An assessment into the use of higher airspeeds during conventional kilning to improve the drying of spruce (CFS 13/06)

Prepared for: James Dewar
Industry advisor
Forestry Commission

30 June 2008

Client report number 231-943

Prepared by

Name Geoff Cooper

Position Senior Consultant

Signature

Approved on behalf of BRE

Name Dr Ed Suttie

Position Director (Timber)

Date 30th June 2008

Signature

Building Technology
Group
BRE
Garston
WD25 9XX
T + 44 (0) 1923 664200
F + 44 (0) 1923 664096
E construction@bre.co.uk
www.bre.co.uk

Executive Summary

This report details the progress on the Forestry Commission funded project 'An assessment into the use of higher air speeds during conventional kilning to improve the drying of UK spruce' (contract number CFS 13/06) from it's initiation in September 2006 to the end of June 2008.

The main objective of this project is to investigate how increases in airspeed during the drying of spruce can be utilised to reduce drying times. Airflow is an extremely important factor during the drying process, transferring heat from the exchangers to the timber and removing moisture from the wood surface of the drying timber. This project was initiated to investigate how increasing the airspeeds during drying affects the drying times and the resulting quality of the timber after drying.

Task 1 of the work programme (now completed), consisted of undertaking two information collection trials to select a suitable schedule for use as a base-line control schedule in subsequent experimental trials (task 2). Task 2 of the work programme consists of eight sets of experimental trials with stepwise increases in airspeed from 3.5 m/s to 9 m/s. To date, four sets of experimental trials have been completed and material requested for subsequent trials.

Data recorded from these and subsequent trials will be included in the main project database and used for schedule recommendations during the later stages of the project.

As the project nears completion, it should be possible to calculate whether the savings in drying time are off-set by the costs of increasing the air speed, or that increasing the air-speed past a given point results in little or no improvement in drying times. The effect air-speed changes have on final dried wood quality will also require careful analysis.

Contents

Introduction

A number of projects have been completed by BRE over the last three years to optimise the drying of UK spruce. Almost all the industrial kilns used by the UK softwood sawmilling industry have an upper ceiling in their air speeds of between 2.5 and 3.5 M/S. From the small amount of work undertaken within recent projects, it is apparent that small changes in airflow can have large influences on the drying process.

The objective of this project is to investigate how increases in airspeed during the drying of spruce can be utilised to reduce drying times. Airflow is an extremely important factor during the drying process. The circulating air within the drying kiln imparts heat from the exchangers to the timber and in turn removes moisture from the wood surface. This project will investigate how increasing the airspeeds affects the drying times and the resulting quality of the timber at the end of the schedule.

Increasing the air-speeds during the drying process also results in an increase in energy consumption. This aspect of the project is obviously very important to our industrial partners. An increase in air-speed may significantly reduce drying times, but at a cost. During each experimental drying schedule, energy consumption is being closely monitored to provide comparative costs.

The UK softwood sawmilling industry is constantly investigating new methods to improve their processing technology and the quality of material produced. The use of higher air speeds has been discussed by the UK sawmillers at several of the BRE dissemination meetings. It was felt that the possible benefits to the drying process by increasing air speeds could be easily incorporated on existing equipment with an acceptable economic outlay. This project will provide evidence of the effects this process has on the quality of timber produced, the schedule length and economics surrounding the process.

Description of the project

Background

A number of projects have been completed over the last two years on optimising the drying of UK spruce. As almost all the industrial kilns used by the UK softwood sawmilling industry have an upper ceiling to their air speeds of between 2.5 and 3.5 M/S, the incorporation of investigating the use higher air speeds has only been minimal. From the small amount of work undertaken within these projects, it is apparent that small changes to the airflow can have large influences on the drying parameters.

Work programme

The work programme consists of undertaking a series of trials to investigate how increases in airflow affect the drying of UK spruce and how these increases can be incorporated into the drying schedules used by the industry at the moment. These changes will also be assessed for energy consumption to provide information on the economic viability of the process.

Task 1. Baseline control run

Two packs of 50 x 100 x 3000 mm battens will be selected from freshly processed material from a participating sawmill. Each of these packs will be dried using a typical spruce drying schedule with specific air speeds (2 M/S and 3.5 M/S) similar to those used in industry. The dried material from both trials will be measured for distortion and moisture content uniformity at BRE to ensure similarity of drying conditions. The schedules utilised in this work task will form the baseline with which subsequent experimental trials will be compared.

Task 2. Accelerated air speed trials

This work task will consist of approximately 8 drying trials. Each experimental trial will see an increase in airspeed of 0.5 M/S, from 2 M/S to 6 M/S (or higher if possible). Each trial will consist of an experimental trial and control trial (undertaken using the baseline schedule). The material used in each trial will come from the same pack to allow comparisons between schedule length and drying quality to be undertaken. The timber from each trial will be measured for distortion and uniformity of moisture content. On completion of the task, a dissemination workshop will be organised to distribute findings to all participating partners.

Task 3. Further investigation

Depending on the results obtained from the first programme of trials, further trials will be undertaken to verify the initial results. This work task will also be used to optimise the airflow throughout the schedule (in normal schedules, the airflow is not constant throughout the drying cycle, but varies depending on the drying phase). Results obtained from this set of trials will allow more precise recommendations to be made on the best airflow levels to be used during the drying of spruce.

Task 4. Energy consumption

During each kiln trial, the energy requirements of both the fans and heat generation will be monitored and recorded. This will enable a comparison to be made between the expected improvements in drying and the energy requirements of both the fans and changes in heat energy requirements.

Task 5. Dissemination

Dissemination will be an ongoing process throughout the project. At it's close, a final report will be produced which summarises the results, conclusions and recommendations derived from the individual work tasks undertaken. Six short progress reports will be produced over the course of the project to keep funders and partners abreast of the project progress.

A dissemination meeting will be organised at the mid-point of the work tasks, to report progress and results to date. On completion of the project, a workshop will be organised and results from the project presented.

Project progress

The work tasks within this project were designed to investigate how increases in airflow affect the drying of UK spruce. In order to undertake these investigations, a series of trials were initiated in BRE's experimental conventional kiln. Prior to starting the project, an investment of over £20,000 was made to install a new boiler and high pressure humidification system. During refurbishment, meters were also fitted to monitor and record the energy consumed during each kiln trial. This data will provide valuable information on whether raising the air flow results in an increase or decrease in energy consumption during the drying process.

Task 1. Baseline control trials

Task 1 of the work programme consisted of undertaking two information collection trials to select a suitable schedule for use as a base-line control schedule for use in work task 2. Freshly processed spruce (50 x 100 x 4800 mm) was kindly supplied by Adam Wilson & Son's, Troon. On arrival at BRE the material was coded, cross-cut and moisture content samples removed, prior to being mixed and re-stacked to form two near identical packs. The first pack was dried using a kiln schedule (figure 1) similar to that used by one of the industrial partners in a previous drying project.

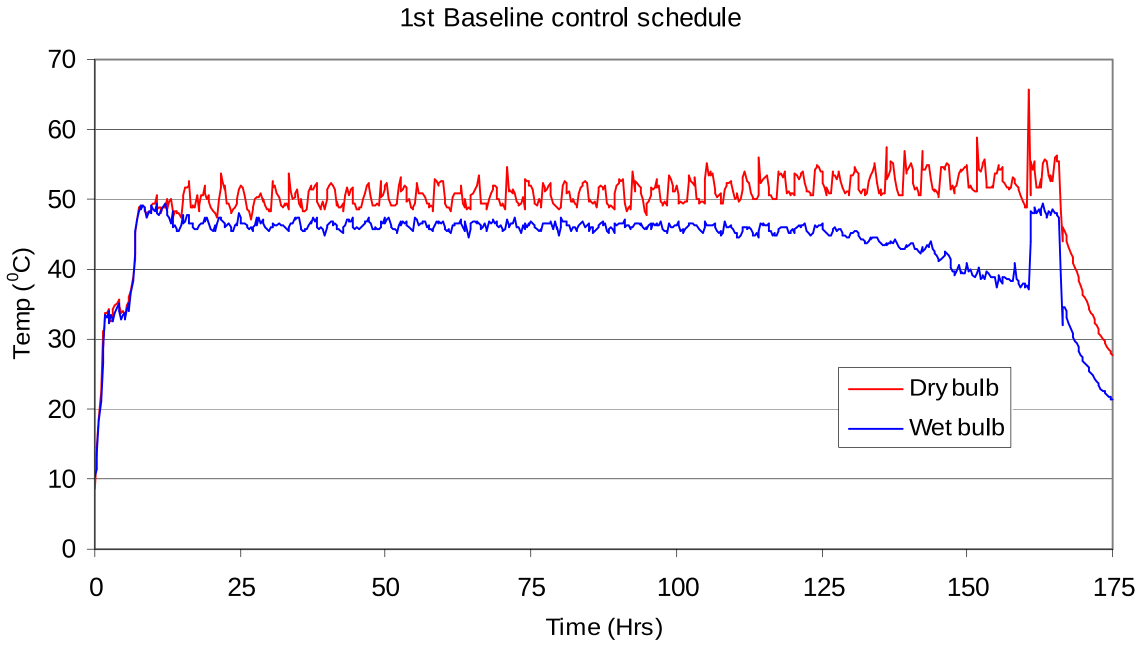

Figure 1. First baseline control schedule

On completion of the first trial, it was identified that the schedule was much longer than most of those used by other industrial partners, and with only moderate drying occurring during the initial phases of the programme. In light of these results, the schedule was further refined by removing part of the slower drying stages and widening the wet and dry bulb during the later stages in order to speed up the overall drying time.

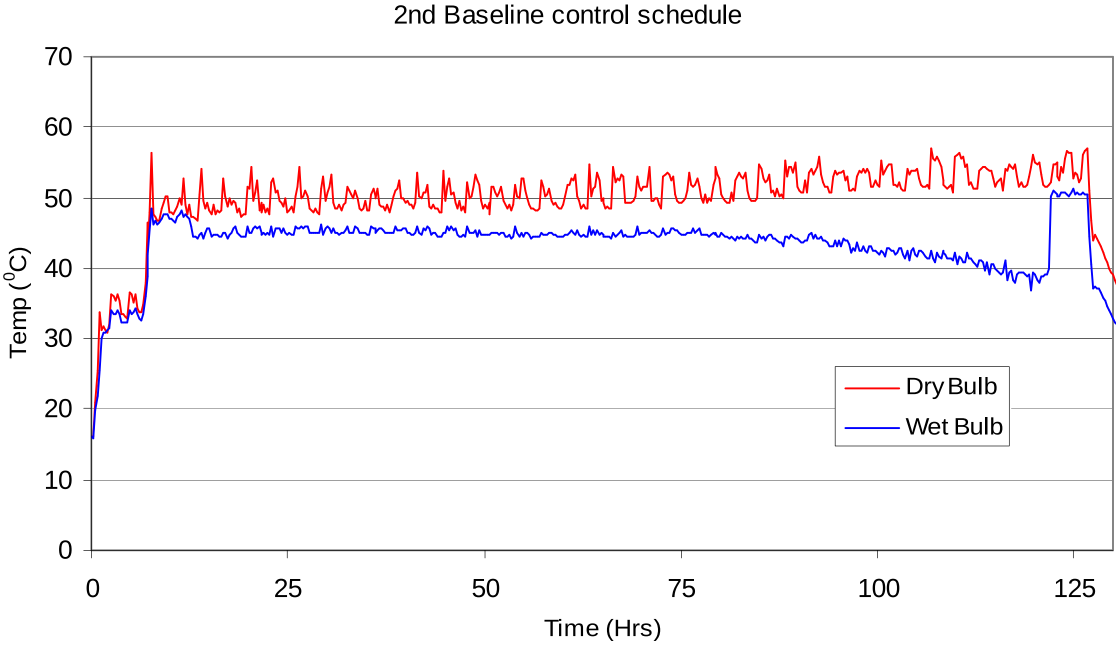

Figure 2. 2nd Baseline control schedule

Figure 2 shows the schedule after the inclusion of these changes. The changes resulted in an overall improvement in the drying time, with very small changes in the distortion values when compared with results from the first schedule (table 1). The slight difference in the distortion values can be attributed to the difference in the final average moisture contents. The first baseline schedule was undertaken with an air-speed of 4.5 m/s and the second an air-speed of 3.5 m/s.

Table 1. Average distortion values

Kiln schedule	Twist (mm)	Bow (mm)	Spring (mm)	Cup (mm)	M/C (%)
1	3.1	1.8	1.8	0.3	16.7
2	2.2	1.3	1.5	0.3	18.2

It was felt that the baseline trial 2 provided a good compromise of what was required by a control schedule. The drying was fairly fast and maximum temperatures not to high. Results from the distortion assessments indicated that the schedule did not have any adverse effects on distortion. Energy use was also reasonable (See task 4). In light of these results, baseline schedule 2 was selected as the control schedule for use throughout the remainder of the programme.

Task 2. Accelerated air speed trials

This work task consists of undertaking approximately 8 sets of control/experimental drying trials. Each of the trials will consist of one experimental trial and one control trial (undertaken using the baseline schedule). The material used in each of these trials will come from the same pack to allow comparisons to be made between schedule length and drying quality. Each experimental trial will see an increase in airspeed of between 0.5 and 1 m/s, from 3.5 m/s to 9 m/s (or higher if possible). The timber from each completed trial will then undergo measurement for distortion and uniformity of moisture content. The drying schedule used is based partly on time and partly on monitoring moisture content of the load during drying.

A summary of results from the experimental trials completed to date

As described above. Each trial consists of drying two near identical packs of spruce, one pack using the baseline control schedule with an air velocity of 3.5 m/s and one experimental pack with an initial step-wise increase in air velocity starting at 4.0 m/s. Table 2 indicates the air-speed, average green moisture content of the pack before drying, the average moisture content of the load after drying and the schedule length for each of the four sets of trials completed to date.

Table 2. Air speed and schedule length of experimental trials completed to date

Trial number	Trial type	Air-speed (m/s)	Average green M/C (%)	Final average M/C (%)	Schedule length (Hrs)
1	Control	3.5		18.4	120
	Experimental	4.0		16.7	127
2	Control	3.5		19.0	127
	Experimental	5.0		17.8	117
3	Control	3.5		16.4	123
	Experimental	7.0		15.7	125
4	Control	3.5		17.0	122
	Experimental	7.0		16.7	115

As table 2 shows, trials 3 and 4 were both undertaken with an air-speeds of 7.0 m/s. The reason for this repeat is that trial three returned similar schedule lengths for both the control and experimental schedules. Considering that the air-flow in the experimental trial was double that of the control, this result could not be explained and a decision was made to repeat the trial. Therefore trial 4 was undertaken as the repeat trial. Results from this trial show the higher air-flow experimental trial schedule length showed a reduction in drying time when compared to the control trial, although only by 7 hours.

It was decided at the start of the main work programme to undertake each experimental trial using 0.5 m/s incremental increases. As the results to date show, increases in air-flow rate of 1 m/s are resulting in fairly small decreases in schedule length. Due of these results, further trials will only be done on 1 m/s increments from 4 m/s to 9 m/s

Distortion during drying

After each trial both the control and experimental material is assessed for twist, bow, spring, cup and moisture content.

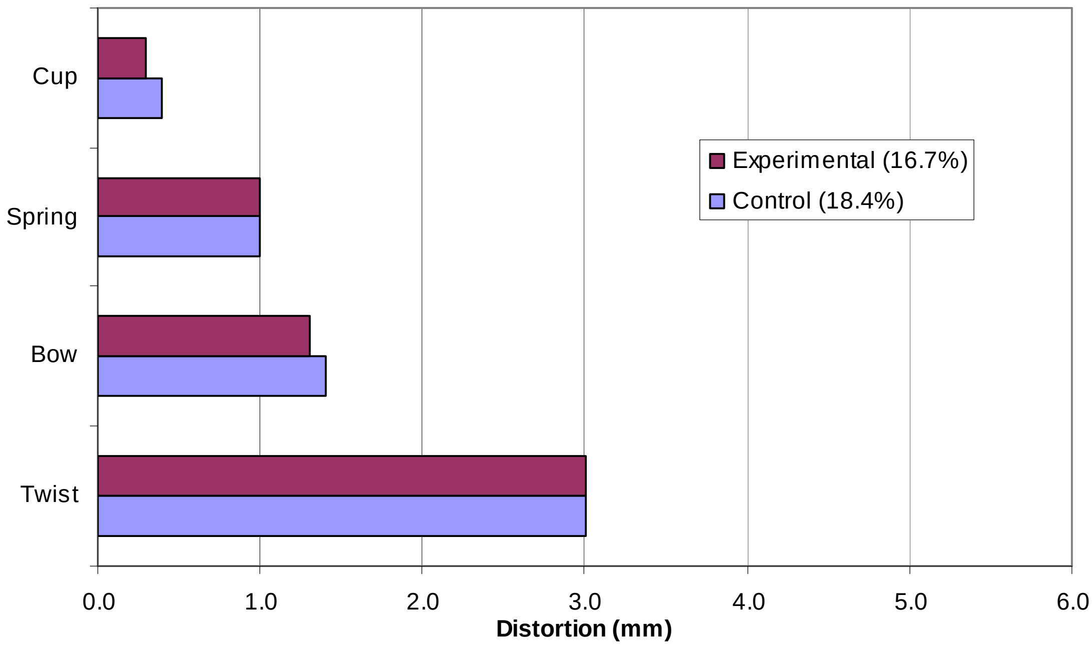

Figure 3. Average distortion values recorded on trial 1 material

Figure 3 shows the average distortion values for both the control and experimental material from the first trial. These values indicate very little change has occurred after increasing the air velocity by 0.5 m/s from that of the control material. It is also very difficult to explain why the experimental schedule had a slightly extended drying time considering the velocity increase, other than the vagaries of the computer monitoring apparatus and a slightly lower final moisture content at the finish of drying.

It is interesting to note that results from the other trials competed to date are very similar to those shown in figure 3. Whether this trend remains the same throughout the experimental trials remains to be seen. If so, this may indicate that timber quality is very closely linked to the environmental conditions within the kiln during drying.

Task 4. Energy consumption

It was planned that during each kiln trial, the energy requirements of both fans and heat would be monitored and recorded. This would enable a comparison to be made between the expected improvements in the drying process and the energy requirements of fans, boiler and associated equipment required to generate these improvements.

Figure 4 indicates the total energy requirement from the first and second baseline control trials. The heat for the kiln is generated by a gas fired hot water boiler. The fans and associated equipment (pumps, control unit & humidification unit) are powered by electricity. The legend contained in the graph identifies the trial number and drying time in hours.

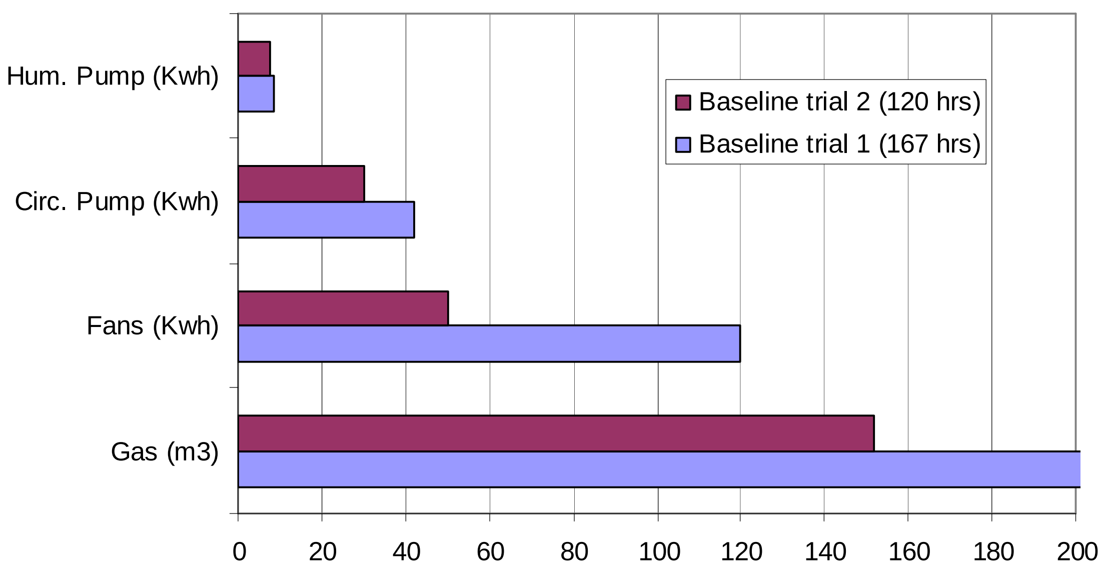

Figure 4. Comparison of energy consumption during the baseline control trials

Figure 4 indicates how much more energy is required when a kiln schedule is extended for any significant period. Baseline schedule 1 was completed in 167 hours and baseline schedule 2 in 120 hours. As expected, gas consumption in schedule 1 has increased due to the extra heat requirement of a longer schedule. Although the most significant factor shown, is the increase in fan Kwh required due to schedule 1 being undertaken with an air velocity of 4.5 m/s and schedule 2 with 3.5 m/s. As the fans in the experimental kiln are fitted with frequency inverters, a reduction in fan velocity equates to a large saving in electricity consumption.

Figure 5 shows the energy consumption recorded from both the first control and experimental schedules. The fan velocity used on the control schedule was 3.5 m/s and the experimental schedule, 4.0 m/s. As expected, the energy use of the fans has increased slightly due to the velocity increase, whilst the gas consumption has decreased. It is not certain why the experimental trial required 127 hours of drying time, whilst the control trial was completed in 120 hours.

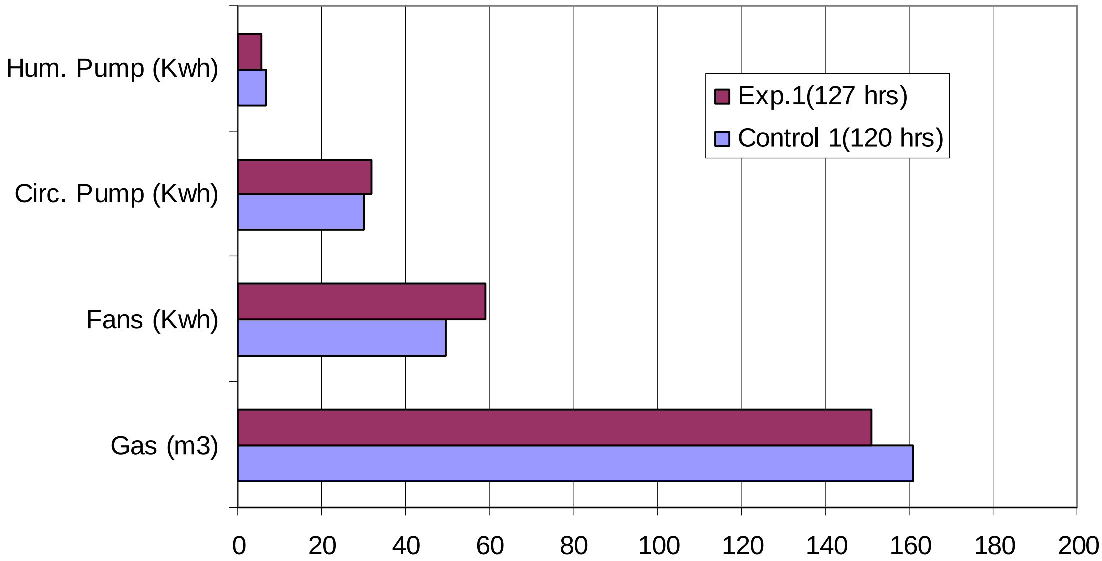

Figure 5. Comparison of energy consumption from trial 1

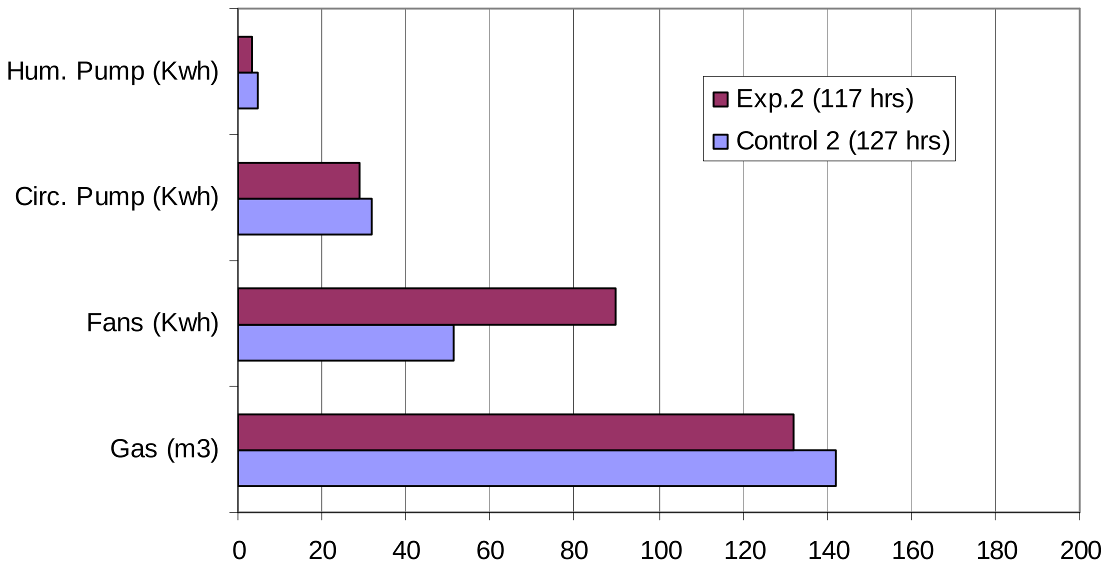

Figure 6. Comparison of energy consumption from trial 2

Figure 6 shows the energy consumption recorded from both the second control and experimental schedules. The fan velocity used on the control schedule was 3.5 m/s and the experimental schedule, 5.0

m/s. As expected, the energy use of the fans has increased significantly more than the previous experimental schedule due to the velocity increase. Gas consumption has decreased, mainly due to the decrease in kiln schedule length and increase in the speed of drying.

As further trials are undertaken, it is hoped that a set pattern of energy consumption will emerge which can then be linked to the increase in air velocity and distortion.

Progress summary

1. BRE's experimental kiln fitted with new boiler and humidifier
2. Energy monitoring devices fitted to record electricity and gas use
3. First baseline control trials completed successfully
4. Baseline control schedule selected for future experimental trials
5. First set of accelerated air speed trials completed (air velocity: 4.0 m/s)
6. Distortion measurements undertaken
7. Dissemination of results to UK sawmillers and project funders (5^{th} June 2007)
8. Second accelerated air speed trials completed (air velocity: 5.0 m/s)
9. Distortion measurements undertaken & analysed
10. Third accelerated air speed trials completed (air velocity: 7.0 m/s)
11. Fourth accelerated air speed trials completed (a repeat of trial 3 with air velocity: 7.0 m/s)
12. Material requested for subsequent experimental trials

Future Work

The coming months will concentrate on the completion of the remaining trials within workpackage 2. Depending on the results, further trials will be required, mainly due to un-expected anomalies appearing during the start of the trials. The results gained from the project to date confirm some of our initial thoughts. Increasing the air speed seems to result in a reduction of the drying time. In turn, this reduces the consumption of gas used to produce the heat. As the project progresses, it should be possible to calculate whether the savings in drying time are off-set by the costs of increasing the air speed, or that increasing the air-speed past a given point results in little or no improvement in drying times. The effect these changes have on wood quality will also require careful analysis.