts is significantly higher than that through the stacks themselves. In fact the volumetric flow rate through glut 2/3 is similar to the total volumetric flow rate through all of level 3. A similar situation exists with respect to glut 1/2 and levels 1 and 2 although it is not so severe. This is caused by there being a relatively large gap where the gluts are placed (approx. 100mm), compared with the gaps between the stickers (approx. 19mm), Hence the air would prefer to pass through the areas with least resistance and thus one measures larger air velocities through the glut regions.

It also became apparent during this portion of the investigation that as the air flowed from the fans it hit the wall which directed the air straight down it until it hit the floor which redirected it upwards again and set up an eddy next to row (a) see fig 2.

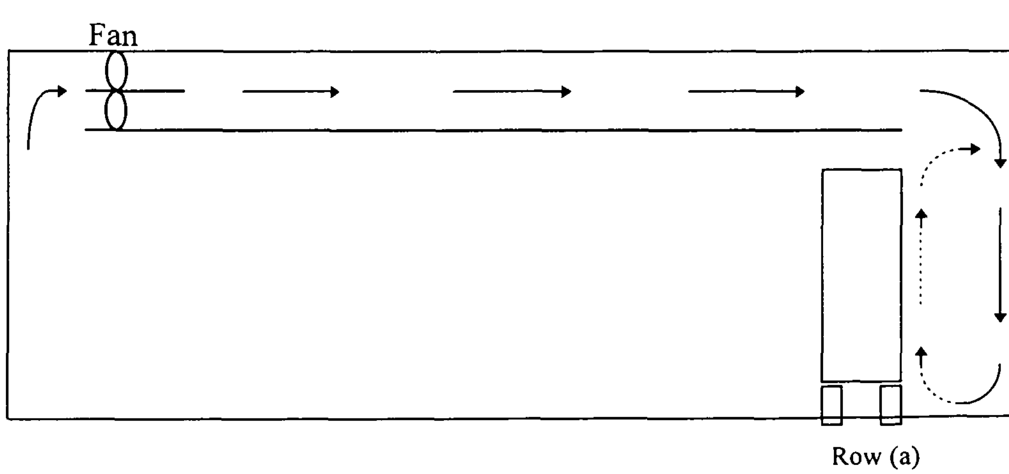


fig. 2 showing the possible air flow near row (a)

This situation could explain why negative air flow was measured near the top of the stack in row (a) above level 3.

Because the greatest average air flow, for a particular level, in row (a) was found to be on level 2 it was decided that the remainder of the investigation should involve air flow readings from level 2 exclusively as this would probably give an upper boundary on the air flow through a given row. Tables 2 and 3 show the results obtained from varying the fan speed and investigating the resulting changes, of air flow, through level 2 at rows a, d and h. These rows were chosen to give a good spread of readings through the pre-drier. While table 2 shows the raw data table 3 gives the data in an average form for each row at a given fan speed. In some instances the average air flow is more useable because it provides a clear picture of what the air flow is doing and trends can be easily seen. However what the average air flow graphs don't provide is an indication as to where air may be escaping around the stacks. For instance in graph 1 the air flow readings taken at position 1 are lower than that for position 2 for all fan speeds used. This is probably due to the absence of a baffle at this end between rows (a) and (b) so the air tends to escape around row (a) instead of going through the stack. This is also evident in rows (d) and (h) but not to the same extent.

From graph 2 at motor speeds 645 rpm and 877 rpm it can be seen that there is a decrease in air velocity as one moves from stack position 6 to 7. It should be noted that there is a baffle missing from this end between rows (d) and (e) which would probably account for this. However at higher motor speeds the air velocity actually increases at this end of the row. The reason why this occurred is uncertain but to obtain these air speeds in row (d) one requires unacceptably high air speeds through row (a) and hence this situation is rather academic. From graph 3 a similar situation can be seen to that in graph 2. Once again there is no baffle at the end of the row, row (h), and the air is escaping around the stack.

An interesting comparison can be made between graphs 4, 5 and 6. That is the air speed decreases from the face of row (a) to the face of row (d) and then increases at the face at row (h). The precise reason for this is uncertain at this stage but it is hoped that further investigation using a surveyors barometer, which allows the determination of pressure and hence pressure drops across the stacks, will give greater insight into the situation.

Recommendations

1) As can be seen from above it would appear that by replacing the missing baffles a gain could be made in the amount of air that flows through the stack. This would hopefully act to increase the air speed through the rows.

2) By placing boards across the gaps created by the gluts this would also cause the air to be redirected so that it goes through the stacks.

3) It would also be advantageous to attempt to correct the air flow at the entrance to row (a). This could possibly be helped by placing angled baffles at the corner of the pre-drier above row (a) which could redirect the air flow in a more desirable pattern. The optimal placing of any baffles would largely be trial and error and as such future readings would have to conducted to confirm any advantage.

Table 1 Raw Data of Air Velocity and Fan Speed

Position of Reading	Air Velocity (m/s)	Fan Speed (rpm)
Aa	0.47	645
Ba	0.60	645
Ca	0.55	645
Da	0.60	645
Ea	0.60	645
Fa	0.50	645
Ga	0.92	645
Ad	0.18	645
Bd	0.28	645
Cd	0.14	645
Dd	0.18	645
Ed	0.10	645
Fd	0.10	645
Gd	0.00	645
Ah	0.34	645
Bh	0.43	645
Ch	0.34	645
Dh	0.40	645
Eh	0.40	645
Fh	0.18	645
Gh	0.25	645
Aa	0.60	877
Ba	0.76	877
Ca	0.64	877
Da	0.72	877
Ea	0.66	877
Fa	0.72	877
Ga	0.62	877
Ad	0.30	877
Bd	0.34	877
Cd	0.34	877
Dd	0.30	877
Ed	0.34	877
Fd	0.34	877
Gd	0.30	877
Ah	0.42	877
Bh	0.54	877
Ch	0.52	877
Dh	0.48	877
Eh	0.40	877
Fh	0.40	877
Gh	0.22	877
Aa	0.78	1080
Ba	0.88	1080
Ca	0.90	1080
Da	0.86	1080
Ea	0.84	1080
Fa	0.76	1080

Ga	0.86	1080	
Ad	0.40	1080	
Bd	0.38	1080	
Cd	0.54	1080	
Dd	0.56	1080	
Ed	0.32	1080	
Fd	0.42	1080	
Gd	0.44	1080	
Ah	0.56	1080	
Bh	0.60	1080	
Ch	0.50	1080	
Dh	0.52	1080	
Eh	0.48	1080	
Fh	0.40	1080	
Gh	0.42	1080	
Aa	0.92	1280	
Ba	1.02	1280	
Ca	1.10	1280	
Da	1.18	1280	
Ea	1.00	1280	
Fa	1.28	1280	
Ga	1.10	1280	
Ad	0.48	1280	
Bd	0.56	1280	
Cd	0.40	1280	
Dd	0.42	1280	
Ed	0.40	1280	
Fd	0.48	1280	
Gd	0.50	1280	
Ah	0.62	1280	
Bh	0.84	1280	
Ch	0.80	1280	
Dh	0.64	1280	
Eh	0.64	1280	
Fh	0.76	1280	
Gh	0.38	1280	
Aa	0.88	1423	
Ba	1.20	1423	
Ca	1.34	1423	
Da	1.00	1423	
Ea	1.08	1423	
Fa	1.02	1423	
Ga	1.08	1423	
Ad	0.50	1423	
Bd	0.50	1423	
Cd	0.60	1423	
Dd	0.58	1423	
Ed	0.44	1423	
Fd	0.54	1423	

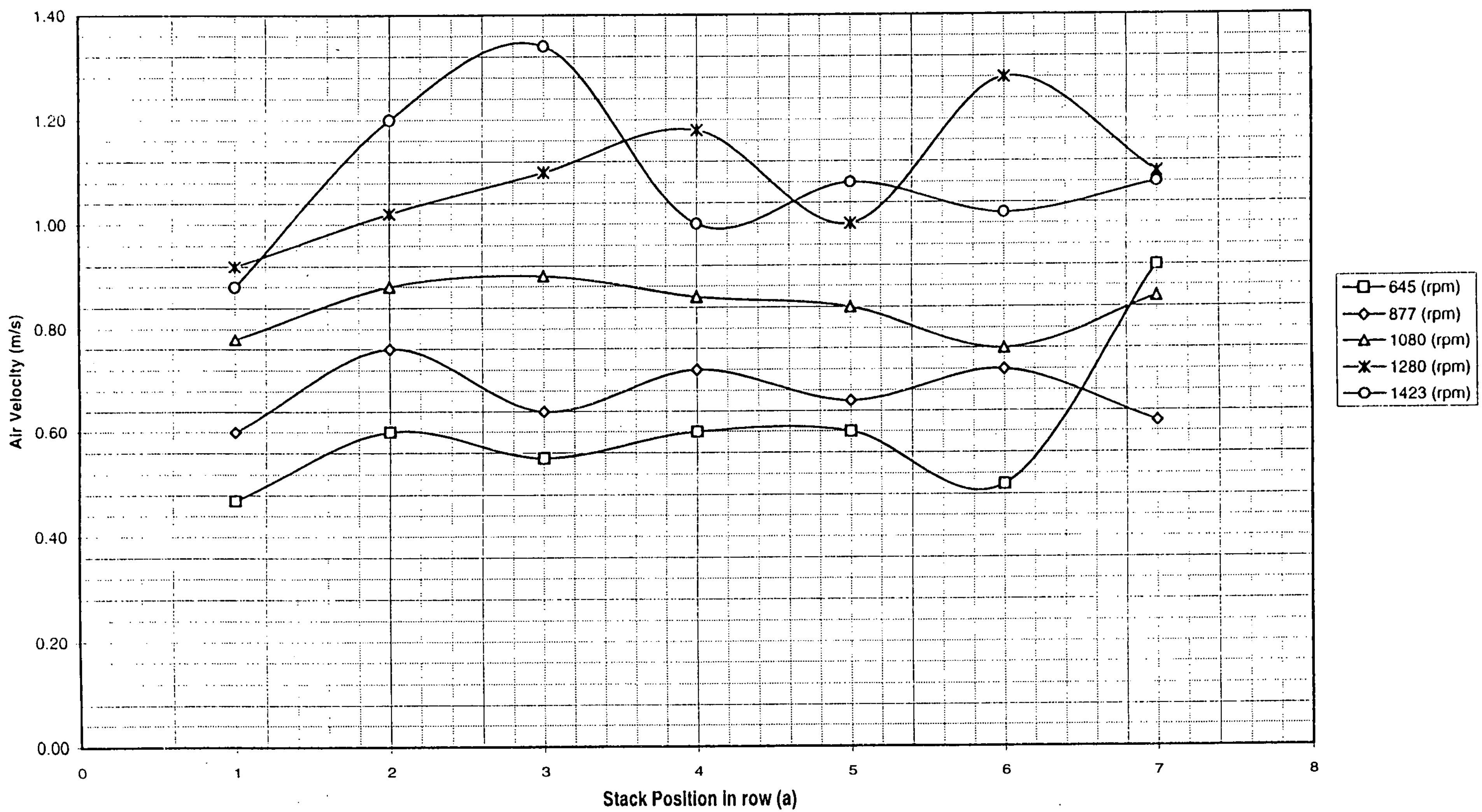
Gd	0.58	1423	
Ah	0.56	1423	
Bh	0.60	1423	
Ch	0.50	1423	
Dh	0.52	1423	
Eh	0.48	1423	
Fh	0.40	1423	
Gh	0.43	1423	

Table 2 Variation of Air Velocity (m/s) with Fan Speed					
	Fan Speed				
Stack Position	645 (rpm)	877 (rpm)	1080 (rpm)	1280 (rpm)	1423 (rpm)
1	0.47	0.60	0.78	0.92	0.88
2	0.60	0.76	0.88	1.02	1.20
3	0.55	0.64	0.90	1.10	1.34
4	0.60	0.72	0.86	1.18	1.00
5	0.60	0.66	0.84	1.00	1.08
6	0.50	0.72	0.76	1.28	1.02
7	0.92	0.62	0.86	1.10	1.08
ck Position Ro	645 (rpm)	877 (rpm)	1080 (rpm)	1280 (rpm)	1423 (rpm)
1	0.18	0.30	0.40	0.48	0.50
2	0.28	0.34	0.38	0.56	0.50
3	0.14	0.34	0.54	0.40	0.60
4	0.18	0.30	0.56	0.42	0.58
5	0.10	0.34	0.32	0.40	0.44
6	0.10	0.34	0.42	0.48	0.54
7	0.00	0.30	0.44	0.50	0.58
ck Position Ro	645 (rpm)	877 (rpm)	1080 (rpm)	1280 (rpm)	1423 (rpm)
1	0.34	0.42	0.56	0.62	0.64
2	0.43	0.54	0.60	0.84	0.66
3	0.34	0.52	0.50	0.80	0.96
4	0.40	0.48	0.52	0.64	0.68
5	0.40	0.40	0.48	0.64	0.70
6	0.18	0.40	0.40	0.76	0.52
7	0.25	0.22	0.42	0.38	0.48

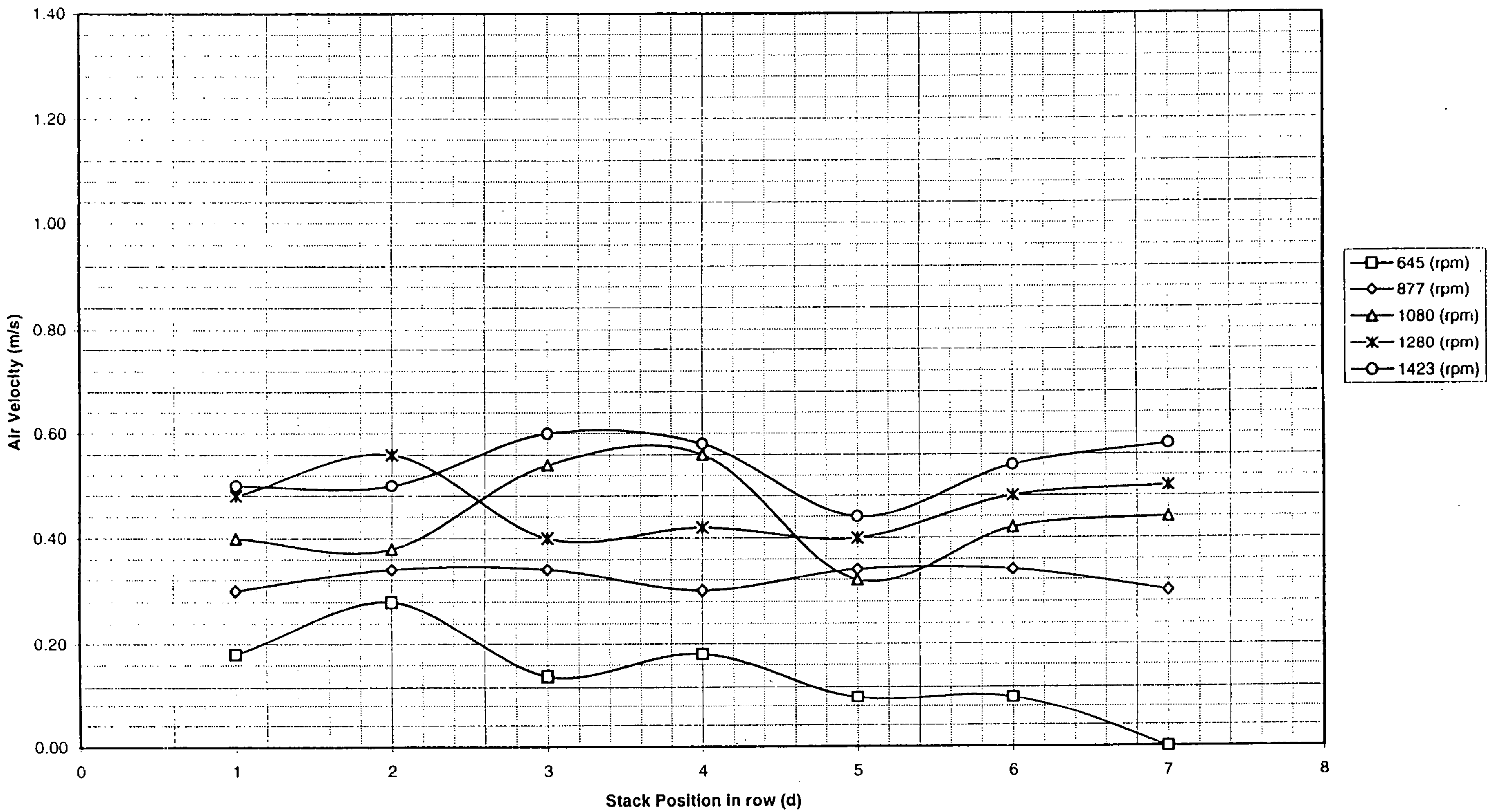
Table 3 Variation of Average Air Speed with Fan Speed					
	Fan Speed				
	645 (rpm)	877 (rpm)	1080 (rpm)	1280 (rpm)	1423 (rpm)
1	0.61	0.67	0.84	1.09	1.09
2	0.61	0.67	0.84	1.09	1.09
3	0.61	0.67	0.84	1.09	1.09
4	0.61	0.67	0.84	1.09	1.09
5	0.61	0.67	0.84	1.09	1.09
6	0.61	0.67	0.84	1.09	1.09
7	0.61	0.67	0.84	1.09	1.09
	645 (rpm)	877 (rpm)	1080 (rpm)	1280 (rpm)	1423 (rpm)
1	0.14	0.32	0.44	0.46	0.53
2	0.14	0.32	0.44	0.46	0.53
3	0.14	0.32	0.44	0.46	0.53
4	0.14	0.32	0.44	0.46	0.53
5	0.14	0.32	0.44	0.46	0.53
6	0.14	0.32	0.44	0.46	0.53
7	0.14	0.32	0.44	0.46	0.53
	645 (rpm)	877 (rpm)	1080 (rpm)	1280 (rpm)	1423 (rpm)
1	0.33	0.43	0.50	0.67	0.66
2	0.33	0.43	0.50	0.67	0.66
3	0.33	0.43	0.50	0.67	0.66
4	0.33	0.43	0.50	0.67	0.66
5	0.33	0.43	0.50	0.67	0.66
6	0.33	0.43	0.50	0.67	0.66
7	0.33	0.43	0.50	0.67	0.66

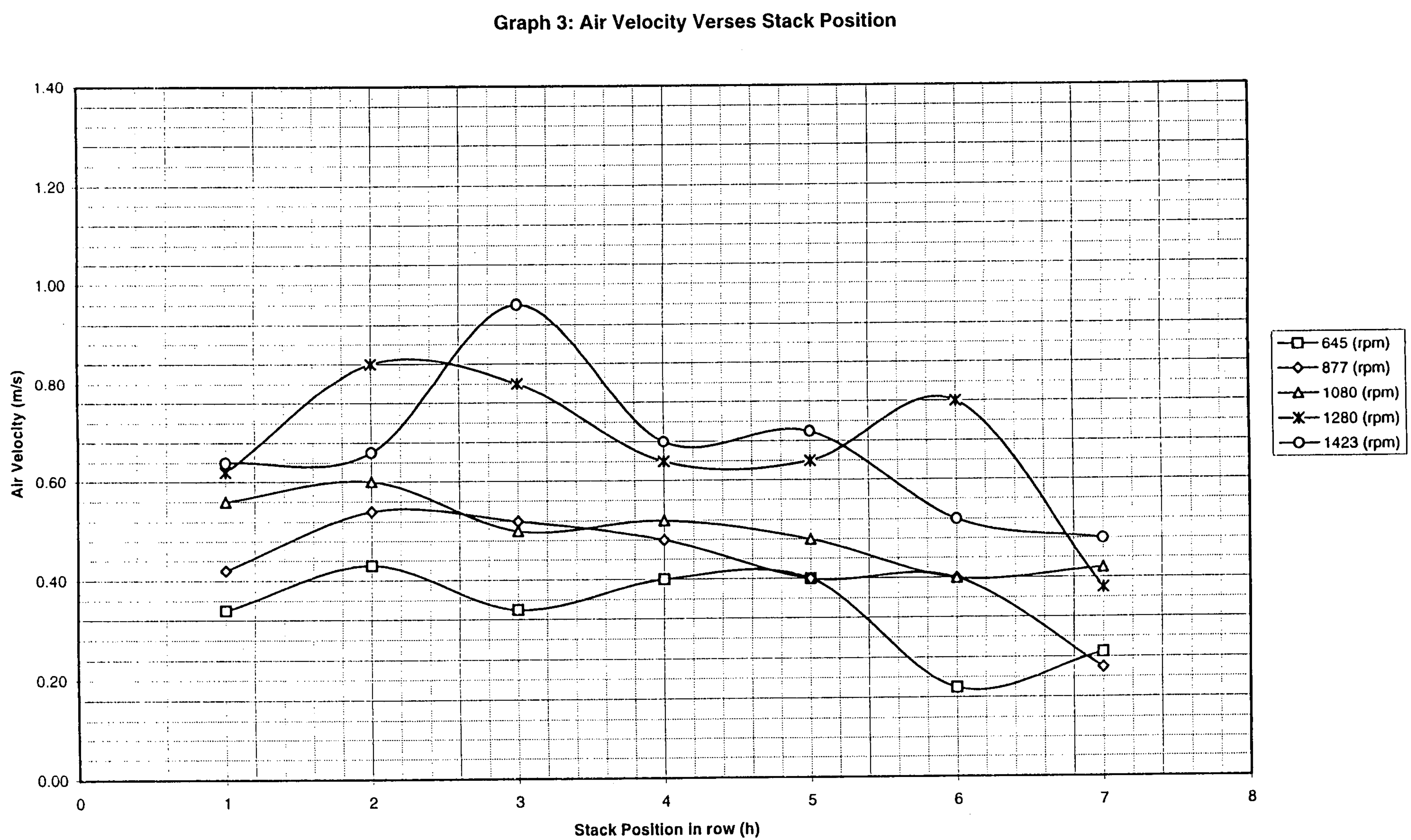
Table 4 Variation of Air Velocity Across Row 1						
	Level 1	Glut 1/2	Level 2	Glut 2/3	Level 3	Above Level 3
Aa	0.37	1.20	0.47	1.63	0.21	-0.02
Ba	0.43	0.70	0.60	0.74	-0.14	0.04
Ca	0.38	0.65	0.55	0.81	-0.08	0.00
Da	0.41	0.69	0.60	0.70	0.18	-0.10
Ea	0.54	0.68	0.60	1.30	0.06	0.00
Fa	0.54	1.08	0.50	1.48	0.22	0.10
Ga	0.30	0.75	0.46	0.92	0.00	-0.30
	Level 1	Glut 1/2	Level 2	Glut 2/3	Level 3	Above Level 3
Aa	0.42	0.82	0.54	1.08	0.06	-0.04
Ba	0.42	0.82	0.54	1.08	0.06	-0.04
Ca	0.42	0.82	0.54	1.08	0.06	-0.04
Da	0.42	0.82	0.54	1.08	0.06	-0.04
Ea	0.42	0.82	0.54	1.08	0.06	-0.04
Fa	0.42	0.82	0.54	1.08	0.06	-0.04
Ga	0.42	0.82	0.54	1.08	0.06	-0.04

Graph 1: Air Velocity Verses Stack Position

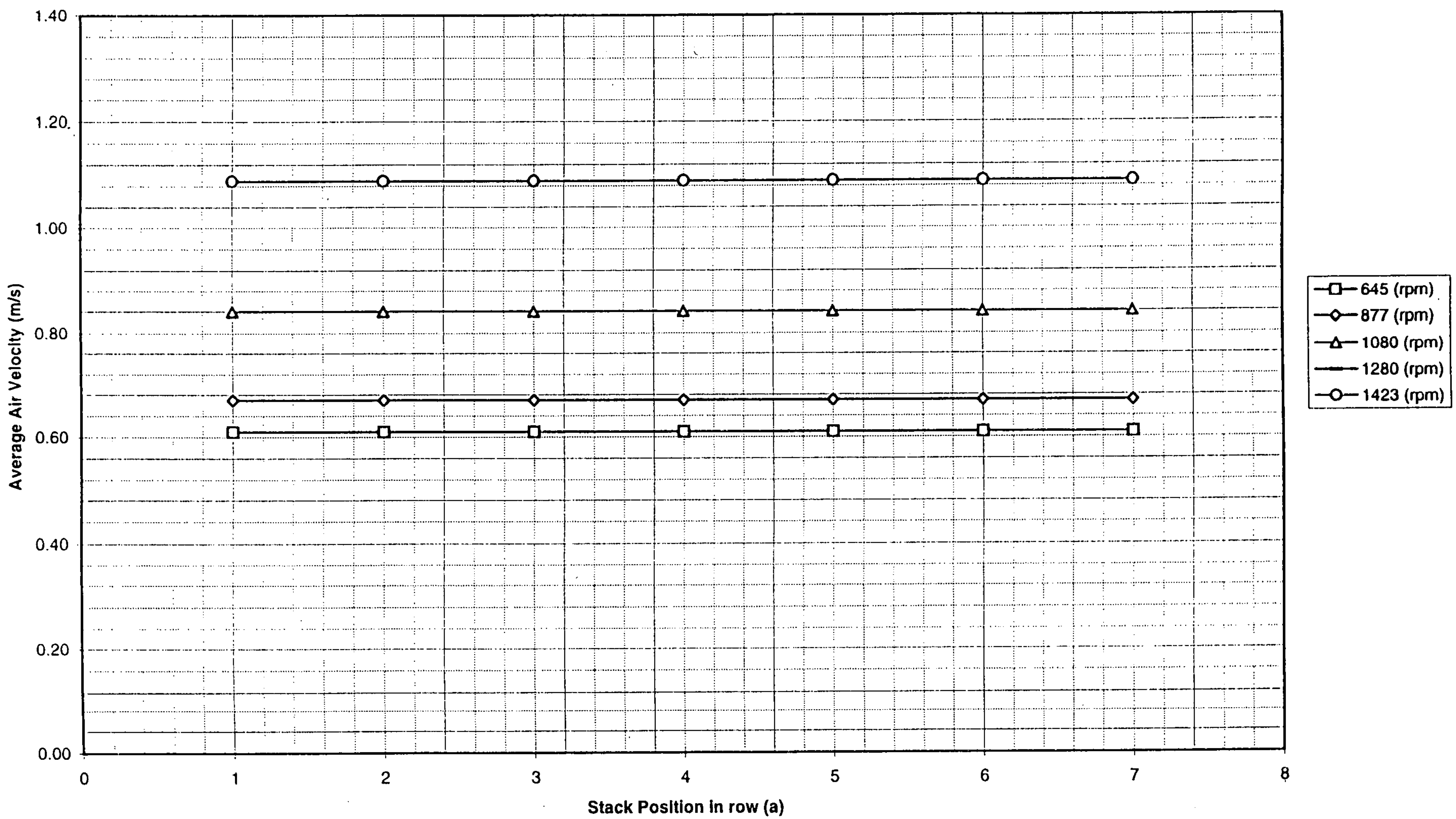


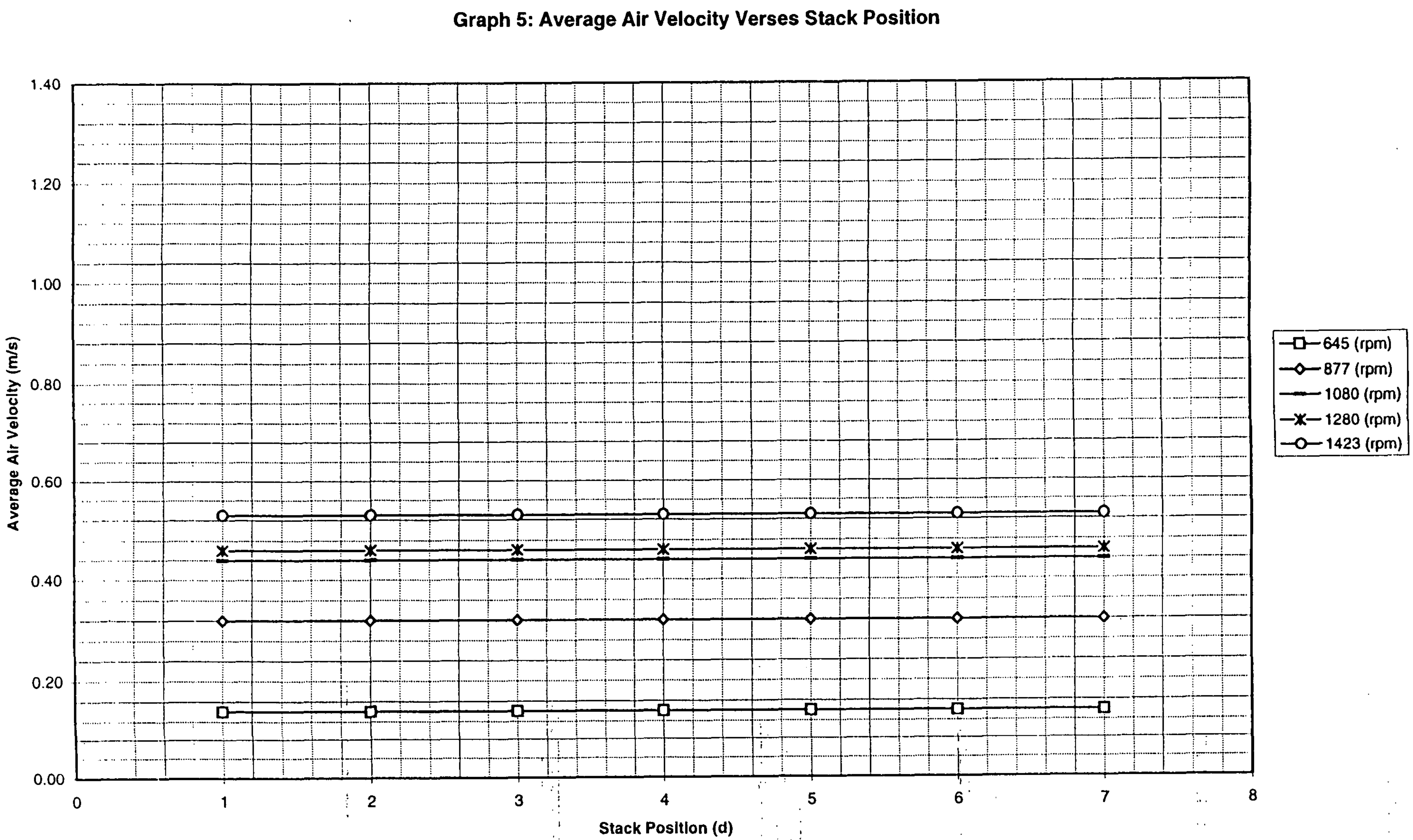
Graph 2: Air Velocity Verses Stack Position




Graph 3: Air Velocity Verses Stack Position
Air Velocity (m/s)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1
2
3
4
5
6
7
8
Stack Position in row (h)
645 (rpm)
877 (rpm)
1080 (rpm)
1280 (rpm)
1423 (rpm)

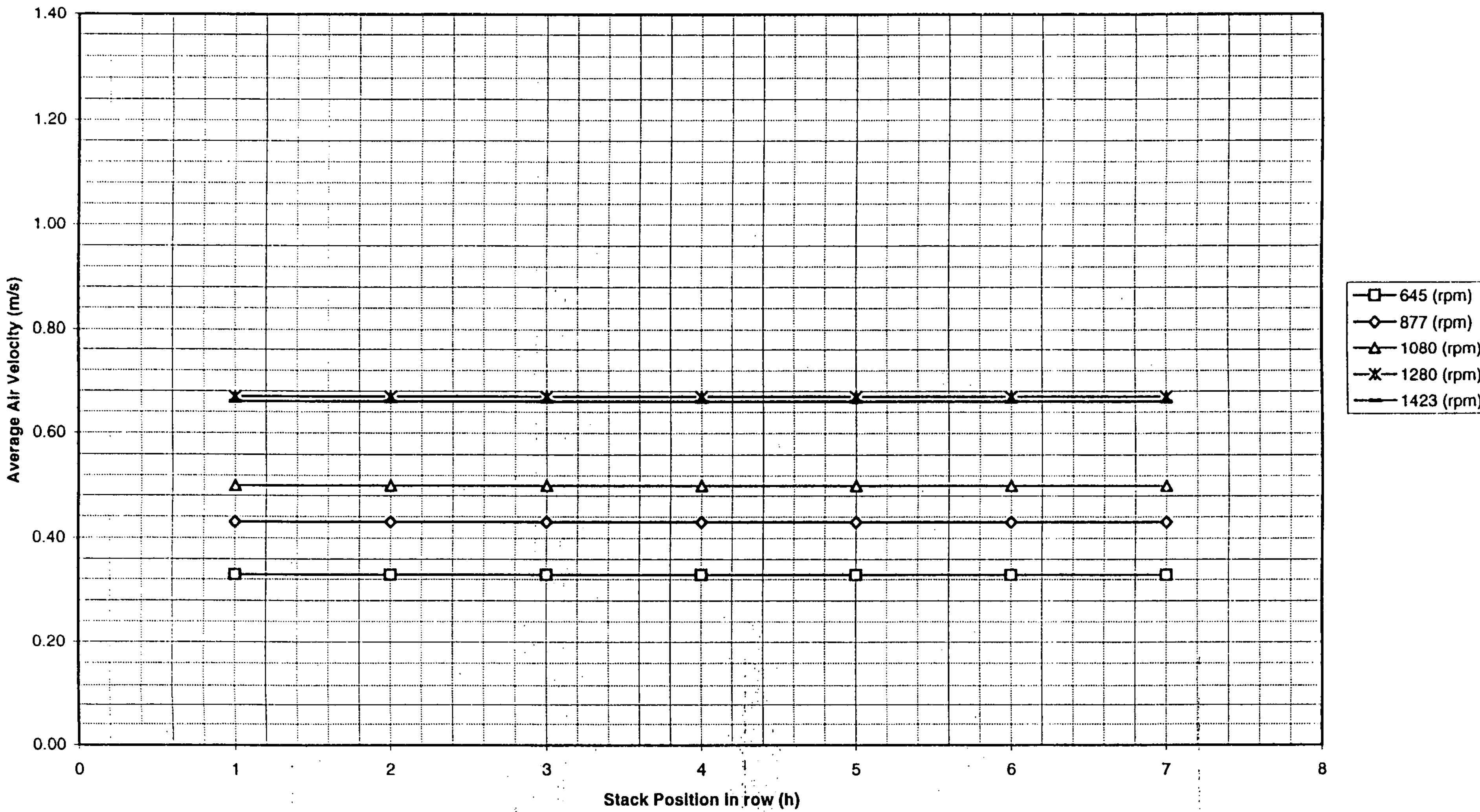
Graph 4: Average Air Velocity Verses Stack Position

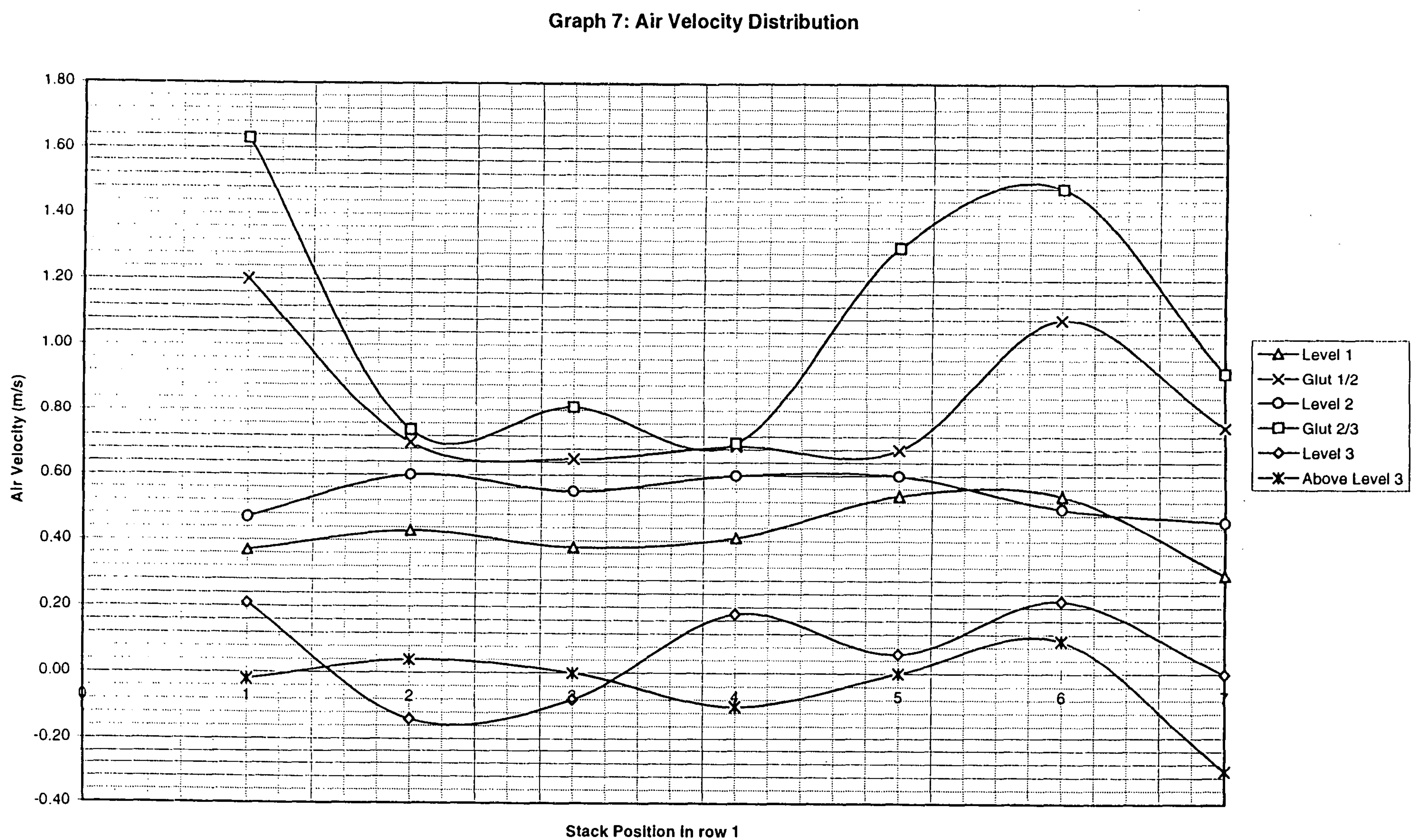



Graph 5: Average Air Velocity Verses Stack Position
Average Air Velocity (m/s)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1
2
3
4
5
6
7
8
Stack Position (d)
645 (rpm)
877 (rpm)
1080 (rpm)
1280 (rpm)
1423 (rpm)

C13

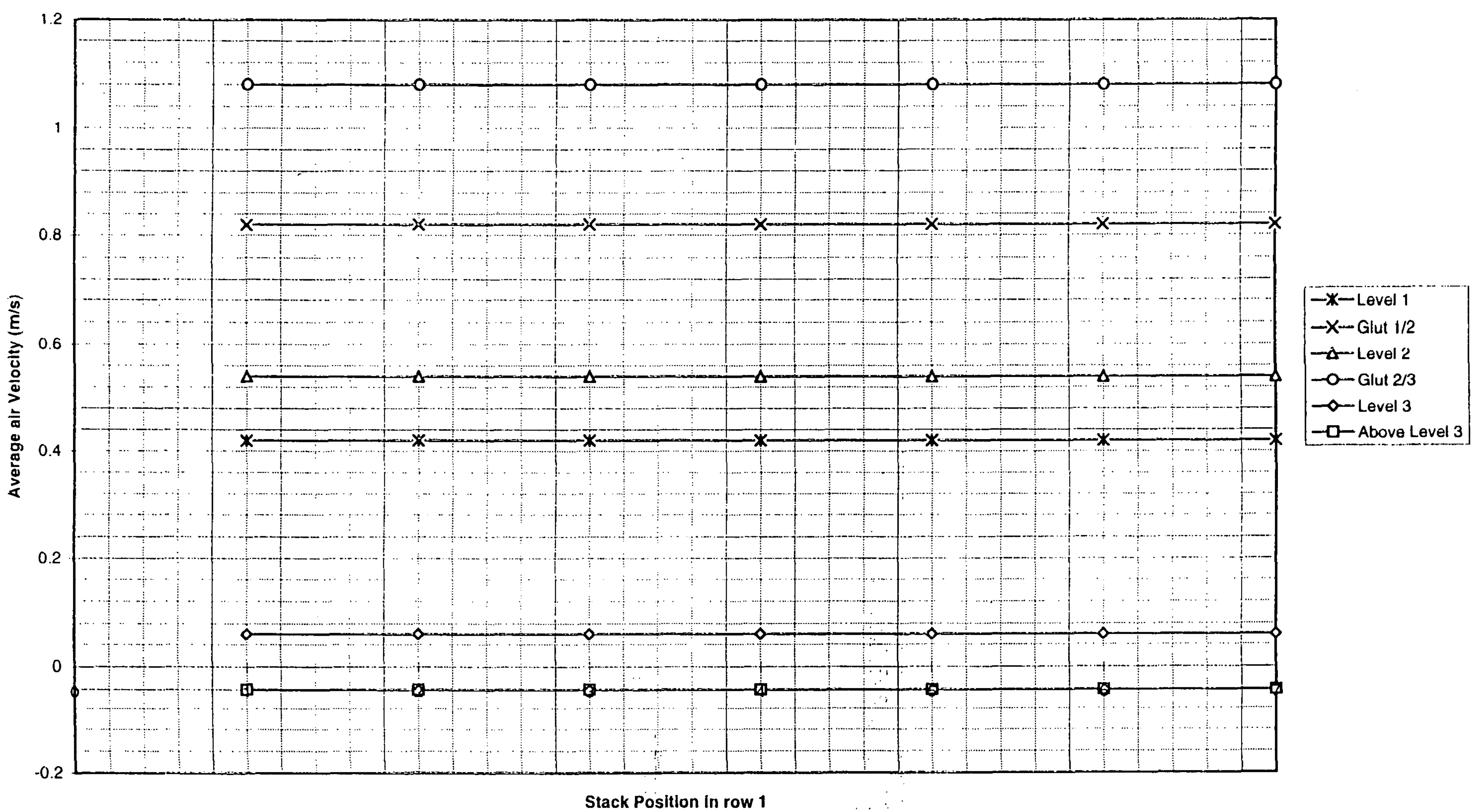
Graph 6: Average Air Velocity Verses Stack Position




Graph 7: Air Velocity Distribution
Air Velocity (m/s)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
0
1
2
3
4
5
6
7
Stack Position in row 1
Level 1
Glut 1/2
Level 2
Glut 2/3
Level 3
Above Level 3

C15

Graph 8: Average Air Velocity Verses Stack Position



C2. Preliminary Report - Clennetts

Preliminary investigation into air-flow characteristics through Clennetts Timber kiln at Glenorchy Hobart conducted on the 27/11/96.

Mike Lee, Adam Redman, Dean Chatwin.

An investigation was carried out on the Clennetts kiln in Moonah on the 27/11/96 to determine the air flow characteristics and make suggestions for improvements.

The kiln has a design air speed flow of 2 m/s which is supplied by eight fans located above the false roof that run between the two rows. Although this value is being reached or exceed at some locations there are vast areas that are only receiving a much lower air speed and hence the drying performance of the kiln is possibly being compromised.

Reference should be made to figures 1 and 2 so the orientation of the kiln and the identification system used for the stacks is understood allowing air speed readings to be related to the correct position.

One of the immediate deductions that can be made from the results is that the magnitude of the air speed going through the second row shows a substantial reduction on level 1 and an increase on level 3 while the air speed through level 2 was comparatively unaffected. The reduction in the average air speed through level 1 resulted in a decrease from 1.4 m/s to 0.4 m/s (see graphs 5 and 6). When the air flow direction was reversed a similar result was seen with the air speed decreasing from 1.7 m/s to 0.7 m/s (see graphs 7 and 8). The ratio in the reduction of the level 1 air flow was 2.50 (normal air direction) and 2.43 (reversed air direction) thus indicating the drop in air speed on this level is a function of the kiln set-up itself and not the direction of air flow.

The reverse of the situation on level 1 is seen on level 3 with the average air speed increasing from 1.1 m/s to 2.0 m/s (see graphs 5 and 6) for normal flow direction. Reversed air flow saw a similar situation with the air speed increasing from 0.9 m/s to 1.8 m/s (see graphs 7 and 8). The ratio of the increase in air speed through level 3 was 1.82 (normal air flow) and 2.00 (reversed air speed) hence also indicating that the changing of the direction of the air flow is not affecting the performance of the kiln.

Level 2 air speed seemed to be relatively unaffected while flowing through the two rows. For normal air direction the decrease is from 1.1 m/s to 0.7 m/s (see graphs 5 and 6) while for reversed direction 1.0 m/s to 0.8 m/s (see 7 and 8).

Recommendations

It could well be to your advantage to consider replacing the existing corrugated tin baffles, at positions end 1 of stack A, end 2 of stack F and end 1 of stack D with, for example, a canvas curtain like the one at end 2 of stack C. This should allow more controlled directing of the air flow as well as easier access for personal. These baffles could be made retractable so they are not damaged when loading or unloading the kiln. Also if baffles were to be placed between stacks D and E, and, E and F, on the outside face, as well as possibly between the ends of the rows the air flow could be better directed which in turn could lead to improved efficiency in drying.

As can be seen from the graphs a significant amount of air is lost because it flows through the area above the stacks and below the false roof. This could largely be eliminated by either placing a hinged baffle or curtain device that can be retracted when loading the kiln. This would result in much of this air going through the stacks and improving the drying efficiency. Also to enhance air flow the old heating coils near rack C should be removed.

It could be advantageous to select the kiln charges so they are not mixed charges ie. timber from different source regions. It is known that green timber from different regions can have vastly different drying regimes. As a result of this timber from a particular area might dry acceptably well under a given set of kiln conditions, but the timber from a different source might not dry at all well. Thus the question is really one of economics. That is whether the loss of monies from not filling the kiln to capacity is less than that which would be lost by the degrade of wood that would result from filling the kiln to capacity plus the extra fuel cost that would have been used to dry a full charge. It could even be the case that timber may be put aside until there is enough to make up a full kiln load.

Care needs to be exercised when using stickers that they are all the same size. This will ensure that the air speed distribution through the stacks is as uniform as possible. Also the use of stickers of different sizes can result in the boards warping as they dry which adds to a reduction in recovery.

It would also appear that some form of investigation needs to be done into the fuel consumption as a function of temperature of the kiln. As it may be the case that a small increase in the temperature (say 5 to 10 deg. C) may result in a much larger relative increase in fuel consumption. Thus the time saved, and money gained, in drying the kiln charge by increasing the temperature may be less than that spent on the additional fuel hence the result is a net loss.

When the air flow has been made more acceptable we would investigate the temperature and humidity distribution throughout the kiln and thus with this all the controllable parameters of the kiln will be covered.

Conclusion

It is imperative that the minor work on the baffles is carried out as soon as possible as without this being done no further investigation can be carried out.

It is imperative that the same sized stickers are used as this will increase efficiency. Also to increase efficiency the baffles need to be in place and the glut spaces need to be covered as well as the racks being level ended. This work practice will result in efficiency due to good loading.

It cannot be stressed enough that it is crucial not to mix the racks from Dover and Bridgewater. Because of the known differentials in the drying characteristics, ie. density and initial M.C., the kiln conditions while being adequate for one "type" of timber is more than likely detrimental to other types.

Figures 1 and 2 showing stack orientation and normal air flow direction. Reversed air flow is in the opposite direction to normal air flow.

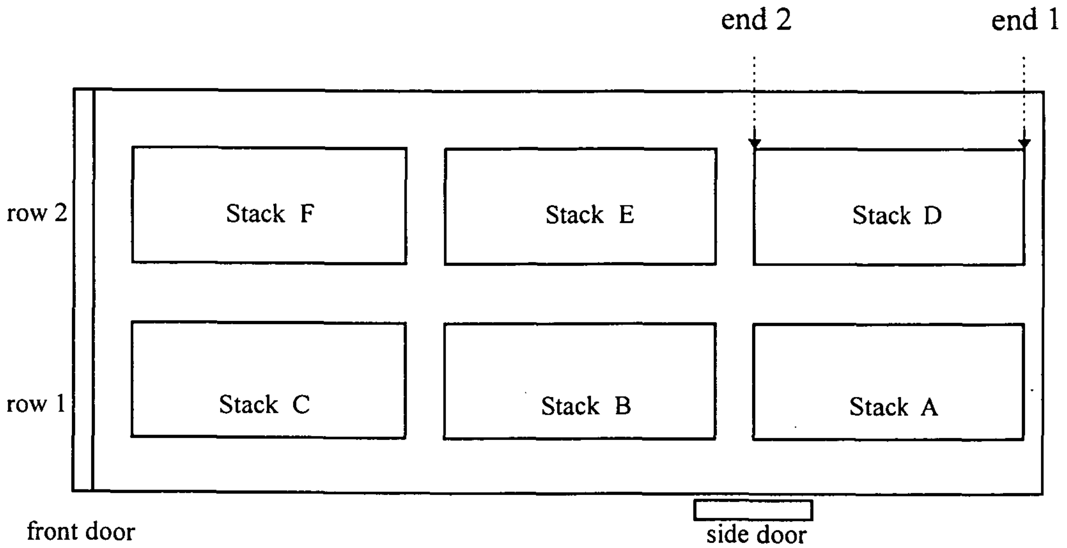


fig. 1 Plan view of kiln

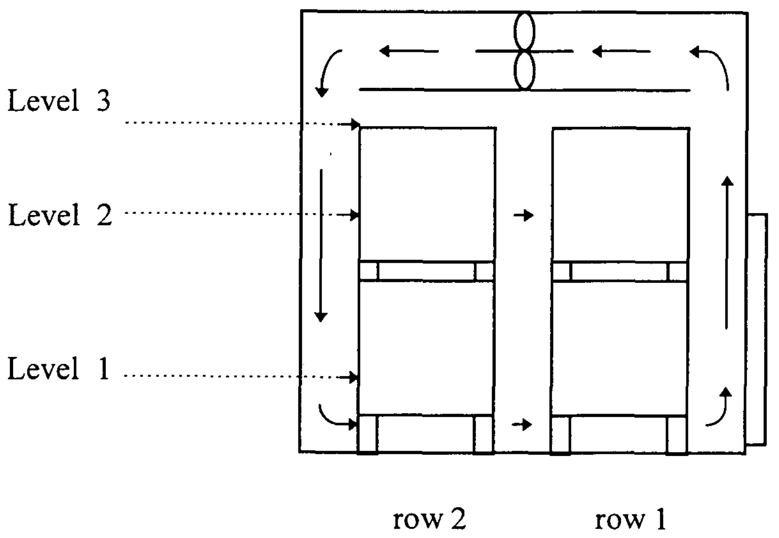


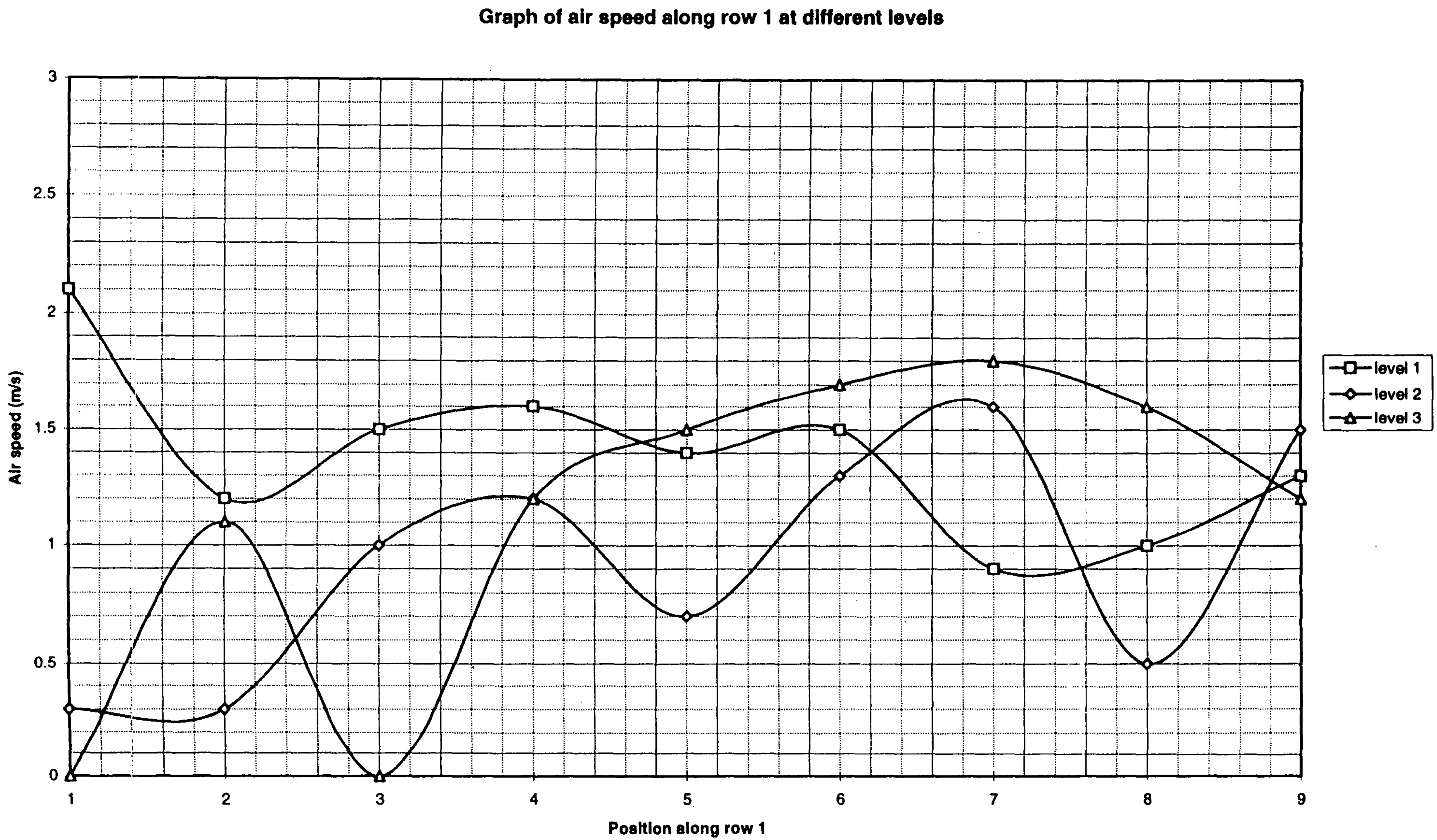
Figure 2. Front elevation showing normal air flow

Table 1 and 2: Air speeds (m/s) for normal air flow direction.							
Date of readings: 27/11/96							
Position		**A**	**B**	**C**	**D**	**E**	**F**
	End 1	2.1	1.6	0.9	0.4	0.4	0.2
Level 1	**Middle**	1.2	1.4	1.0	0.6	0.5	0.5
	End 2	1.5	1.5	1.3	0.4	0.5	0.2
	End 1	0.3	1.2	1.6	0.7	0.4	0.7
Level 2	**Middle**	0.3	0.7	0.5	0.6	0.8	1.0
	End 2	1.0	1.3	1.5	0.6	1.0	0.1
	End1	0.0	1.2	1.8	1.5	2.0	2.4
Level 3	**Middle**	1.1	1.5	1.6	2.0	2.6	1.9
	End 2	0.0	1.7	1.2	1.7	2.1	1.6
Row 1				**Row 2**			
Position	**level 1**	**level 2**	**level 3**	**Position**	**level 1**	**level 2**	**level 3**
End 1	2.1	0.3	0.0	**End 1**	0.4	0.7	1.5
A Middle	1.2	0.3	1.1	**D Middle**	0.6	0.6	2.0
End 2	1.5	1.0	0.0	**End 2**	0.4	0.6	1.7
End 1	1.6	1.2	1.2	**End 1**	0.4	0.4	0.7
B Middle	1.4	0.7	1.5	**E Middle**	0.5	0.8	1.0
End 2	1.5	1.3	1.7	**End 2**	0.5	1.0	0.1
End1	0.9	1.6	1.8	**End1**	1.5	2.0	2.4
C Middle	1.0	0.5	1.6	**F Middle**	2.0	2.6	1.9
End 2	1.3	1.5	1.2	**End 2**	1.7	2.1	1.6

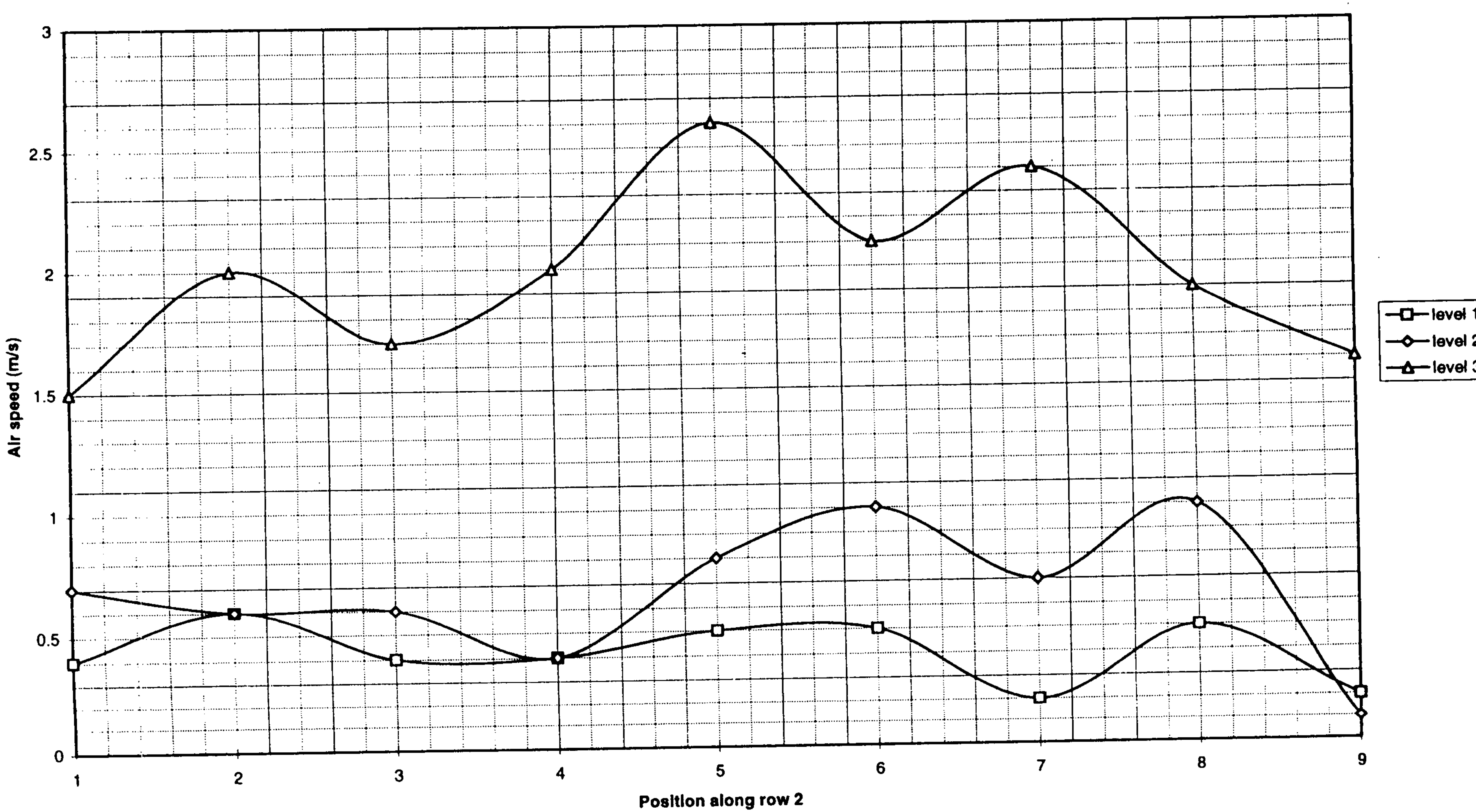
Table 3 and 4 Clennetts kiln 27/11/96

Table 3 and 4: Air speeds (m/s) for reversed air flow direction							
Date of readings: 27/11/96							
Position		**A**	**B**	**C**	**D**	**E**	**F**
	End 1	0.6	0.5	0.7	1.5	1.9	1.5
Level 1	**Middle**	0.8	0.6	0.8	1.6	1.6	2.3
	End 2	1.3	0.5	0.7	2.0	1.7	1.6
	End 1	0.4	0.5	0.6	1.2	1.4	1.1
Level 2	**Middle**	1.1	1.0	0.7	0.7	0.8	1.2
	End 2	1.1	0.8	0.7	1.4	1.4	0.2
	End1	1.5	2.2	1.7	2.0	0.8	0.9
Level 3	**Middle**	2.6	2.4	2.1	1.5	1.6	0.4
	End 2	1.6	1.1	1.1	0.6	0.1	0.0
Row 1				**Row 2**			
Position	**level 1**	**level 2**	**level 3**	**Position**	**level 1**	**level 2**	**level 3**
End 1	0.6	0.4	1.5	**End 1**	1.5	1.2	2.0
A Middle	0.8	1.1	2.6	**D Middle**	1.6	0.7	1.5
End 2	1.3	1.1	1.6	**End 2**	2.0	1.4	0.6
End 1	0.5	0.5	2.2	**End 1**	1.9	1.4	0.8
B Middle	0.6	1.0	2.4	**E Middle**	1.6	0.8	1.6
End 2	0.5	0.8	1.1	**End 2**	1.7	1.4	0.1
End1	0.7	0.6	1.7	**End1**	1.5	1.1	0.9
C Middle	0.8	0.7	2.1	**F Middle**	2.3	1.2	0.4
End 2	0.7	0.7	1.1	**End 2**	1.6	0.2	0.0

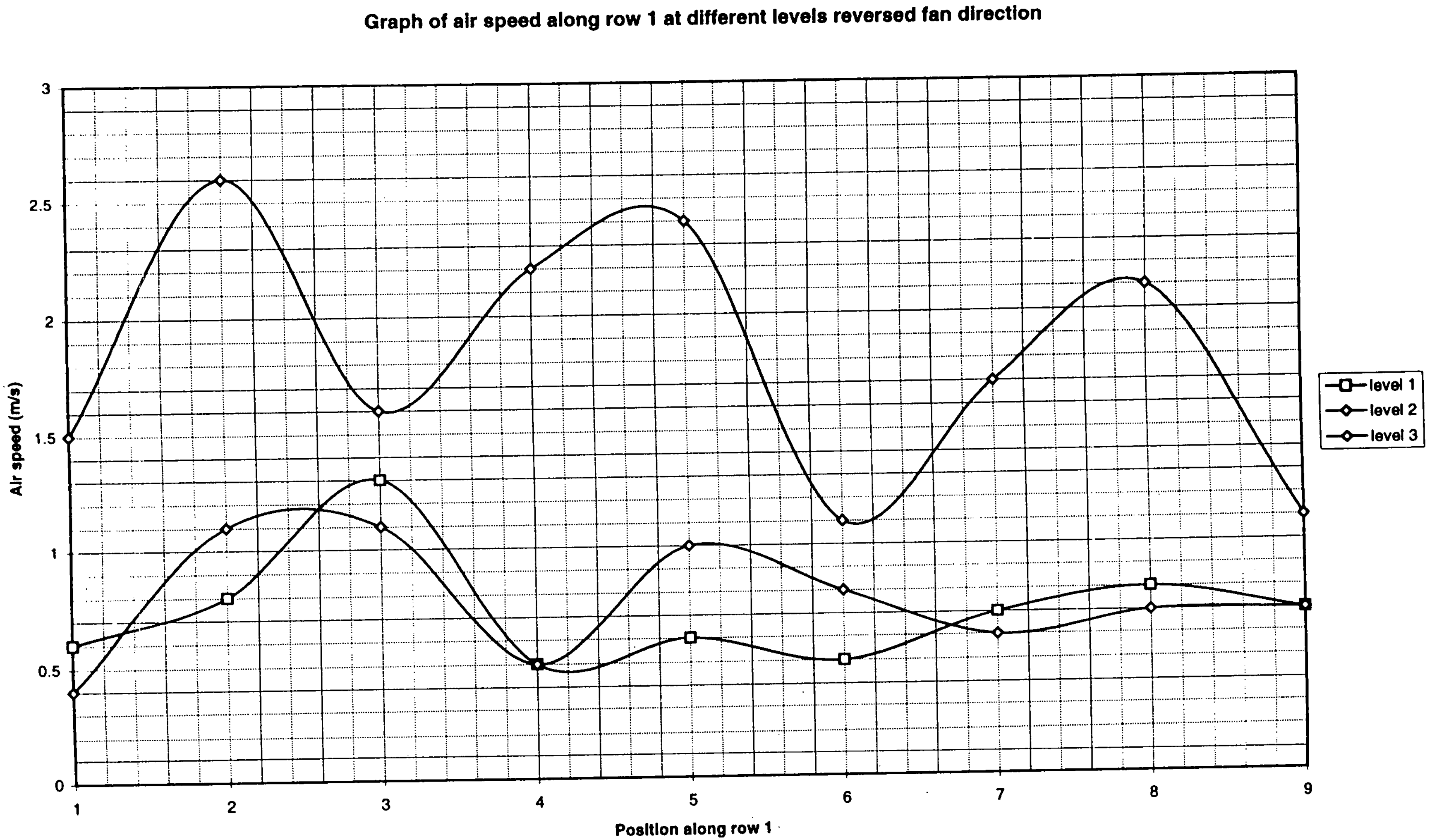
Graph 1 Clennetts kiln 27/11/96



Graph of air speed distribution along row 2 at different levels

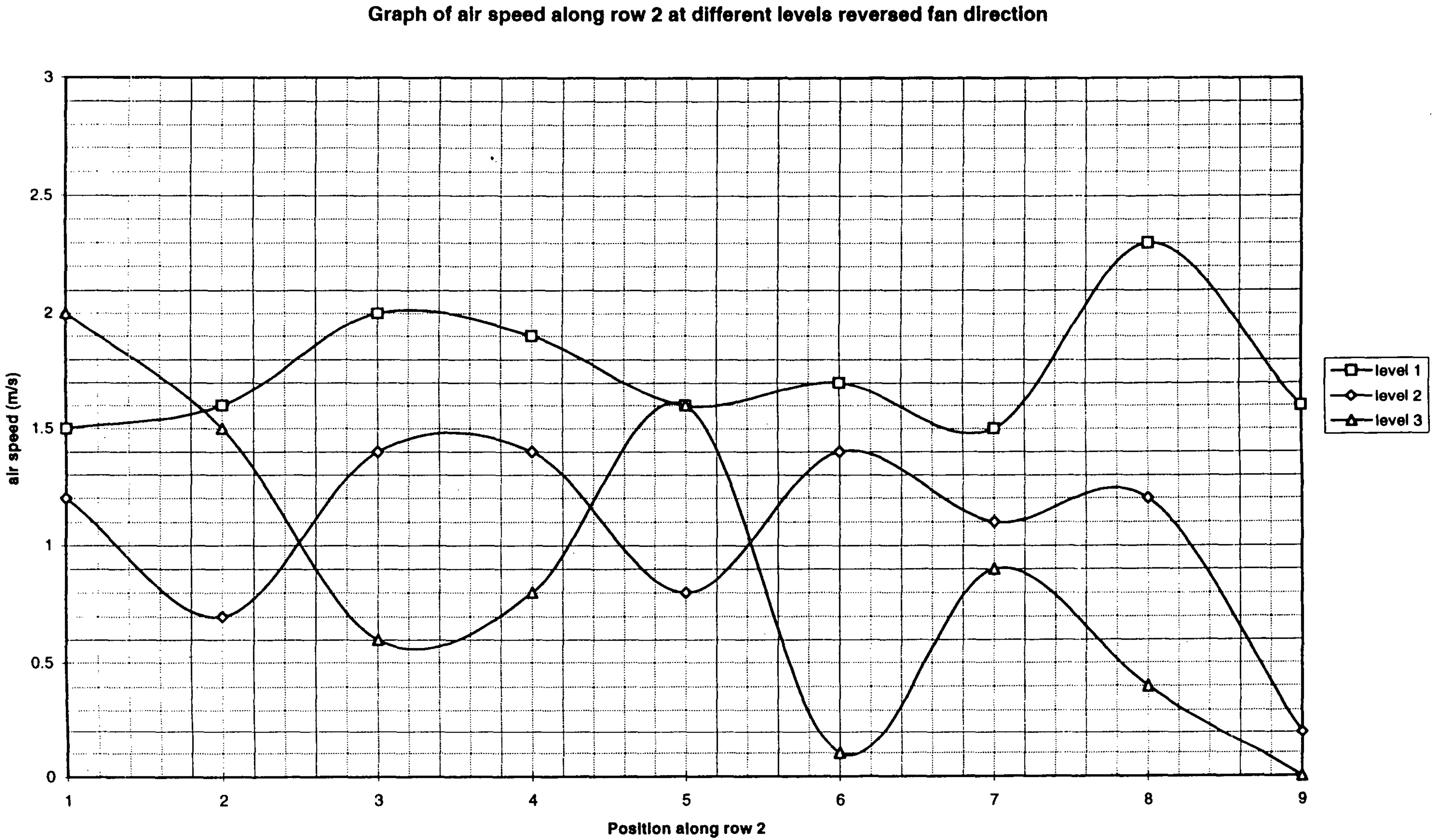


Graph 3 Clennetts kiln 27/11/96



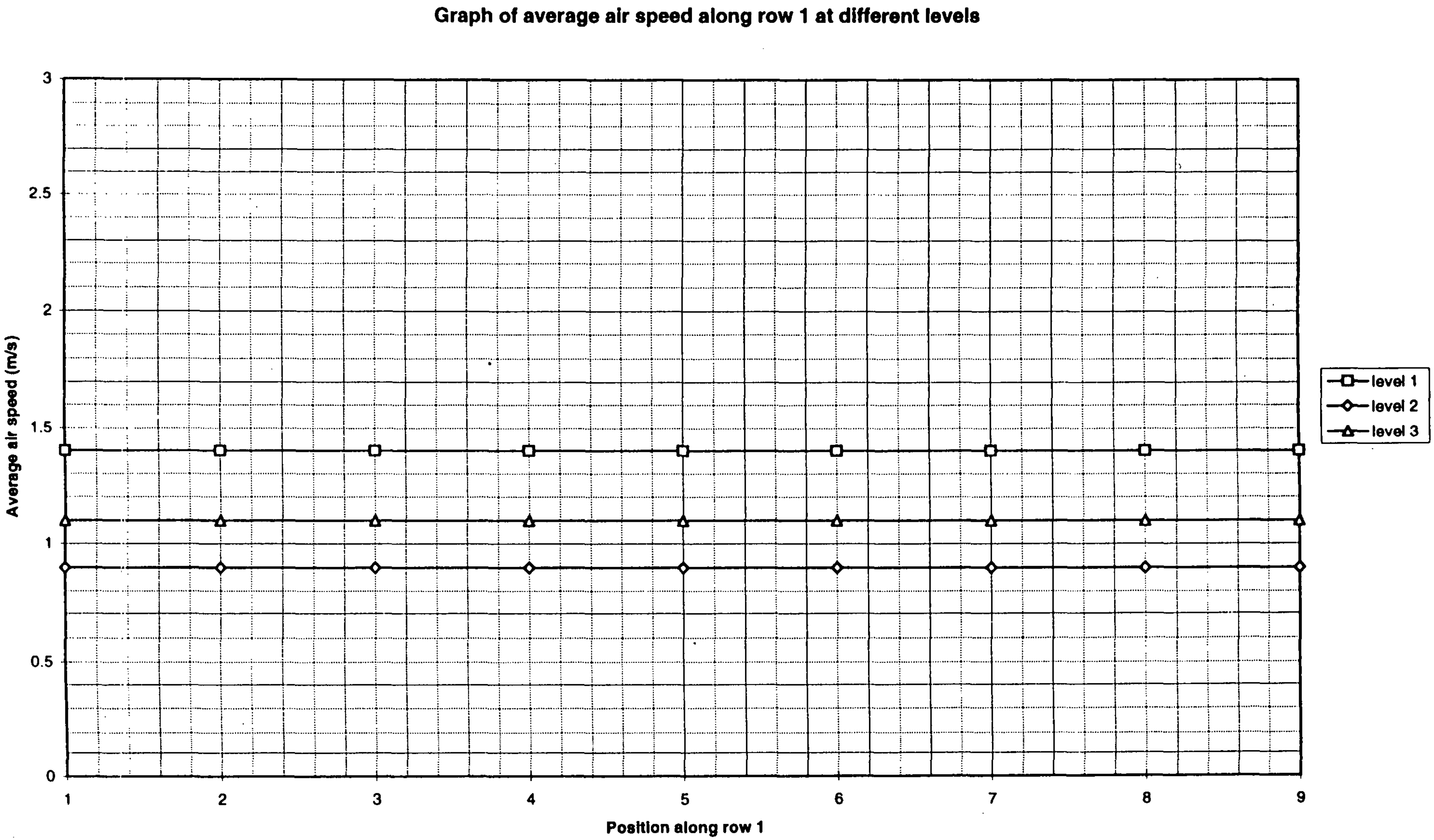
C25

Graph 4 Clennetts kiln 27/11/96

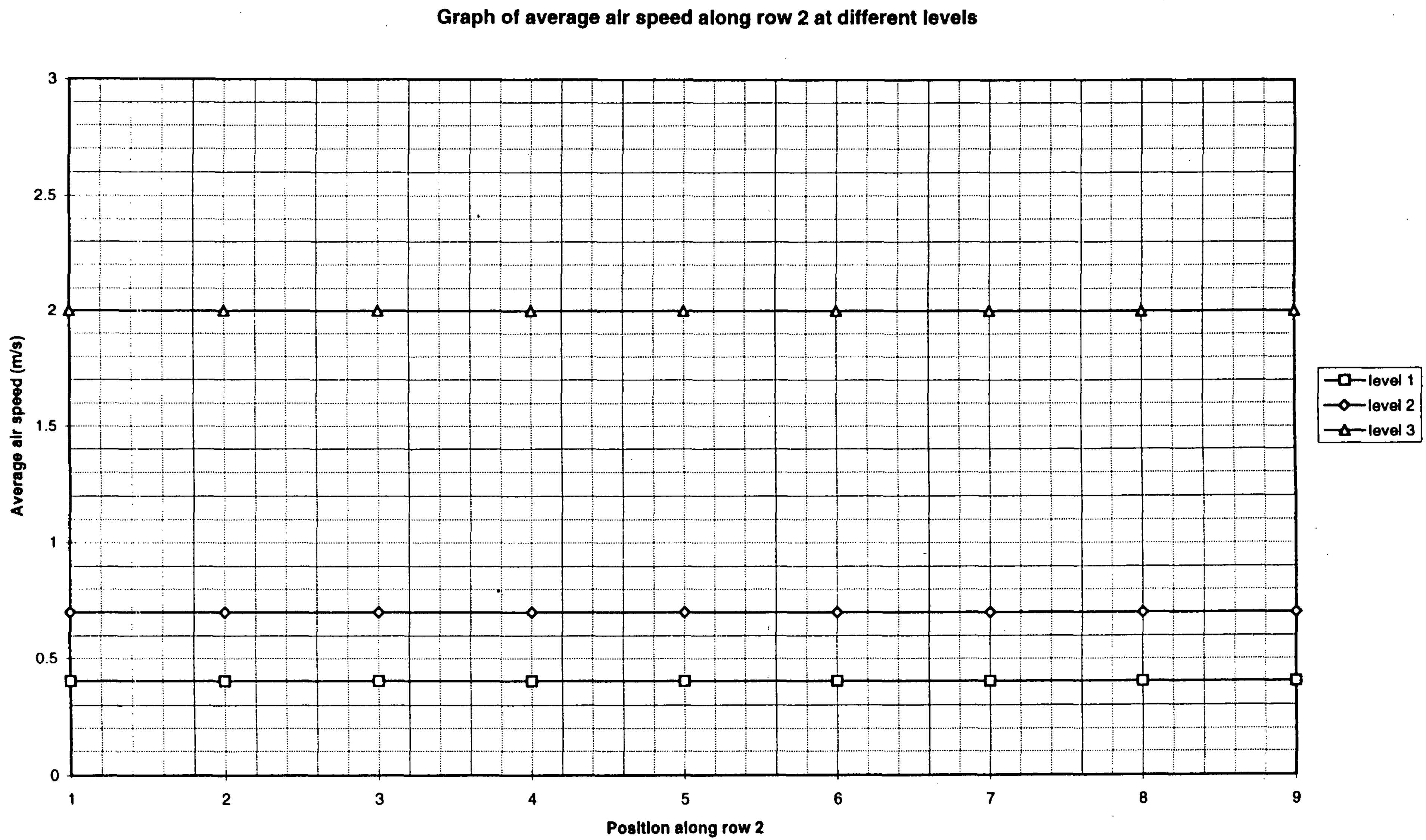


C26

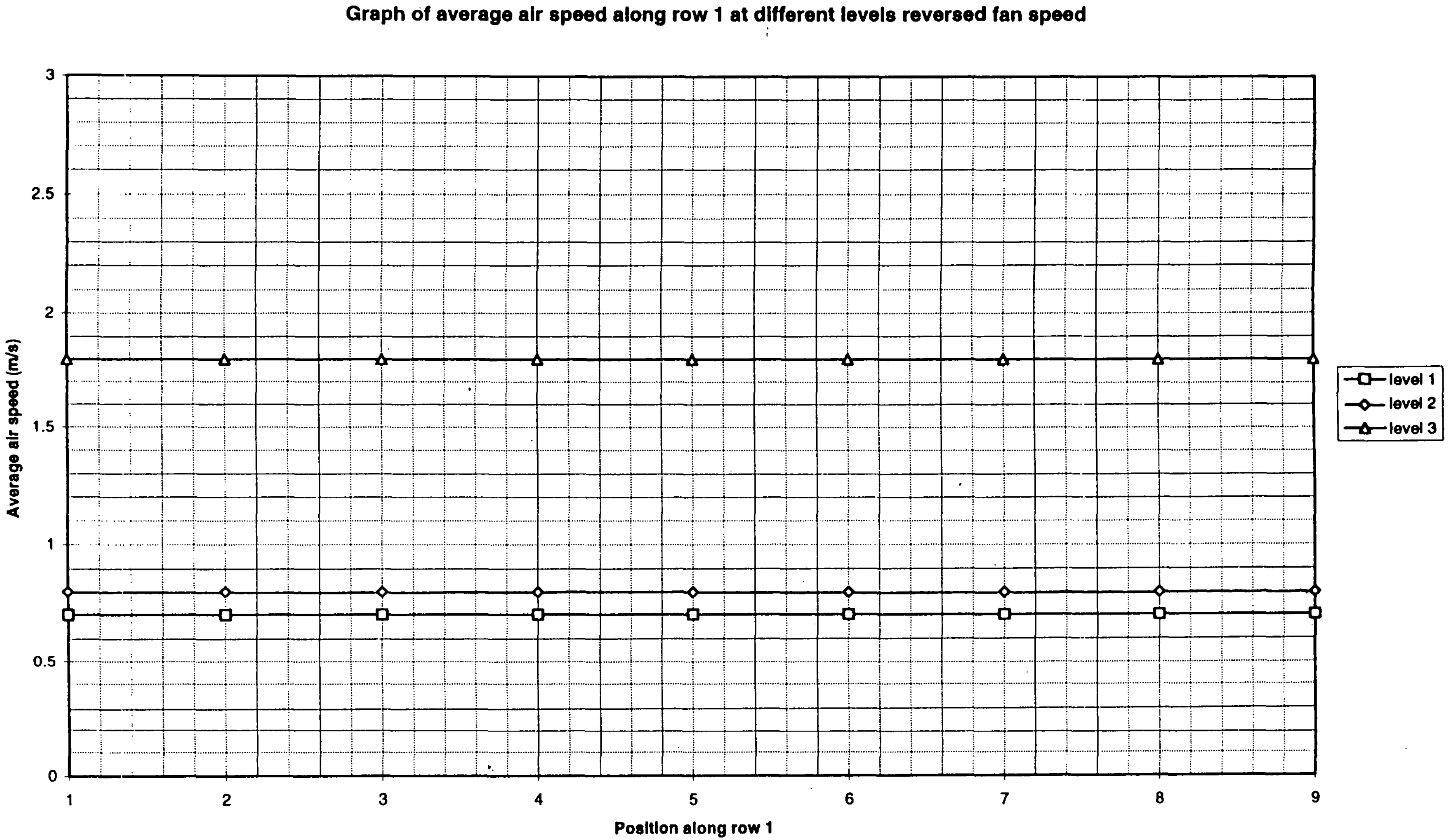
Graph 5 Clennetts kiln 27/11/96



Graph 6 Clennetts kiln 27/11/96

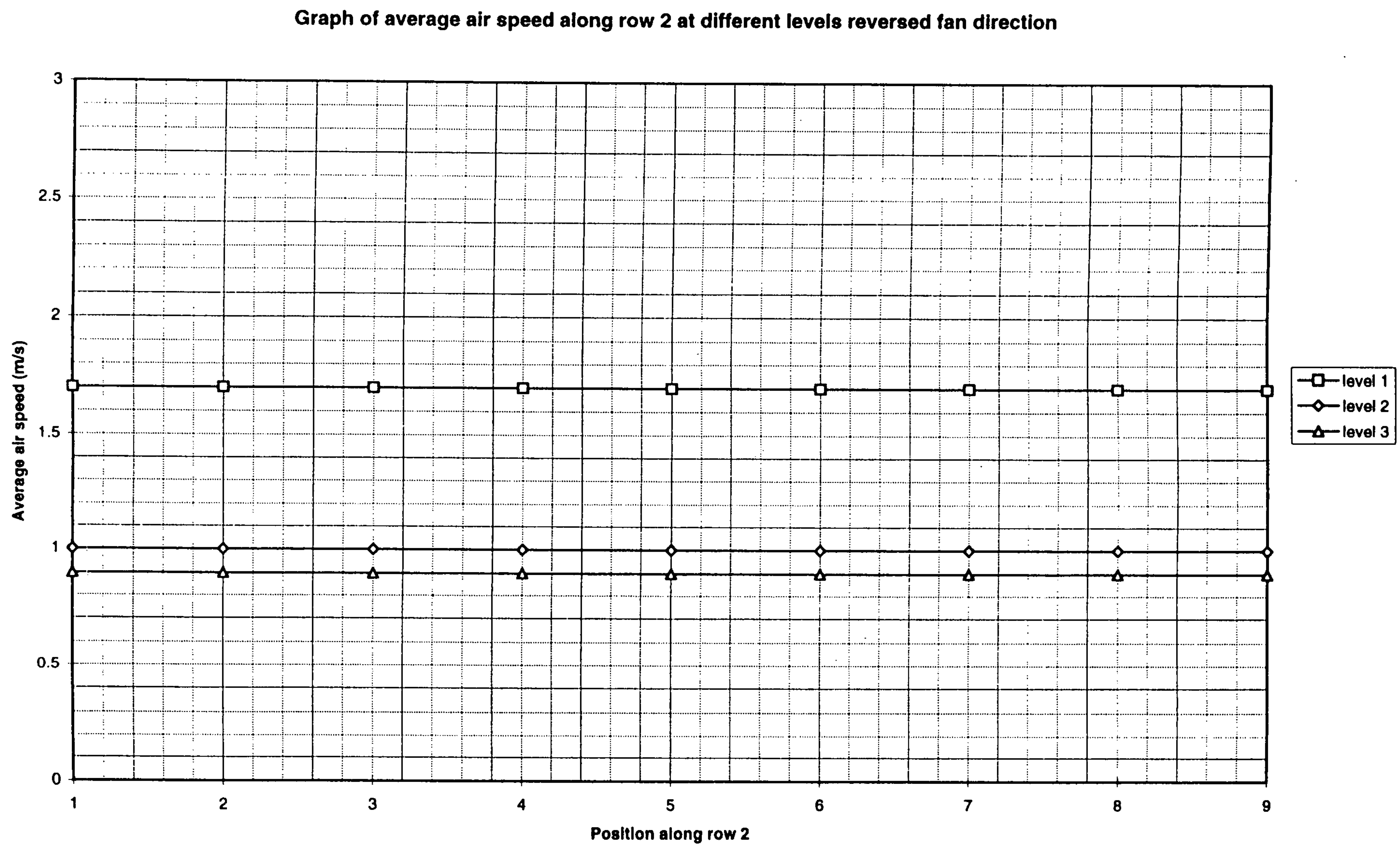


Graph 7 Clennetts kiln 27/11/96



C29

Graph 8 Clennetts kiln 27/11/96



C30

C3. Secondary Report - Clennetts

Follow-up investigation into air-flow characteristics and initial temperature/humidity measurement for Clennetts Timber kiln at Glenorchy Hobart conducted on the 11/2/97.

Adam Redman, Dean Chatwin, Mike Lee.

Upon completion of the initial air flow investigation a number of recommendations were made. These were as follows:

1) Installation of a baffle above the stacks to prevent air going over the top.

2) Replacement of roofing iron baffles with a more suitable material.

3) The use of stickers that are the same size.

4) Kiln charges should not be mixed.

Points 1 to 3 are directly related to the quality of the air flow within the kiln, while point 4 is directly related to the drying characteristics of the timber and not with air flow.

It should be noted that the kiln set-up was different to when the preliminary investigation was undertaken. On this occasion there were only two stacks in row 1 where there had been three before, and the temperature was about 65 °C instead of about 35 °C as it had been previously. As such this could have had some effect on the results and hence comparison between this and the preliminary investigation cannot be 100 % valid. Also it should be noted that because of the high temperature it was difficult to operate in the kiln for any length of time.

It would appear from the results that progress has indeed been made with regard to the air flow performance of the kiln. In particular the reduction in the air flow over the stacks (i.e. level 3, see figure 2) has been substantially reduced due the installation of baffling. This can best be seen in graphs 5 and 9 where the average air speed over the stacks was reduced from 2.7 m/s to 0.5 m/s and 1.7 m/s to 0.2 m/s respectively. Although this result is very promising the apparent gain in air flow does not appear to have been picked up elsewhere. Hence there is an apparent contradiction in that there has been a significant increase in the available air volume to go through the wood but this available air does not appear to be doing this. The design air speed was thought to be around 2 m/s and this value is not being reached. This could be due to a variety of reasons but the most probable is that the combination of kiln design, fans and desired air speed cannot be reached without changing something such as fan speed.

More typical average air speeds measured ranged from 1 to 1.5 m/s. Although these actual air speeds are considerably lower than the design air speed it may be the case that the extended drying time as a result of the lower air speeds may only be several hours in which case it is perhaps better to leave the situation as it is.

Although baffles have been placed as suggested there are still problems with regard to this. A baffle was not in-place between stacks A and B (see figure 1) and the workmanship of the baffles at the ends is inadequate. The fact that one of the baffles was not in place is inexcusable and can only act to decrease the value of the final product as well as wasting precious resources. The baffles on either side of the front door still do not seal as well as they could and worker access is also impeded. The sealing problem arises because the canvas is too long height wise and as a result the baffle acts similar to a sail in that it bellows out and allows the air to go through the gap between the edge of the baffle and the end of the stack. While the method for securing these baffles at the top appears to be adequate, with respect to preventing air flow and allowing easy access, this good work is being undone by what has been done at the bottom. Instead a method such as that used to secure annexes to caravans could be employed. This would allow a better seal and easier access. If the canvas is cut such that it is just long enough to span the gap from top to bottom then a good seal, with the wood stack, should be able to be obtained without the need to fasten the canvas to the stack itself.

There are several areas were it is possible that the baffles are causing problems with both air stagnation and letting air through and these can be seen on the air speed graphs. On graph 1 it can be seen that at position 3 for level 2 there is a stagnation of air and hence the drying of the stacks could be being compromised. Another point on the graph of interest is position 6 level 3 where it appears the baffle is not working properly as the air speed is much higher here than at other positions along this level.

From graph 2 it appears that the flow is more developed after going through the two rows as the air speed readings are generally more consistent along the levels. However at position 1 for level 2 it appears the baffle is stagnating the air speed as there was no reading here.

However on the whole, with the exception of the air speed through level 3, there has not been a dramatic increase in the air flow through the stacks. It must be remembered that the air flow is only one portion of the total that makes up the conditions for effective and efficient drying. Also of important consideration, and something that could have a bigger impact on the drying efficiency that improvements in air flow, is that of matching batches of timber because timber from different areas will have different drying characteristics and because of this productivity could be compromised. Also it appears that the stickers being used are still not the same size. It has been recognised that these stickers have been in the stacks for a considerable amount of time and as such there has been no opportunity to replace them. This point was emphasised in the preliminary report and as soon as possible stacks should be made up with same sized stickers. It must be remembered that the use of stickers the same size is imperative to a good quality final product and is essential in trying to prevent a twist and warp free final product.

The design of the kiln is such that the heated air is blown in under the floor lengthways and mixes with the air circulating around the stacks. However upon arrival the baffle that was not in place between stacks A and B was covering some of the area where the heated air comes up through the floor and because of this the air flow would be compromised. The unused heat exchanger next to the front doors should also be removed because the presence of this certainly would not be enhancing the air flow.

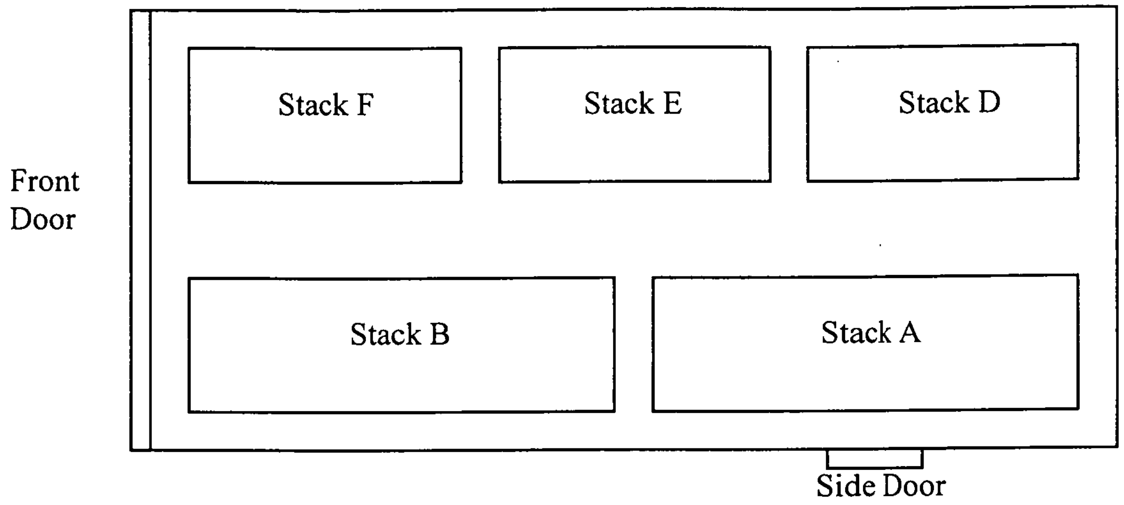


Figure 1. Plan view of kiln

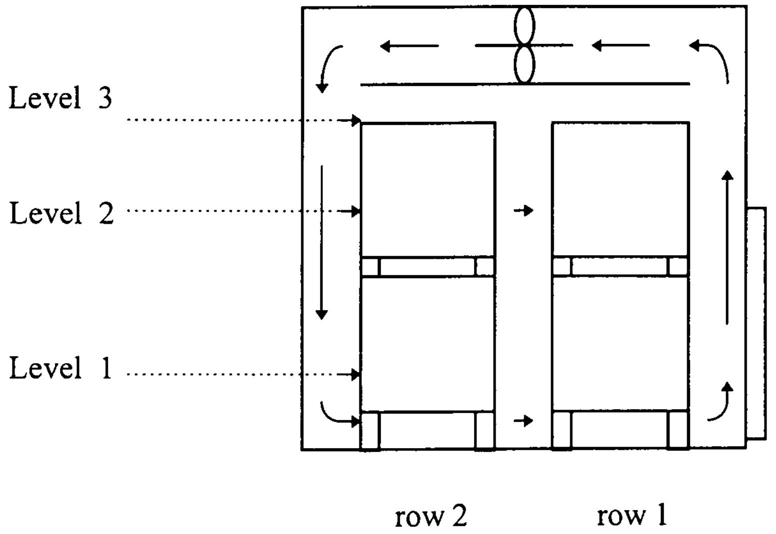


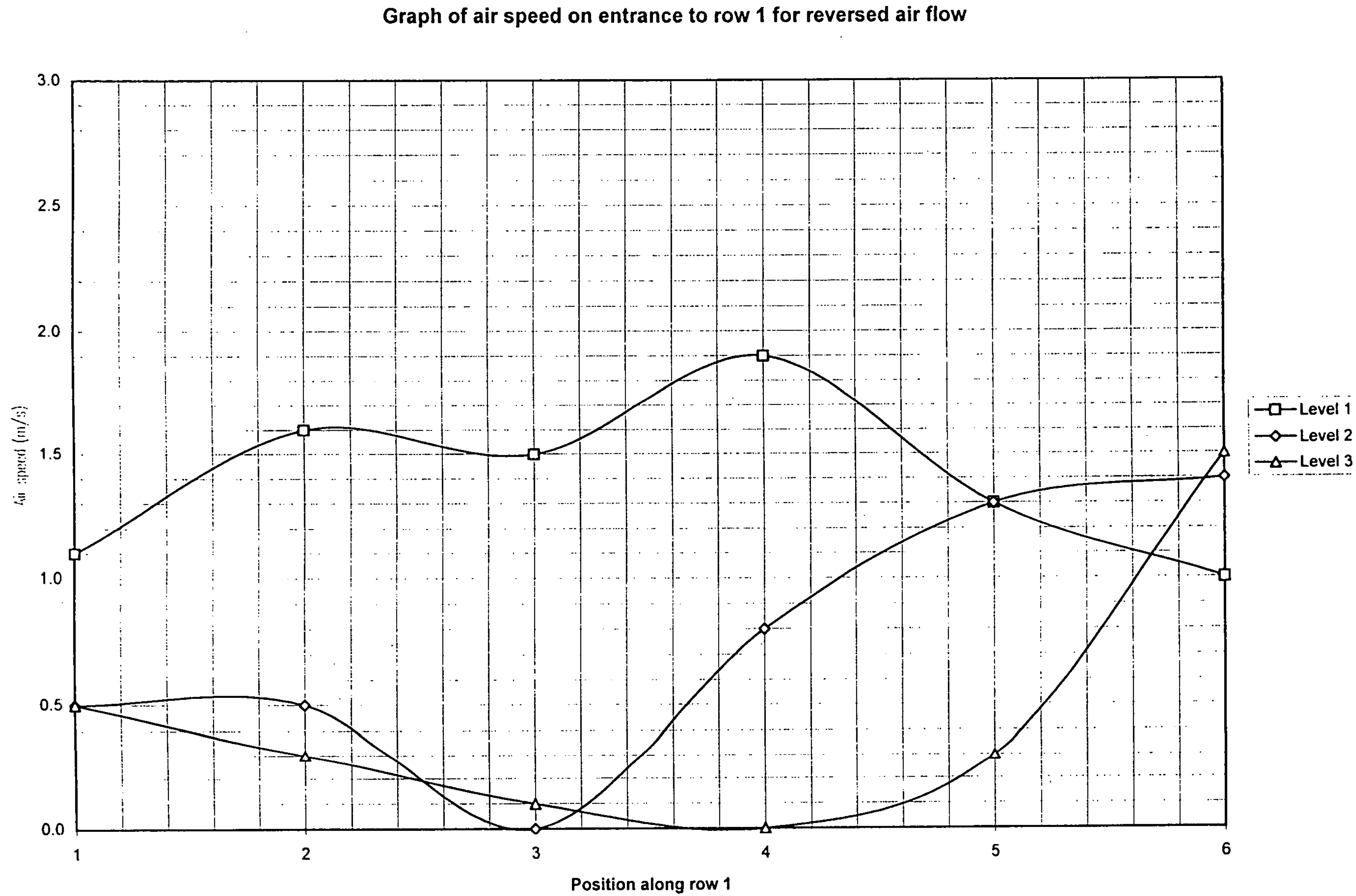
Figure 2. Front elevation showing normal air flow

Table 1: Air speeds (m/s) for normal air flow direction.
Date of readings: 11/2/97

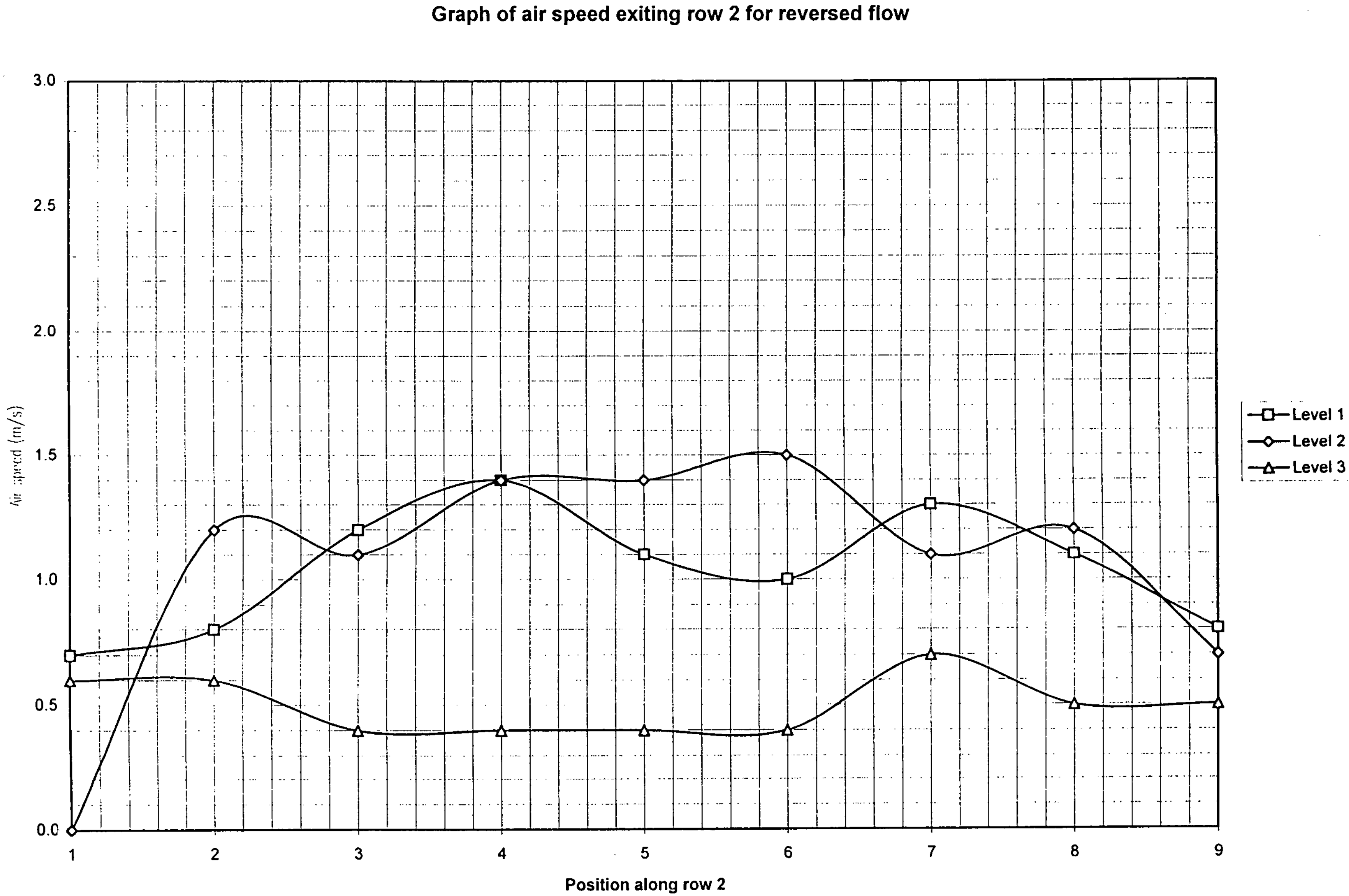
Row 1			
Position	level 1	level 2	level 3
End 1	1.6	0.2	0.3
A Middle	1.6	0.5	0.2
End 2	1.5	0.1	0.2
End 1	1.6	0.6	0
B Middle	1.3	1.3	0.1
End 2	1.6	1.3	0.1

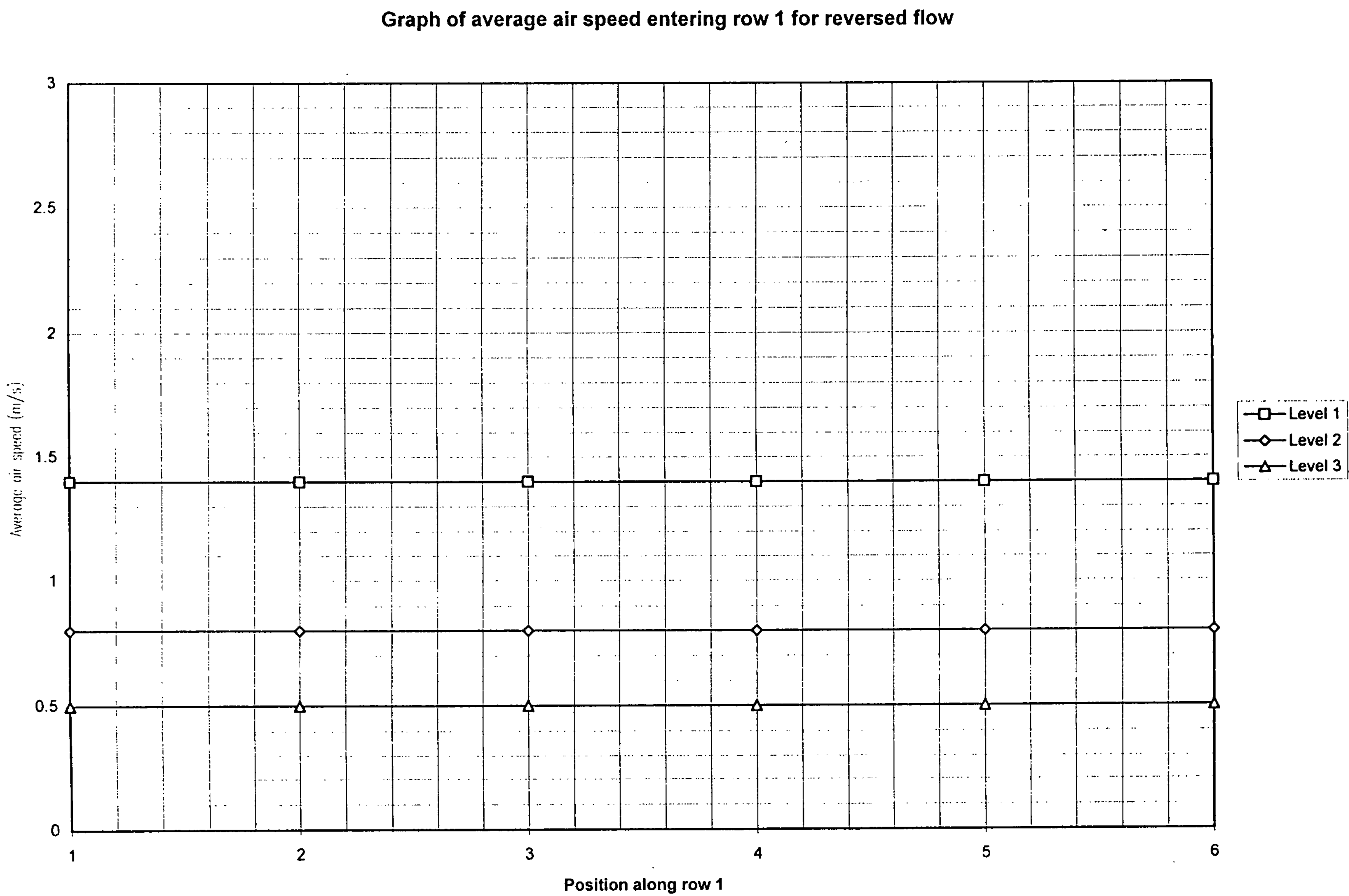
Table 2: Air speeds (m/s) for reversed air flow direction.
Date of readings: 11/2/97

Row 1				Row 2			
Position	Level 1	Level 2	Level 3	Position	Level 1	Level 2	Level 3
End 1	1.1	0.5	0.5	End 1	0.7	0.0	0.6
A Middle	1.6	0.5	0.3	C Middle	0.8	1.2	0.6
End 2	1.5	0.0	0.1	End 2	1.2	1.1	0.4
End 1	1.9	0.8	0.0	End 1	1.4	1.4	0.4
B Middle	1.3	1.3	0.3	D Middle	1.1	1.4	0.4
End 2	1.0	1.4	1.5	End 2	1.0	1.5	0.4
				End 1	1.3	1.1	0.7
				E Middle	1.1	1.2	0.5
				End 2	0.8	0.7	0.5

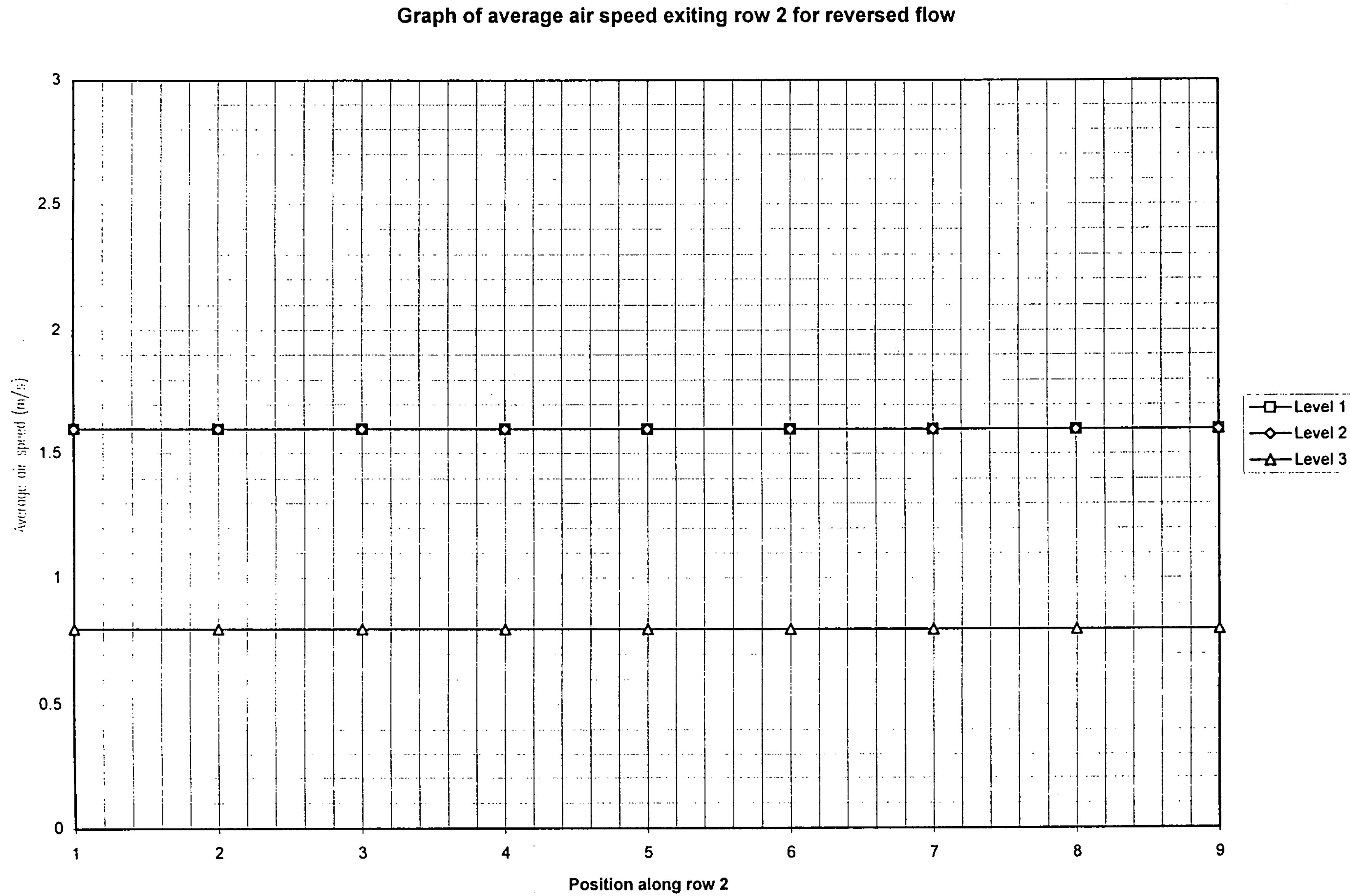

Graph of air speed on entrance to row 1 for reversed air flow
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Air speed (m/s)
1
2
3
4
5
6
Position along row 1
Level 1
Level 2
Level 3

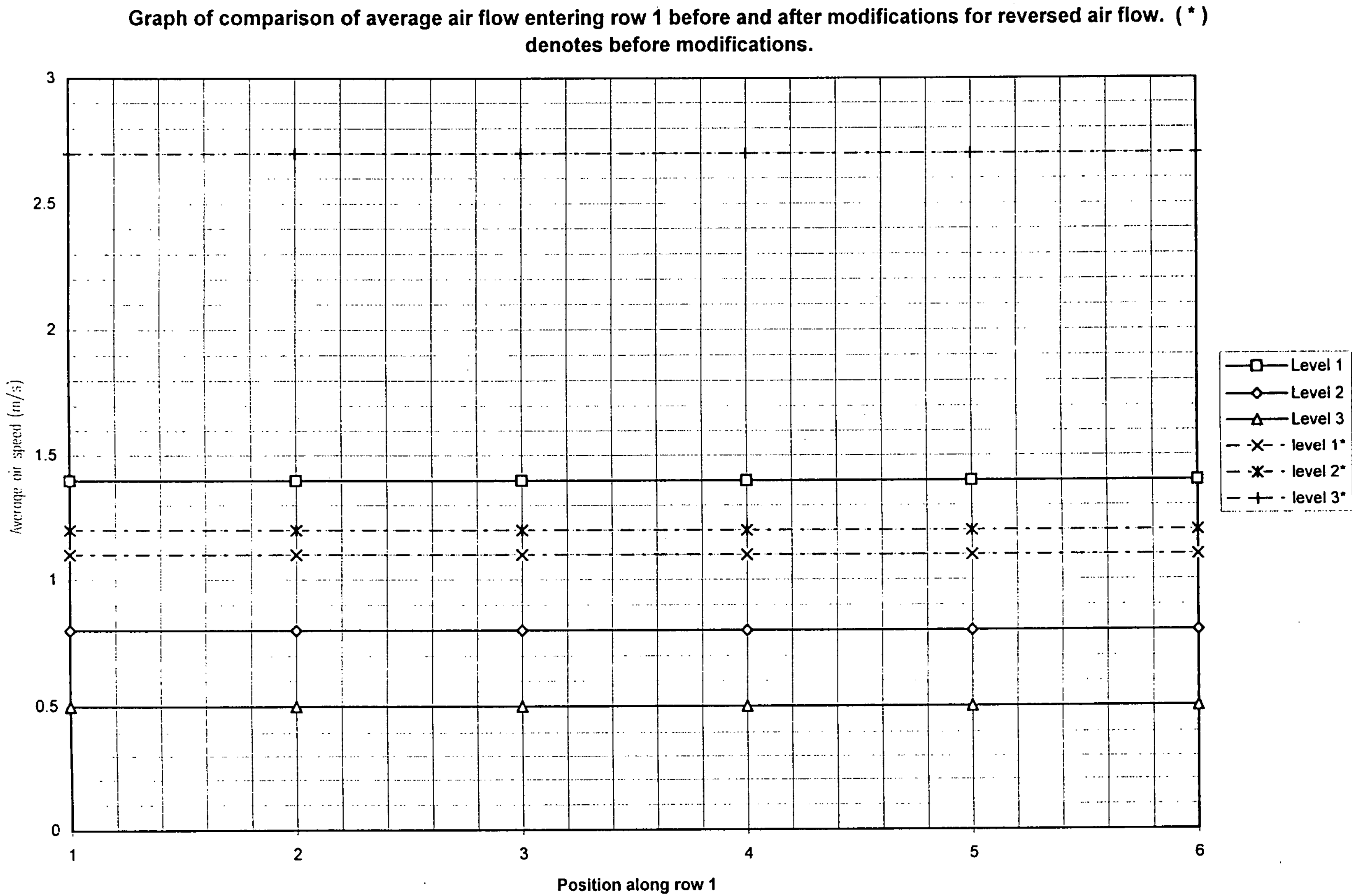
Graph 2 Clennetts kiln 11/2/97



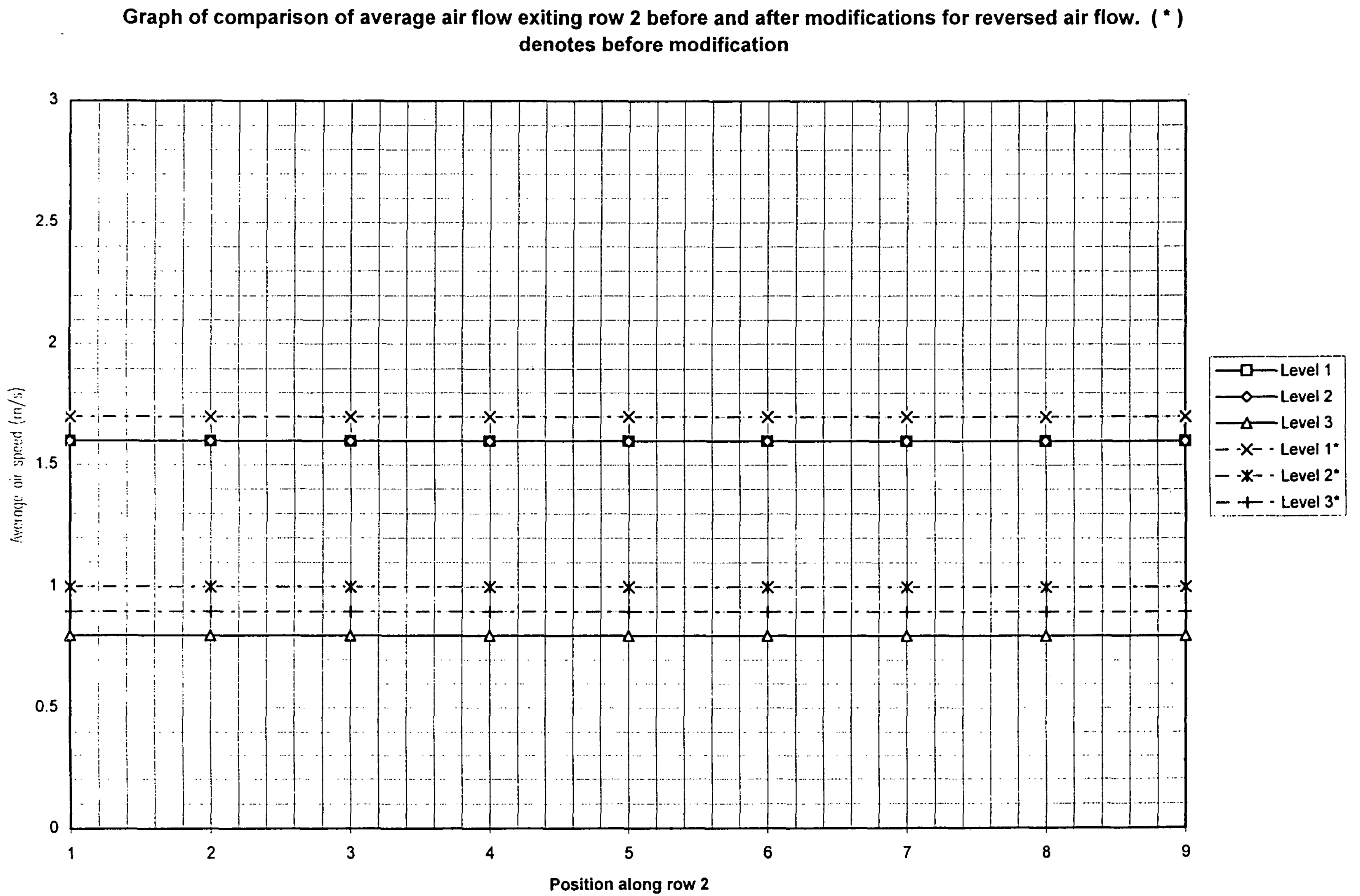

Graph of average air speed entering row 1 for reversed flow
Average air speed (m/s)
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
Position along row 1
Level 1
Level 2
Level 3

Graph 4 Clennetts kiln 11/2/97

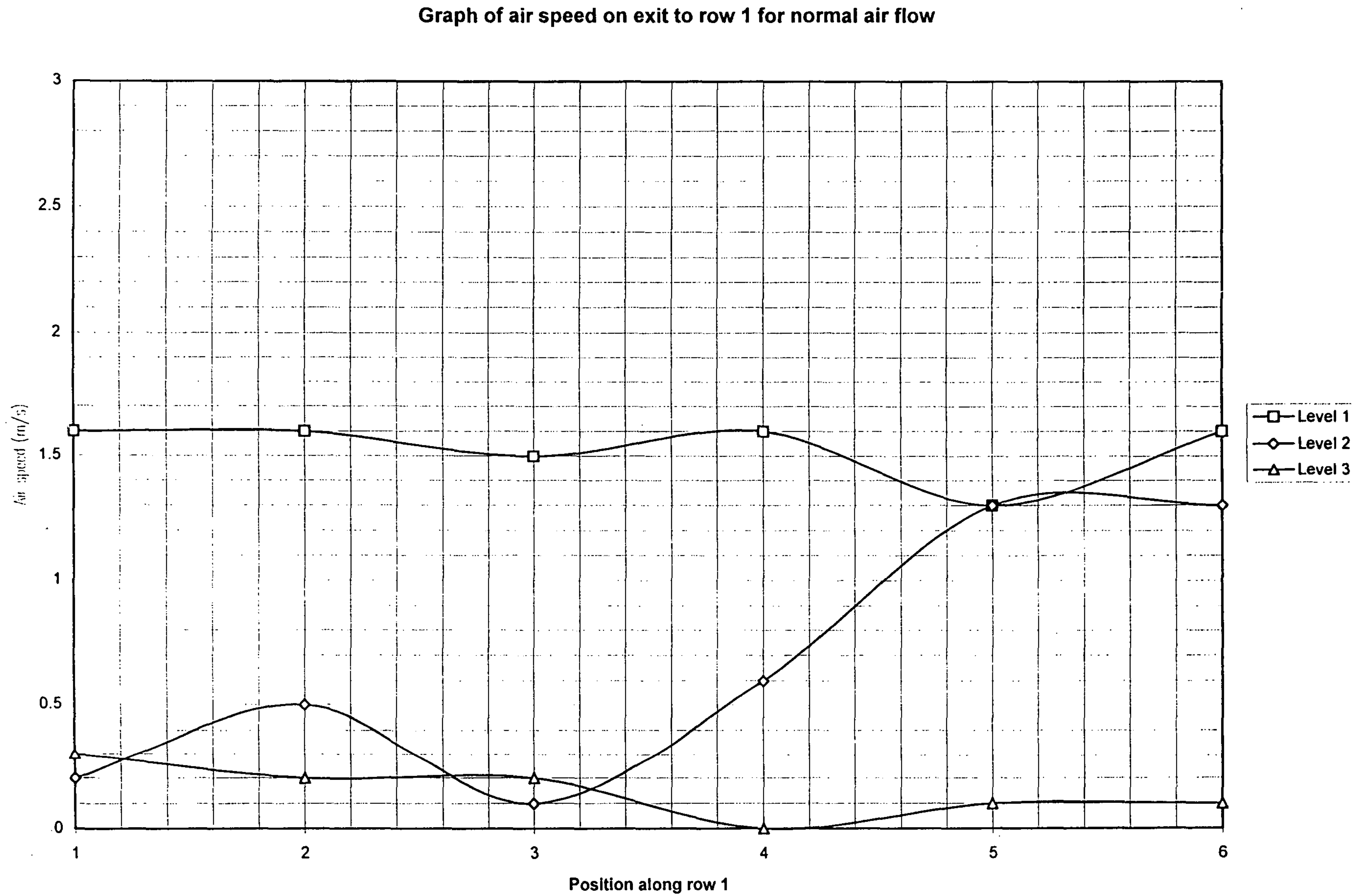


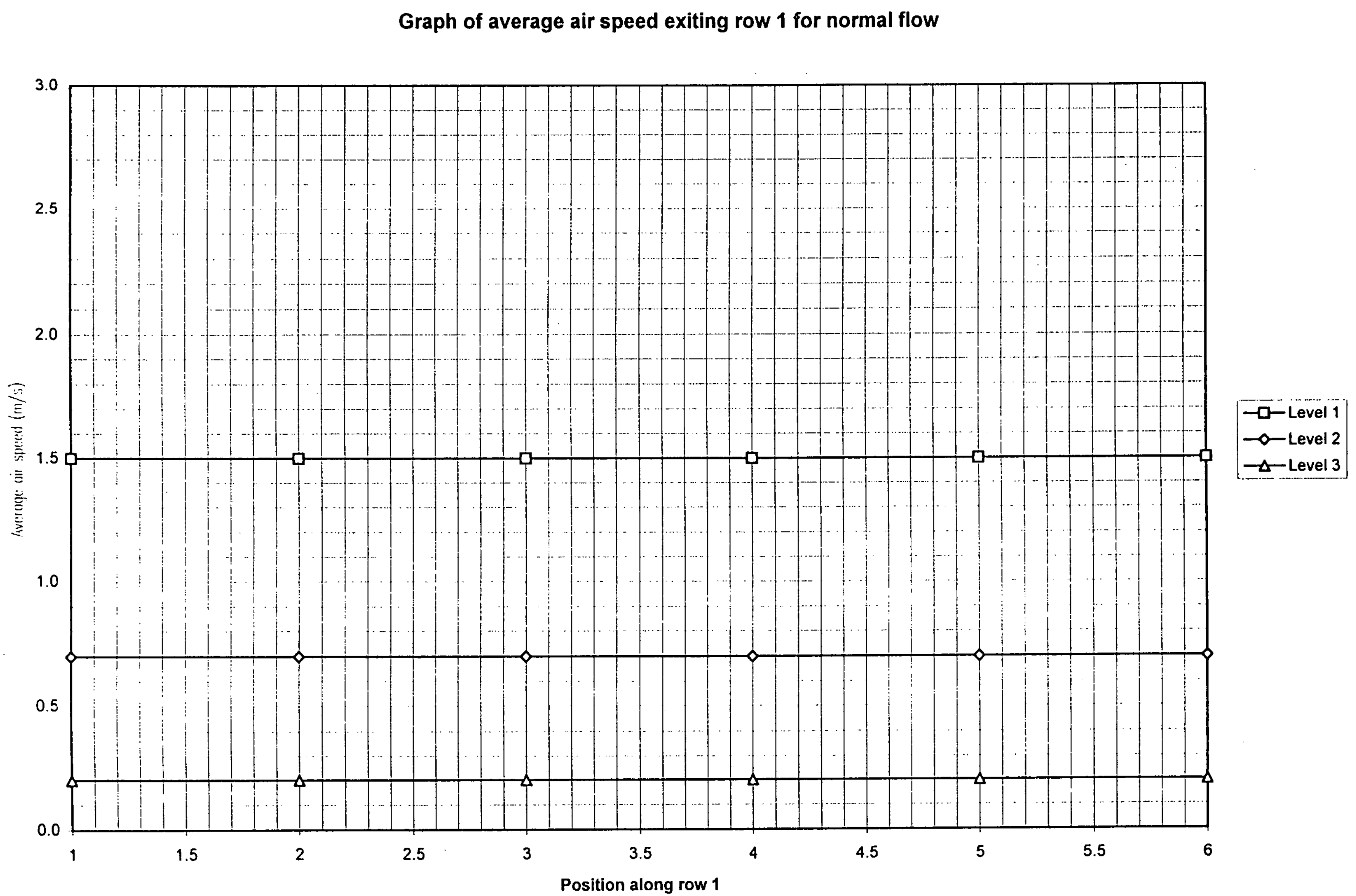

Graph of comparison of average air flow entering row 1 before and after modifications for reversed air flow. (*) denotes before modifications.
Average air speed (m/s)
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
Position along row 1
Level 1
Level 2
Level 3
level 1*
level 2*
level 3*

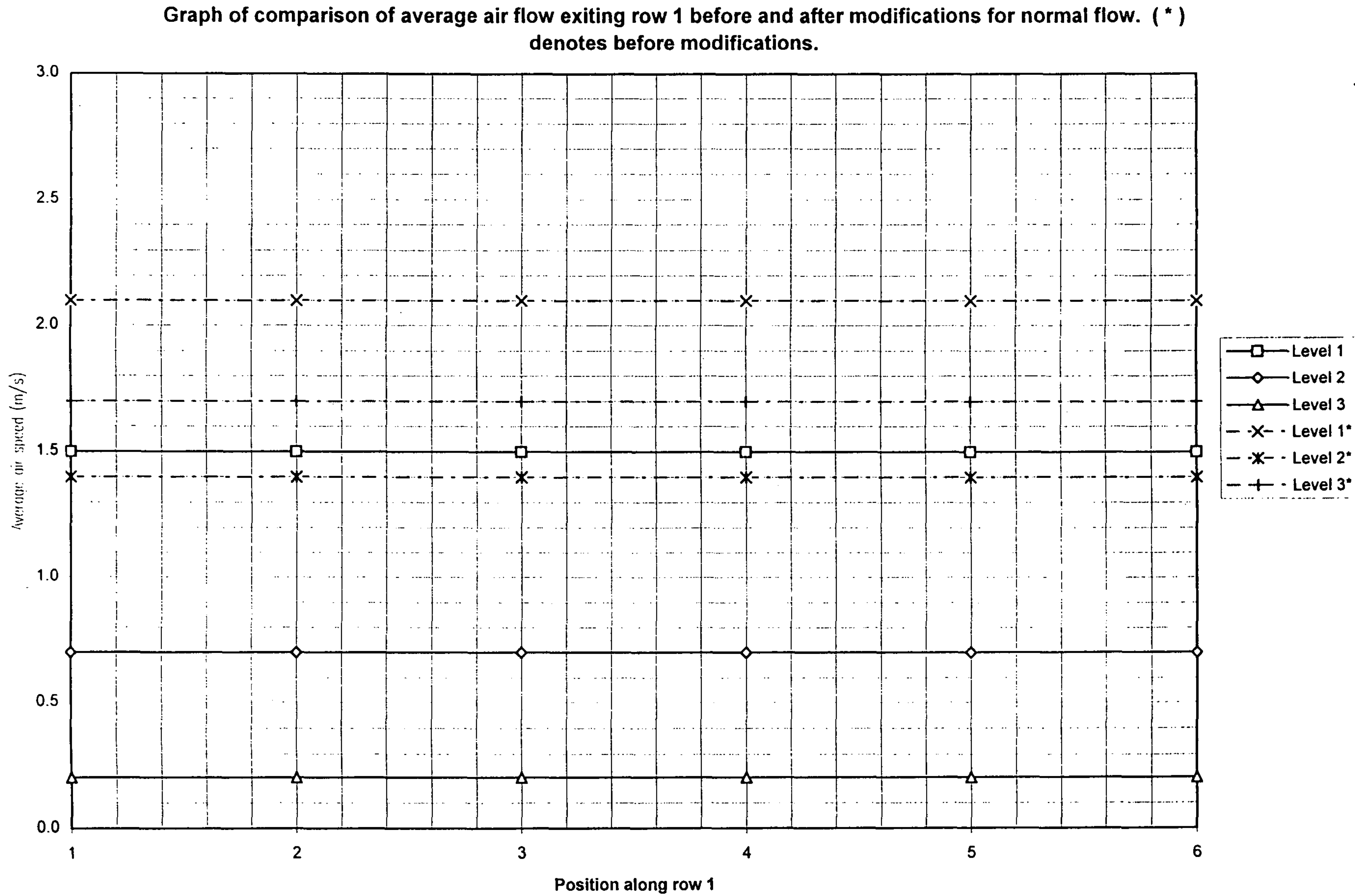
C39


Graph of comparison of average air flow exiting row 2 before and after modifications for reversed air flow. (*) denotes before modification
Average air speed (m/s)
Position along row 2
Level 1
Level 2
Level 3
Level 1*
Level 2*
Level 3*
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9

C40


Graph of air speed on exit to row 1 for normal air flow
Air speed (m/s)
Position along row 1
Level 1
Level 2
Level 3
0
0.5
1
1.5
2
2.5
3
1
2
3
4
5
6


Graph of average air speed exiting row 1 for normal flow
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Average air speed (m/s)
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
Position along row 1
Level 1
Level 2
Level 3


Graph of comparison of average air flow exiting row 1 before and after modifications for normal flow. (*) denotes before modifications.
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Average air speed (m/s)
1
2
3
4
5
6
Position along row 1
Level 1
Level 2
Level 3
Level 1*
Level 2*
Level 3*

Temperature Distribution.

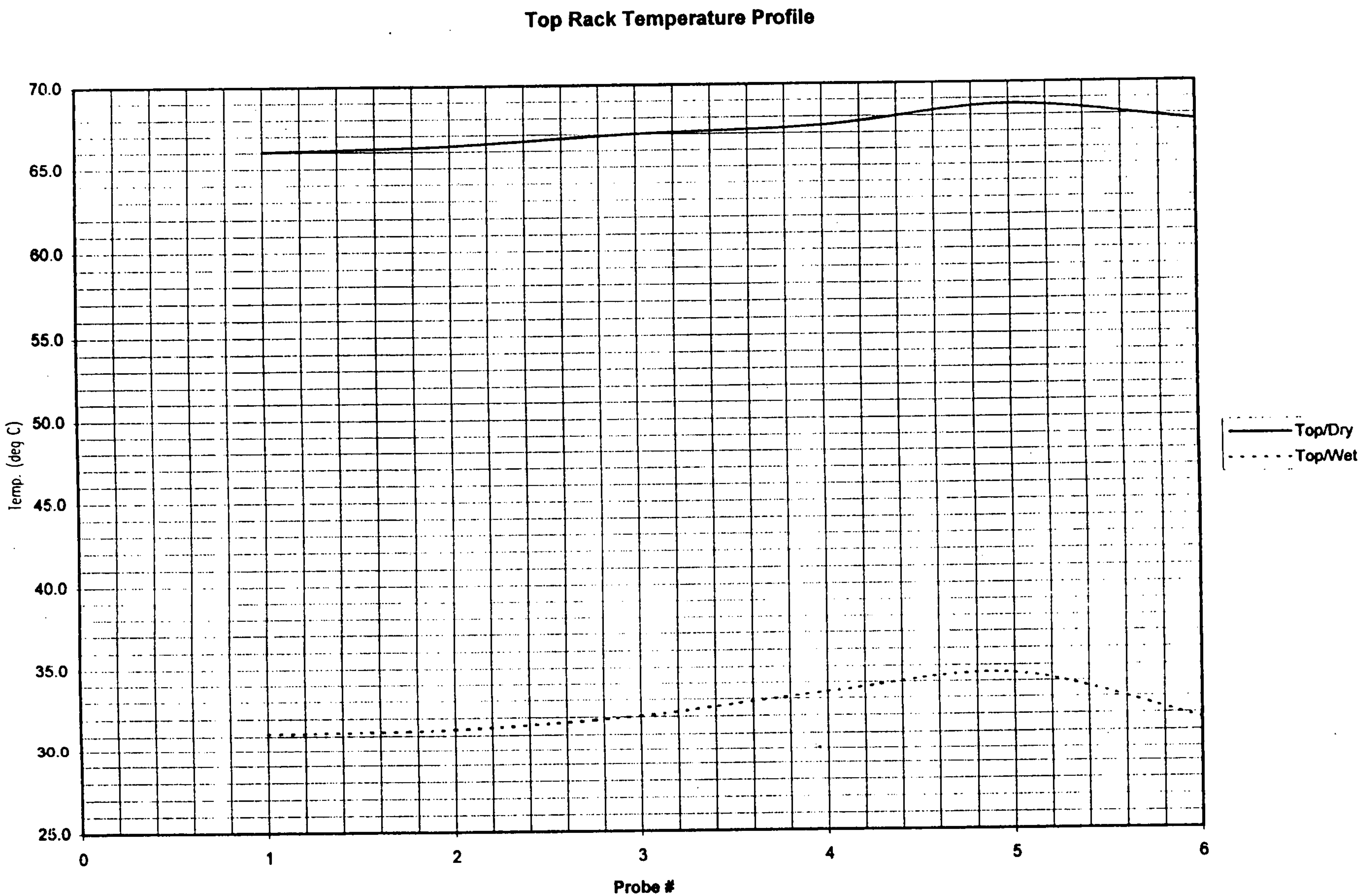
Wet and dry bulb temperatures were taken using RTD's and a datataker at six equally spaced distances along stacks A and B on the top and bottom racks on the inlet side. Results were measured every 30 seconds at each position. The temperatures were then averaged for each probe at every position giving the following results.

AVERAGE

PROBE	Top/Dry	Top/Wet	Bottom/Dry	Bottom/Wet
1	66.1	31.2	65.0	33.5
2	66.4	31.4	65.3	33.4
3	67.0	32.1	65.0	36.3
4	67.5	33.4	65.3	37.2
5	68.7	34.5	66.2	37.5
6	67.6	31.7	65.3	33.2

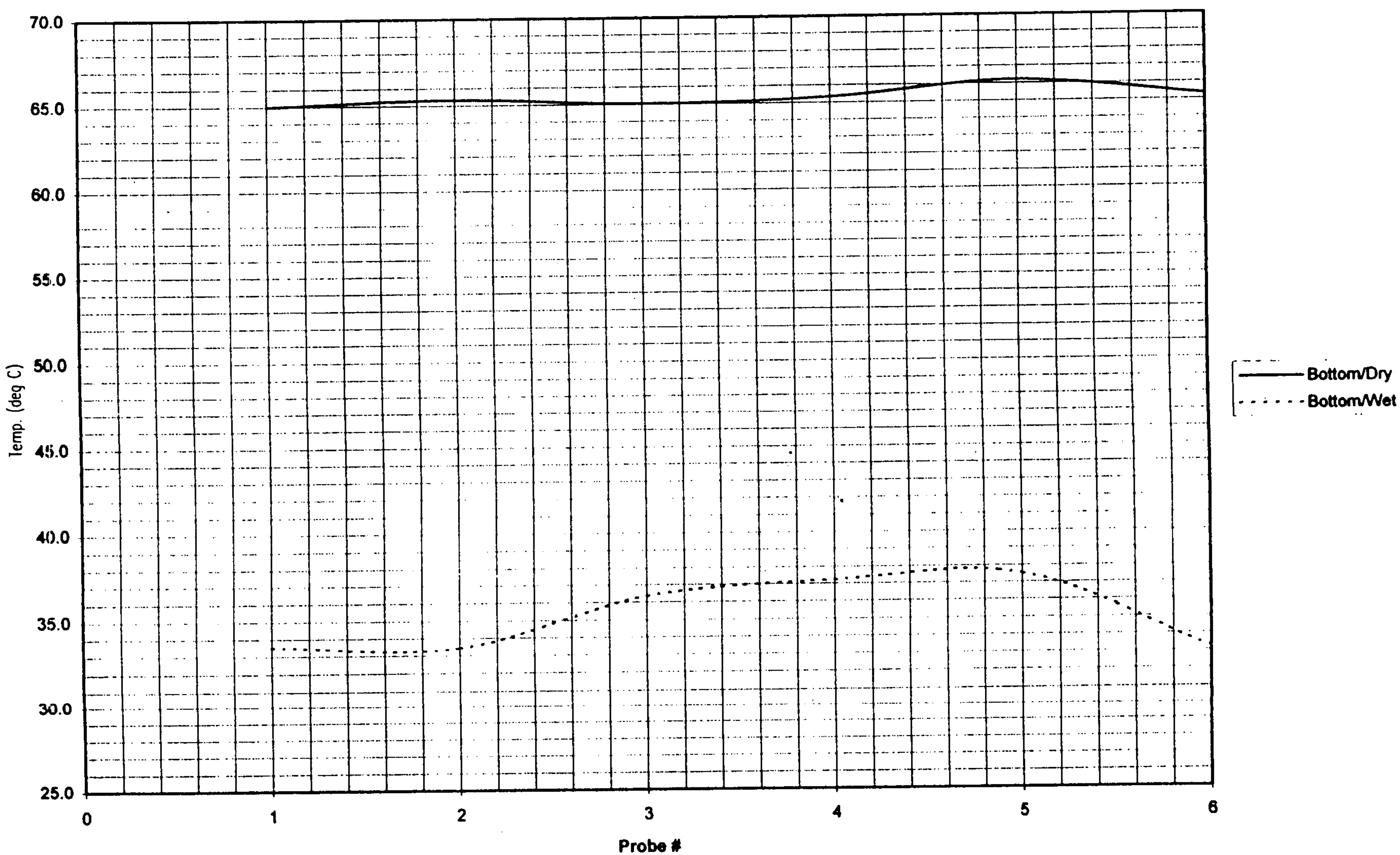
These results can be observed graphically on the following two graphs. It can be noted from these graphs that the temperature is quite constant over the length of the stacks with a maximum difference of ± 2 °. The depression between wet and dry bulb temperatures is also consistent along the stacks. It can be noted that the temperature increases slightly towards the large front door, however this change is minimal and not a problem.

Following the two graphs is the raw data taken by the datataker


Top Rack Temperature Profile
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
Temp. (deg C)
0
1
2
3
4
5
6
Probe #
Top/Dry
Top/Wet

C45

Bottom Rack Temperature Profile



Top Rack Dry Bulb Temperature

	Probe #					
Time	1	2	3	4	5	6
10:26:00	64.9	65.2	65.7	66.0	66.8	65.6
10:26:30	65.0	65.3	65.8	66.2	67.0	65.9
10:27:00	65.1	65.4	65.9	66.3	67.2	66.0
10:27:30	65.2	65.4	66.0	66.4	67.5	66.2
10:28:00	65.3	65.5	66.1	66.5	67.6	66.3
10:28:30	65.3	65.6	66.2	66.6	67.7	66.4
10:29:00	65.4	65.7	66.3	66.7	67.6	66.5
10:29:30	65.5	65.7	66.3	66.7	67.7	66.7
10:30:00	65.5	65.8	66.4	66.8	67.8	66.8
10:30:30	65.6	65.9	66.5	66.9	67.8	66.8
10:31:00	65.6	65.9	66.5	66.9	67.9	66.9
10:31:30	65.7	65.9	66.5	67.0	68.0	67.0
10:32:00	65.7	66.0	66.6	67.0	68.1	67.1
10:32:30	65.8	66.0	66.7	67.1	68.2	67.1
10:33:00	65.8	66.1	66.7	67.1	68.2	67.2
10:33:30	65.9	66.2	66.8	67.2	68.4	67.2
10:34:00	65.9	66.2	66.8	67.3	68.5	67.3
10:34:30	65.9	66.3	66.9	67.3	68.5	67.4
10:35:00	66.0	66.3	66.9	67.4	68.6	67.4
10:35:30	66.0	66.3	67.0	67.4	68.6	67.5
10:36:00	66.0	66.3	67.0	67.4	68.7	67.6
10:36:30	66.1	66.4	67.0	67.5	68.7	67.6
10:37:00	66.1	66.5	67.1	67.5	68.8	67.7
10:37:30	66.2	66.5	67.2	67.6	68.8	67.8
10:38:00	66.2	66.6	67.2	67.6	68.8	67.9
10:38:30	66.2	66.6	67.2	67.7	68.9	67.9
10:39:00	66.2	66.6	67.2	67.7	68.9	67.9
10:39:30	66.3	66.6	67.3	67.8	69.1	67.9
10:40:00	66.3	66.6	67.3	67.8	69.1	68.0
10:40:30	66.3	66.7	67.4	67.9	69.1	68.1
10:41:00	66.4	66.7	67.4	67.9	69.2	68.1
10:41:30	66.4	66.7	67.4	67.9	69.2	68.2
10:42:00	66.5	66.8	67.5	68.0	69.2	68.3
10:42:30	66.4	66.7	67.5	68.0	69.3	68.3
10:43:00	66.3	66.6	67.5	68.0	69.4	68.3
10:43:30	66.4	66.6	67.6	68.0	69.4	68.3
10:44:00	66.5	66.7	67.6	68.0	69.4	68.4
10:44:30	66.4	66.8	67.6	68.1	69.4	68.5
10:45:00	66.5	66.9	67.7	68.1	69.4	68.5
10:45:30	66.6	66.9	67.7	68.1	69.4	68.5
10:46:00	66.7	66.9	67.7	68.1	69.5	68.6
10:46:30	66.7	67.0	67.7	68.2	69.5	68.6
10:47:00	66.7	67.0	67.7	68.2	69.6	68.6
10:47:30	66.8	67.0	67.8	68.3	69.6	68.7
10:48:00	66.8	67.0	67.8	68.3	69.7	68.8
10:48:30	66.7	67.0	67.7	68.2	69.5	68.7
10:49:00	66.7	66.8	67.6	68.1	69.3	68.6
10:49:30	66.5	66.7	67.4	67.9	69.0	68.3
10:50:00	66.4	66.5	67.2	67.7	68.6	68.2

Bottom Rack Dry Bulb Temperature

	Probe #					
Time	1	2	3	4	5	6
10:56:00	65.1	65.1	65.4	65.7	65.9	66.2
10:56:30	65.0	65.0	65.3	65.6	65.7	66.0
10:57:00	64.9	64.9	65.3	65.5	65.6	66.0
10:57:30	64.8	64.8	65.2	65.4	65.5	65.8
10:58:00	64.7	64.7	65.1	65.3	65.4	65.7
10:58:30	64.6	64.7	65.0	65.2	65.3	65.6
10:59:00	64.6	64.6	65.0	65.2	65.2	65.5
10:59:30	64.5	64.5	64.9	65.1	65.0	65.4
11:00:00	64.4	64.4	64.8	65.0	65.0	65.3
11:00:30	64.4	64.3	64.8	65.0	64.9	65.2
11:01:00	64.3	64.3	64.7	64.9	64.8	65.1
11:01:30	64.2	64.2	64.6	64.8	64.6	65.0
11:02:00	64.2	64.1	64.6	64.7	64.4	64.8
11:02:30	64.1	64.0	64.5	64.6	64.3	64.7
11:03:00	64.1	64.0	64.4	64.6	64.3	64.6
11:03:30	64.0	63.9	64.4	64.5	64.2	64.5
11:04:00	63.9	63.9	64.3	64.5	64.1	64.4
11:04:30	63.9	63.8	64.3	64.4	64.1	64.4
11:05:00	63.8	63.8	64.2	64.4	64.0	64.2
11:05:30	63.8	63.7	64.2	64.3	63.9	64.2
11:06:00	63.7	63.7	64.1	64.2	63.9	64.1
11:06:30	63.7	63.6	64.1	64.2	63.8	64.1
11:07:00	63.6	63.6	64.1	64.2	63.8	64.0
11:07:30	63.6	63.5	64.0	64.1	63.7	64.0
11:08:00	63.5	63.4	63.9	64.0	63.7	63.9
11:08:30	63.5	63.4	63.9	64.0	63.6	63.8
11:09:00	63.5	63.3	63.8	63.9	63.5	63.7
11:09:30	63.4	63.3	63.8	63.9	63.5	63.7
11:10:00	63.5	63.5	63.8	64.0	63.7	63.7
11:10:30	63.7	63.8	64.0	64.2	64.2	63.8
11:11:00	64.0	64.2	64.2	64.4	64.9	64.1
11:11:30	64.3	64.7	64.4	64.7	65.4	64.4
11:12:00	64.7	65.2	64.7	65.0	66.1	64.6
11:12:30	65.1	65.6	64.9	65.2	66.6	64.9
11:13:00	65.4	66.0	65.1	65.4	67.2	65.2
11:13:30	65.6	66.3	65.3	65.7	67.7	65.4
11:14:00	65.8	66.7	65.4	65.9	68.0	65.7
11:14:30	66.0	66.9	65.6	66.1	68.4	65.9
11:15:00	66.2	67.2	65.8	66.3	68.6	66.1
11:15:30	66.5	67.4	65.9	66.4	69.0	66.2
11:16:00	66.6	67.7	66.0	66.5	69.2	66.4
11:16:30	66.7	67.8	66.1	66.6	69.4	66.5
11:17:00	66.8	67.9	66.3	66.8	69.6	66.7
11:17:30	66.9	68.0	66.4	66.9	69.8	66.9
11:18:00	67.1	68.2	66.5	67.0	70.0	67.0
11:18:30	67.2	68.2	66.5	67.1	70.1	67.1
11:19:00	67.3	68.3	66.6	67.3	70.2	67.3
11:19:30	67.4	68.4	66.7	67.3	70.5	67.3
11:20:00	67.5	68.5	66.7	67.4	70.6	67.5
11:20:30	67.5	68.7	66.8	67.4	70.6	67.5
11:21:00	67.6	68.7	66.9	67.5	70.8	67.6

Bottom Rack Wet Bulb Temperature

	Probe #					
Time	1	2	3	4	5	6
11:28:00	32.4	32.8	33.7	33.0	33.9	33.8
11:28:30	33.0	33.3	36.5	37.0	37.7	33.6
11:29:00	33.3	33.5	36.5	37.0	37.7	33.5
11:29:30	33.5	33.6	36.4	37.1	37.7	33.4
11:30:00	33.6	33.6	36.4	37.1	37.6	33.3
11:30:30	33.6	33.6	36.4	37.1	37.6	33.3
11:31:00	33.7	33.6	36.4	37.2	37.6	33.3
11:31:30	33.6	33.6	36.4	37.2	37.6	33.2
11:32:00	33.6	33.6	36.3	37.2	37.6	33.2
11:32:30	33.5	33.6	36.3	37.2	37.6	33.2
11:33:00	33.5	33.5	36.3	37.2	37.6	33.2
11:33:30	33.5	33.5	36.3	37.2	37.6	33.2
11:34:00	33.5	33.5	36.3	37.3	37.6	33.2
11:34:30	33.6	33.5	36.3	37.3	37.6	33.2
11:35:00	33.5	33.5	36.3	37.3	37.6	33.2
11:35:30	33.5	33.4	36.4	37.3	37.6	33.2
11:36:00	33.6	33.4	36.4	37.4	37.6	33.2
11:36:30	33.6	33.3	36.4	37.4	37.6	33.2
11:37:00	33.5	33.3	36.4	37.4	37.5	33.2
11:37:30	33.5	33.3	36.4	37.4	37.4	33.2
11:38:00	33.5	33.2	36.3	37.3	37.3	33.1
11:38:30	33.4	33.1	36.2	37.2	37.1	33.0
11:39:00	33.3	33.0	36.2	37.1	37.1	33.0
11:39:30	33.3	32.9	36.1	37.1	38.2	32.9
11:40:00	33.2	32.8	36.0	37.0	40.8	32.8
11:40:30	33.1	33.0	35.9	36.9	44.6	32.7
11:41:00	33.1	33.6	35.8	36.8	48.1	32.6
11:41:30	33.0	34.5	35.8	36.8	51.5	32.6
11:42:00	33.0	35.5	35.7	36.8	54.3	32.5
11:42:30	32.9	36.7	35.7	36.7	56.6	32.4
11:43:00	32.8	38.0	35.6	36.7	58.7	32.3
11:43:30	32.8	39.0	35.5	36.8	60.3	32.2
11:44:00	32.7	40.0	35.5	37.2	61.7	32.2
11:44:30	32.7	41.3	35.9	38.6	62.8	32.2
11:45:00	32.6	43.3	37.2	40.7	63.8	32.1

Top Rack Wet Bulb Temperature

	Probe #					
Time	1	2	3	4	5	6
11:52:00	31.0	34.7	31.6	33.9	34.8	32.5
11:52:30	31.1	32.9	31.8	33.8	35.1	32.4
11:53:00	31.2	32.1	31.8	33.7	35.3	32.3
11:53:30	31.2	31.7	31.9	33.6	35.4	32.1
11:54:00	31.2	31.5	31.9	33.5	35.4	32.0
11:54:30	31.1	31.3	31.9	33.5	35.3	31.9
11:55:00	31.1	31.2	32.0	33.4	35.2	31.8
11:55:30	31.1	31.2	31.9	33.3	35.1	31.7
11:56:00	31.2	31.1	31.9	33.3	35.0	31.7
11:56:30	31.2	31.1	31.9	33.3	34.9	31.6
11:57:00	38.0	31.1	31.9	33.2	34.8	31.5
11:57:30	48.4	31.0	31.9	33.2	34.7	31.4
11:58:00	54.6	31.0	31.9	33.2	34.6	31.4
11:58:30	58.3	31.0	31.9	33.2	34.5	31.4
11:59:00	60.7	31.1	31.9	33.2	34.4	31.5
11:59:30	62.1	31.1	31.9	33.2	34.3	31.5
12:00:00	63.0	31.2	31.9	33.2	34.2	31.6
12:00:30	63.7	31.2	32.0	33.3	34.2	31.6
12:01:00	64.1	31.3	32.1	33.3	34.2	31.7
12:01:30	64.5	31.4	32.1	33.4	34.1	31.6
12:02:00	64.7	31.4	32.2	33.4	34.1	31.6
12:02:30	64.9	31.4	32.2	33.5	34.1	31.7
12:03:00	65.0	31.5	32.3	33.6	34.0	31.7
12:03:30	65.1	31.5	32.4	33.6	34.0	31.8
12:04:00	65.3	31.6	32.4	33.7	34.0	31.8
12:04:30	65.3	31.6	32.4	33.7	34.0	31.8
12:05:00	65.4	31.7	32.5	33.7	33.9	31.9
12:05:30	65.5	31.8	32.5	33.8	33.8	31.9
12:06:00	65.6	31.9	32.6	33.8	33.6	31.9
12:06:30	65.6	32.0	32.6	33.9	33.5	32.0
12:07:00	65.7	32.8	32.6	33.9	33.3	32.0
12:07:30	65.7	34.9	32.6	34.0	33.3	32.1