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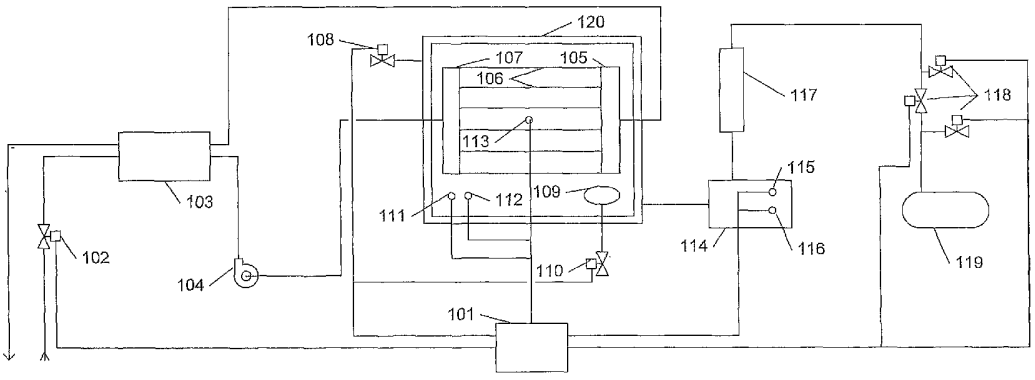
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(54) Title: TIMBER CRYING APPARATUS, METHOD AND SYSTEM



(57) Abstract: A timber drying apparatus for drying of timber in a controlled environment, wherein the timber drying apparatus includes: a) vacuum enclosure for accommodating and drying timber placed within the vacuum enclosure; b) heating support means for supporting and layering of timber between the heating support means, wherein the heating support means when within the vacuum chamber are adapted to transfer heat to the timber; and c) control means for controlling the environment and the rate of drying of the timber within the vacuum enclosure. In use, the environment within the vacuum enclosure is adapted to be controlled by the control means by monitoring and controlling the vapour pressure in the wood, the enclosure pressure, humidity and timber moisture content so as to precisely control the rate of evaporation of moisture from the timber so as to avoid drying defects in the timber.

WO 2006/028388 A1

TIMBER DRYING APPARATUS, METHOD AND SYSTEM

Field of Invention

This invention relates to a timber drying apparatus, method and system for drying timber, typically hardwoods such as beech, in particular but not limited to freshly harvested beech.

Background of Invention

After a tree is harvested and sawn into usable dimension, it is usually necessary to remove most of the water from the wood. This reduces the weight but, more importantly, it stabilizes the size of the finished dimension. Without this stabilization, the wood can not be used for most construction or manufacturing.

Removing the excess water from some species of trees is very difficult. With some species, the drying requires so much time that the cost is prohibitive. With some species, the loss of yield from drying defects makes utilization cost prohibitive. If a species requires a long drying process and has high loss of material, it will not be utilized regardless of how many desirable traits the wood might have.

Hardwood timbers and some softwood timbers have great difficulty in being able to be kiln dried in a timely economic method. There are hardwoods which have very good qualities and appeal but are difficult to kiln dry and require 12 months and longer air drying down to below 30% moisture content before kiln drying. The timber develops cell collapse, internal checking, twist and misshaping plus great loss of dimension.

Generally drying wood is currently done by 'air-drying' or use of a wood dry kiln or a combination of the two. Air-drying uses a minimum of equipment. The wood is piled with spacers (called stickers) that allow air flow through the pile. The pile is shaded and slowly dries. There are a number of disadvantages. Colour of the wood can be significantly degraded. Stains are another problem. Cracks can develop in the ends and on the surfaces. And, if the wood is a difficult species, the drying time can run into a year or more.

The commercial desire of drying wood in a vacuum is more than 30 years old: since the boiling point of water is lowered when atmospheric pressure is reduced, water should be boiled out at low temperature. If the wood was kept cool, it was thought it couldn't be damaged.

As early vacuum kiln builders soon found out, nothing could have been farther from the truth. End checks, surface checks, warped wood, wet wood and even honeycomb plagued the process. One early problem was the transfer of heat. Some abandoned hot-water heating plates and attempted a method of alternating a heating cycle at atmospheric pressure and vacuum. Some tried RF. Some continued with heating plates but tried to overcome the heat transfer problem with excessively high temperatures. Still others have given up on low pressure and leave just enough pressure to circulate 'steam' with fans.

There are many variations of the 'conventional' wood dry kiln and the similar dehumidification dry kiln. In all of these kilns, drying is controlled by setting air speed, temperature and humidity inside the kiln chamber. All of these kilns dry in the same way – the moving air picks up water from the surface of the wood. In order to obtain a movement from the wetter core of the wood, the surface must be dryer. With the most difficult species, the surface can become over dried. This leads to structural stresses that degrade (loss in yield). Degrade can include surface cracks, internal cracks, wet pockets, warp and cell collapse.

Another type of kiln is referred to as 'vacuum' dry kilns. There are many variations but they share one principle – when ambient pressure is reduced, the boiling point of water is reduced. Early attempts at building vacuum kilns were failures because the pioneers mistakenly thought that, if the wood was kept cool by maintaining low ambient pressure, water could be safely boiled off without degrade. It became apparent that heat transfer and variations in wood density create problems.

To date there have been varying degrees of success with difficult to dry species notably Red Beech in New Zealand. Air drying followed by conventional kiln or dehumidification drying were the main methods used. Recently vacuum kilns have

been used and approached in the same manner with air drying until the moisture content reached about 30% and then vacuum kiln dried.

As stated above, the results to date when drying difficult hardwoods has been poor. This has meant species such as Red Beech in New Zealand has not been commercially used except for fencing and such uses. Where it has been used in farm huts, stock shelters, etc., it has performed in some amazing ways and has proven the qualities of the timber. However, the problems with drying Red beech remain. The methods used to date for the relatively small volume in commercial use has been air dried for up to 18 months and then kiln dried, with all the problems stated above.

Objects of Invention

It is an object of the invention to provide a timber drying apparatus, method and system for drying timber, typically hardwoods such as beech, in particular but not limited to freshly harvested beech, that ameliorates some of the disadvantages and limitations of the known art or at least provides the public with a useful choice.

Statement of the Invention

In one aspect the invention resides in a timber drying apparatus for drying of timber in a controlled environment, wherein the timber drying apparatus includes:

a) vacuum enclosure for accommodating and drying timber placed within the vacuum enclosure;
b) heating support means for supporting and layering of timber between the heating support means, wherein the heating support means when within the vacuum chamber are adapted to transfer heat to the timber; and
c) control means for controlling the environment and the rate of drying of the timber within the vacuum enclosure,

wherein, in use, the environment within the vacuum enclosure is adapted to be controlled by the control means by monitoring and controlling the vapour pressure in the wood, the enclosure pressure, humidity and timber moisture content to precisely control the rate of evaporation of moisture from the timber so as to avoid drying defects in the timber.

Preferably the drying timber apparatus is adapted to prevent cell collapse, internal checking, twisting, misshaping, loss of dimension and cracking.

Preferably the heating support means are platens, typically heating platens.

Preferably, the control means constantly monitors and controls the vapour pressure, enclosure pressure, humidity and timber moisture content.

Preferably, the vapour pressure and enclosure pressure are balanced by the control means so that the rate of vaporization of water within the timber can be varied.

Preferably, the control means sets the vapour pressure and enclosure pressure. Furthermore, hysteresis of the enclosure pressure allows vaporization rate of water within the timber to vary cyclically resulting in affecting the heat transfer between the heating platens and the timber and equalising of the moisture gradients in the timber.

Preferably, the enclosure pressure varies cyclically over a pressure set point, wherein the pressure set point insures the timber is kept at low temperatures during drying.

Preferably, the balancing of the vapour and enclosure pressures lowers the boiling point of the water in the wood.

Preferably the boiling point in the wood is lowered to less than 40^0C.

Preferably, the cycling alternates between periods of slower drying and increased timber temperature and periods of rapid drying.

Preferably, the vapour pressure is controlled by controlling the temperature of the heating platens.

Preferably, the heating platens are liquid filled platens that are adapted to circulation of the liquid.

Preferably, the temperature of the liquid filled platens is controlled so as to precisely maintain the vapour pressure thereby, with precisely controlled enclosure pressure to maintain the rate of vaporization at the desired rate.

Preferably, the control means controls the humidity in dependence upon the vapour and enclosure pressures so that the moisture content of wood cells at the surface of the timber being dried, is controlled to avoid premature drying at the surface of the timber.

Preferably, the vacuum enclosure is a vacuum chamber, vacuum kiln, or any other suitable vacuum enclosure.

Preferably, the control means includes a modulating valve to regulate the heat source connected to a heat exchanger, wherein the heat exchange is in circuit with the heated platens.

Preferably, control means includes a first controller, a second controller, a third controller and a fourth controller, wherein the first controller is adapted to control the vapour pressure within the timber, the second controller adapted to control the enclosure pressure within the vacuum enclosure, the third controller is adapted to control the humidity within the enclosure and the fourth controller is adapted to monitor the moisture content within the timber.

Preferably, the first controller includes a first computing means, first valve means, heat exchanger, pump means and temperature sensor in communication with the heated platens to regulate and monitor the temperature of water being circulated through the platens so as to set and control the vapour pressure of the water within the timber.

Preferably, the second controller includes a second computing means, second valve means, vacuum pump, and pressure sensor in communication with the vacuum enclosure to set, monitor and control the enclosure pressure within the vacuum enclosure.

Preferably, the vacuum pump is adapted to be connected to a condenser which is connected to a collection means for collecting liquid condensed vapour from the vacuum enclosure.

Preferably, the third controller includes a third computing means, third valve means, condenser and humidity sensor in communication with vacuum enclosure to monitor and control the humidity within the vacuum enclosure.

Preferably, the fourth controller includes a fourth computing means and sensors in communication with the collection means to monitor the quantity of water removed during drying of the timber in order to calculate moisture content of the wood so as to determine the drying rate.

Preferably, the computing means are microprocessors.

Preferably, the first valve means are modulating valves.

Preferably, the second and third valve means are actuated valves.

Preferably, the timber loaded into the vacuum enclosure is freshly harvested.

Preferably, the timber loaded into the vacuum enclosure has been harvested within two weeks of loading.

Preferably, the timber drying apparatus dries timber to the desired level of dryness within three days to three weeks of being placed in the vacuum enclosure depending upon thickness and species.

Preferably, the timber drying apparatus is able to dry all types of timber including softwoods and hardwoods.

Preferably, the timber drying apparatus is suitable for hardwoods, typically NZ Beech and/or similar species of hardwood.

Preferably the timber drying apparatus is adapted to alter the drying conditions within the vacuum enclosure from rapid drying for easy to dry timber species to slow drying for difficult timber species.

In a second aspect the invention resides in a method of drying timber in a controlled environment, wherein the method includes:

a) loading pre cut wet timber onto and in between heating platens to form a layered stack of timber to be dried;
b) loading the stack of timber into a vacuum enclosure; and
c) controlling the environment within the vacuum enclosure by constantly monitoring and/or controlling the vapour pressure of water in the wood, the enclosure pressure, humidity and timber moisture content to thereby precisely control the rate of vaporization of moisture from the timber so as to avoid drying defects in the timber.

Preferably the drying timber method prevents cell collapse, internal checking, warp and misshaping, loss of dimension and external cracking of the timber.

Preferably, balancing the vapour pressure and enclosure pressure so that the rate of vaporization of water within the timber can be controlled.

Preferably, when the vapour pressure and enclosure pressure are balanced, hysteresis of the enclosure pressure occurs to allow vaporization of water within the timber to vary cyclically resulting in affecting the heat transfer between heating support means and the timber and equalising of the moisture gradients in the timber.

Preferably, the heating support means are platens, typically heating platens, that in use timber is supported and layered between the platens, and wherein the platens are adapted to transfer heat to the timber.

Preferably, the enclosure pressure varies cyclically over a pressure set point, wherein the pressure set point insures the timber is kept at low temperatures during drying.

Preferably, the balancing of the vapour and enclosure pressures lowers the boiling point of the water in the wood.

Preferably the boiling point in the wood is lowered to less than 40^0C.

Preferably, the cycling alternates between periods of slower drying and increased timber temperature and periods of rapid drying.

Preferably, the vapour pressure is controlled by controlling the temperature of the heating platens.

Preferably, the heating platens are liquid filled platens and are circulated with heated liquid.

Preferably, controlling the temperature of the liquid filled platens so as to precisely maintain the vapour pressure of the water within the timber and thereby, with precise control the enclosure pressure, maintain vaporization at the desired rate.

Preferably, controlling the humidity in dependence upon the vapour and enclosure pressures so that the moisture content of wood cells at the surface of the timber being dried, is controlled to avoid premature drying at the surface of the timber.

In a third aspect the invention resides in a timber drying system for the drying of timber in a controlled environment, whereby the timber drying system involves dying wet timber in a vacuum enclosure in which the environment within the vacuum chamber is constantly controlled by a control means that is adapted to balance the vapour pressure and enclosure pressure, monitor and control the humidity within the vacuum enclosure and monitor the moisture content of the timber such that the environment is constantly sensed, controlled and adjusted in accordance to the rate of vaporization of moisture from the timber to avoid drying defects in the timber.

Preferably the drying timber system prevents cell collapse, internal checking, warp and misshaping, loss of dimension and external cracking of the timber.

Other aspects of the invention are described herein.

Brief Description of the Drawings

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows a schematic of the timber drying apparatus, method and system in accordance to a preferred embodiment of the invention.

Figures 2 to 12 shows schematic computer generated graphs from data logged during the drying hardwood timber in accordance to a preferred embodiment of the invention.

Description of Invention

The preferred timber drying apparatus, method and system in accordance to a preferred embodiment of the invention is shown in figure 1. The drying apparatus, method and system involves the processing of timber preferably freshly harvested timber, typically hardwoods such as NZ Beech. However other timbers are envisaged to be used such as softwood timbers and other difficult timbers.

With our preferred invention, vacuum drying is almost as simple as originally hoped. Most energy added goes toward vaporization. The drying rate closely follows the heating rate. The wood is kept cool and the process is easy to control and repeat. Quality is high and drying time is short with most species.

The preferred system increases the vapor pressure of water by ramping heat at a set rate with proportionally controlled valves. Other actuated valves precisely control the chamber pressure so the pressure gradient between the water vapor pressure and the chamber pressure is precisely controlled. A third set of actuated valves control the humidity.

Turning to figure 1. Wood is placed in a vacuum chamber (120) and is layered between heating platens (106). The control system (101) sets the vapour pressure of water in the wood by modulating valve (102) which regulates the heat source to heat

exchanger (103). Precisely controlled heating water is circulated by heating water pump (104) and monitored by temperature sensor (113) through manifolds (115) and (117). Control system (101) monitors humidity with humidity sensor (111) and introduces humidity through valve (108) or decreases humidity with valve (110) through condenser (109). Control system (101) monitors chamber pressure with pressure sensor (112) and controls pressure with valve assembly (118) and vacuum pump (119). Condenser (117) converts vapour back to liquid which is collected in tank (114). Control system (101) uses level sensors (115) and (116) to determine the quantity of water removed. This quantity is used by control system (101) to calculate the drying rate and current moisture content of the wood.

A first microprocessor is used to set the vapour pressure of the water in the wood. A second microprocessor is used to set the chamber pressure. When chamber pressure equals vapour pressure, water boils. The rate of vaporization can be varied from a few bubbles to a rapid boil by balancing the two pressures. Hysteresis of the chamber pressure varies the vaporization cyclically resulting in affecting the heat transfer and effecting equalization of moisture gradients in the wood.

The invention precisely controls the drying conditions for wood in a vacuum chamber. Because the drying conditions can easily be altered, conditions can be changed from very rapid drying for easy-to-dry species to very slow drying for the most difficult species.

The use of a first microprocessor based controller to set the vapour pressure of water in the wood by precisely controlling the temperature of the water in the wood with actuated valves. The second microprocessor based controller precisely sets the ambient pressure of the vacuum chamber containing the wood using actuated valves. By carefully balancing vapour pressure against chamber pressure, the rate of evaporation is precisely controlled. In addition, a technique of varying the balance cycles the process between periods of rapid drying and periods of heating. This technique acts to minimize the moisture gradients which cause the stresses that lead to the common drying defects of warp, cracks and cellular collapse. A third microprocessor based controller that, with actuated valves, controls the humidity within the vacuum chamber. A fourth microprocessor based controller measures the

quantity of water removed from the wood and calculates both the drying rate and the current moisture content. This information is useful in setting the balance of vapour pressure and chamber pressure. All of the settings together and the changes made as the moisture is removed is known as the drying schedule. Schedules have been developed which successfully dry the most difficult to dry species of wood.

The invention operates with a reduced atmospheric pressure allowing water to vaporise at lower temperatures, thus the kiln's vacuum lowers the boiling point of water in the wood to a temperature at which the wood is kept cool during the drying process. Preferably the boiling point of the water in the wood is lowered to less than 40^0C.

The invention controls the drying of the timber by matching the waters vapour pressure and the kiln's chamber pressure. This achieved by maintaining the water vapour pressure precisely by the control of heating water circulated through platens adjacent the wood being dried, thus by maintaining the water vapour pressure precisely the chamber pressure can be controlled within the kiln to control the rate of evaporation of water.

Vacuum drying is further enhanced with constant chamber pressure cycling over a pressure set point. The pressure set point insures that the wood is kept cool. The cycling alternates the wood between periods of slower drying and increasing wood temperature and periods of rapid drying. This results in further reduction of moisture content gradients in the wood and assures that heating and vacuum are perfectly matched for the desired drying rates.

The invention includes controlling the relative humidity which allows maximum control of moisture content of wood cells at the surface of the wood being dried. The relative humidity control combined with the heating and pressure control described above allows for the drying of difficult species of timber without the cell damage, cracking and other problems experienced with conventional drying processes.

Drying time for thin material (25mm) can be as short as one fourteenth of conventional drying methods. One day in the invented vacuum kiln will typically

achieve what a conventional kiln can do in a week. For thicker wood (90mm), vacuum drying using the invented vacuum kiln is approximately twenty six times faster than conventional drying. A conventional kiln will require a year to dry thick stock that the invented kiln can do in approximately two weeks.

The method and the methodology of the invention involves green sawn timber being loaded into the vacuum kiln within two weeks of harvest. Cants or boards are milled up to 200mm thick (depending upon species) and varying widths up to 1000mm wide. Each layer will have a liquid filled platen heated, there will be a capacity to inject steam or create steam inside the vacuum kiln. The drying within a few days of harvest and the appropriate schedules dictate the various vacuum pressures, heat, moisture and humidity levels both in the wood and chamber at different stages through the drying process. The total methodology interrelated with different physical functions successfully allows the water to convert to a gaseous state and flow through to the surface and ends of the cants or boards. The ability to register, control and adjust the various physical functions together at all times brings about the drying result.

Figures 2 to 15 pertain to computer generated graphs from data logged during the drying hardwood timber.

In the Figure 2, line 51 is the heating temperature and line 52 is calculated moisture content (MC) from a Programmable Logic Controller (PLC). The PLC is given the species and load size at the beginning of the process. It can then calculate the current MC from the measured amount of water that is condensed and dumped from the system.

The line 51 shows the heating ramp. Initially, the wood is heated quickly to the temperature where evaporation will begin to be rapid. Because of good pressure control, this temperature is known and repeatable. Rapid evaporation begins around 100F (38C) if the chamber pressure is maintained around 50 torr. It is still necessary to gradually increase temperature because it's increasingly difficult to get water out of the wood as free water is removed. However, the rate of increase can be as slow as 0.1 degree per hour. The drying rate is proportional to the heating rate if chamber pressure is maintained and the wood is porous. At the end of the drying cycle, the

temperature is raised to a final point where the temperature, vacuum and (if necessary) humidity are used to bring the final MC of the wood within a narrow range despite variation in wood porosity. Figure 2 also shows the effect of hysteresis (deadband) in the pressure control. The control hysteresis creates a pressure swing above and below the setpoint. The hysteresis was increased (where line 51 widens) but the pressure setpoint was not changed. This pressure swing is the key to drying with low temperature with heating water plates. The slight oscillation that begins in the water temperature is due to the increased load on the heating system from increased drying. The PLC indicates the drying rate increased at the same time the hysteresis was increased.

Figure 2a shows the corresponding changes in chamber pressure and humidity, as a direct result of the change in hysteresis.

As long as water is evaporating at a rapid rate, the wood temperature is cycling up and down with the chamber pressure. Furthermore, as can be seen in Figures 3 and 4, graphs of wood temperature through the entire drying process, the wood temperature is held down by evaporation until some of the free water is removed. Even though the heating water temperature increases linearly, the increase of wood temperature follows the decrease in MC. Not until the MC is under 30% will the wood temperature begin to approach the heating water temperature.

Figure 5 has the chamber pressure recorded in red and the humidity sensor in blue. Figure 6 displays wood temperature.

There is a steady increase in chamber pressure in the 'vac off' side of the cycle. During this pressure increase, the wood temperature and kinetic energy of water in the wood increase. Note that humidity is held down by the in-kiln condenser. At the end of the 'vac off' half-cycle, the pressure is pulled down in the 'vac on' half-cycle. As decreasing chamber pressure approaches the vapor pressure of the water in the wood, evaporation becomes very rapid. The humidity sensor detects this increase in water vapor. Water increases approximately 1600 times in volume at 760 torr when it changes from liquid to gas, and because of this increased volume the vacuum pump's pull on pressure slows at the bottom of the cycle. The vacuum pump's rated capacity

also decreases as pressure decreases. On the downward slope of the red line (chamber pressure), at the point where pressure stopped going down, the PLC had interrupted the vacuum to dump condensed water from the system. Then the pull was continued to the bottom of the 'vac on' half-cycle.

In Figure 6, the increase in chamber pressure allows an increase in wood temperature. This graph additionally shows a peak from the RTD at the same time that the reading from humidity sensor peaks, on the downslope of the 'vac on' half-cycle. This peak is the result of increased heat transfer due to the avenue provided by the initial increase in water vapor concentration between the heating plates and wood. Vacuum is an insulator but water vapor from the wood has replaced the local vacuum. Another parameter that needs to be controlled in vacuum drying is humidity. When wood is being dried in vacuum the RH inside the chamber is set by, among other factors, the temperature of the chamber's steel walls. Water vapor is condensed on the chamber, the steel in the chamber is heated and the RH is able to increase.

Figure 7 shows chamber pressure with numeral 53 and humidity with 54. This is at the start of a new kiln charge. Temperature is slowly ramping above 100F (38C). The pressure swings begin to pull out large volumes of vapor and humidity in the chamber rises. The proper heating and pressure control begins a very well-controlled vaporization of water which results in well-controlled drying.

Figure 8 shows an ideal start in a vacuum kiln. Line 56 is the carefully controlled chamber pressure. Line 57 shows humidity, with the chamber being filled with water vapor. Line 55 shows the wood temperature.

Figure 9 shows the effect of lowering the chamber pressure on a kiln charge as it is drying in which the point where the setpoint was lowered. The small, upward spikes in the downward slope are from the PLC dumping water from the condensate collection tank. A lot of water was pulled out on the way down to the new setpoint, with the relative humidity (RH) settling at a new concentration.

In Figure 10 on the left, the humidity is elevated by frequent shots of steam. As time progresses toward the right, the humidity in the chamber is from the wood and the

need for shots of steam disappears. At other times, evaporation is so rapid that the humidity must be lowered in the kiln.

In Figure 11, the vacuum stopped cycling because the system couldn't handle all of the water being vaporized. If this condition was allowed to continue the pressure would begin to rise, and along with it the boiling point of water and the temperature of the wood. Good control of chamber pressure, heating temperature and humidity are necessary for fast, efficient operation of vacuum kilns. In addition, this cycling between periods of rapid evaporation ('vac on' half-cycle) and periods of minimal evaporation (vac off half-cycle) gives the wood several equalization periods each hour. Stress is minimal and no conditioning is required.

In Figure 12, the schedule is maintained at the end of the load. At lines 1, 2, and 3, the kiln was stopped and MC samples from multiple squares were baked. The mean and population standard deviation was calculated from the shell, core and cross-section MC. As the schedule setpoints are maintained, the moisture content drops without increasing the standard deviation.

The invention allows for timber to be processed in a "green state" without the need of having to "air dry" the timber before drying. Also there is no need to use chemical additives or preservatives to treat the wood before or during or after drying of the wood.

Advantages

- Quick drying with few defects from the drying.
- No cell collapse
- No internal checking except around knots.
- No misshaping of the timber
- Less loss of dimension than other means of drying.
- Excellent colour and brightness unchanged from freshly cut wood.
- Exceptional strength because the wood fibre is not weakened with high temperature.
- The system creates the economies of time, loss on conversion, retention of quality and appearance.

- Allows us to market a quality timber, meeting all the environmental ideals of no chemicals in the processing or genetic changes, a completely untreated natural timber.
- Able to use timber in a "green state"
- No need for chemical treatment of the wood after drying.
- No destruction of the rays and veins in the timber

Variations

Where in the foregoing description reference has been made to integers or components known equivalents, then such equivalents are deemed to be incorporated herein as if individually set forth.

Throughout the description of this specification the word "comprise" and variations of that word such as "comprises" and "comprising", are not intended to exclude other additives, components, integers or steps.

It is to be understood that the scope of the invention is not limited to the described embodiments and therefore that numerous variations and modifications may be made to these embodiments without departing from the ambit and scope of the invention as herein defined in the appended claims.

CLAIMS

Claim 1 A timber drying apparatus for drying of timber in a controlled environment, wherein the timber drying apparatus includes:

a) vacuum enclosure for accommodating and drying timber placed within the vacuum enclosure;
b) heating support means for supporting and layering of timber between the heating support means, wherein the heating support means when within the vacuum chamber are adapted to transfer heat to the timber; and
c) control means for controlling the environment and the rate of drying of the timber within the vacuum enclosure,

wherein, in use, the environment within the vacuum enclosure is adapted to be controlled by the control means by monitoring and controlling the vapour pressure in the wood, the enclosure pressure, humidity and timber moisture content so as to precisely control the rate of evaporation of moisture from the timber so as to avoid drying defects in the timber.

Claim 2 The drying timber apparatus as claimed in claim 1, wherein drying defects in the timber adapted to be avoided by controlling the environment by the control means are cell collapse, internal checking, twisting, misshaping, loss of dimension and cracking.

Claim 3 The timber drying apparatus as claimed in any one of the preceding claims, wherein the heating support means are platens.

Claim 4 The timber drying apparatus as claimed in claim 3, wherein the platens are filled with a liquid that is adapted to circulate within the platen and the liquid is adapted to be heated to heat the platens such that said transfer of heat to the timber is able to take place.

Claim 5 The timber drying apparatus as claimed in any one of the preceding claims, wherein the control means constantly monitors and controls the vapour pressure, enclosure pressure, humidity and timber moisture content.

Claim 6 The timber drying apparatus as claimed in claim 5, wherein, the vapour pressure and enclosure pressure are balanced by the control means so that the rate of vaporization of water within the timber is able to be varied.

Claim 7 The timber drying apparatus as claimed claim 6, wherein the control means sets the vapour pressure and enclosure pressure to form a hysteresis of the enclosure pressure, the hysteresis allows vaporization rate of water within the timber to vary cyclically resulting in and effecting the heat transfer between the heating platens and the timber and equalising of the moisture gradients in the timber.

Claim 8 The timber drying apparatus as claimed claim 6, wherein the enclosure pressure varies cyclically over a pressure set point, wherein the pressure set point insures the timber is kept at low temperatures during drying.

Claim 9 The timber drying apparatus as claimed claim 6, wherein the balancing of the vapour and enclosure pressures lowers the boiling point of the water in the wood.

Claim 10 The timber drying apparatus as claimed claim 9, wherein the boiling point in the wood is lowered to less than 40^0C.

Claim 11 The timber drying apparatus as claimed claim 7 or claim 8, wherein, the cycling alternates between periods of slower drying and increased timber temperature and periods of rapid drying.

Claim 12 The timber drying apparatus as claimed claim 4, wherein the vapour pressure is controlled by controlling the temperature of the heating platens.

Claim 13 The timber drying apparatus as claimed claim 12, wherein the temperature of the liquid filled platens is controlled so as to precisely maintain the vapour pressure along with the precisely controlled enclosure pressure to maintain the rate of vaporization at the desired rate.

Claim 14 The timber drying apparatus as claimed in any one of the preceding claims, wherein the control means controls the humidity in dependence upon the vapour and enclosure pressures so that the moisture content of wood cells at the surface of the timber being dried, is controlled to avoid premature drying at the surface of the timber.

Claim 15 The timber drying apparatus as claimed in any one of the preceding claims, wherein the vacuum enclosure is a vacuum chamber, vacuum kiln, or any other suitable vacuum enclosure.

Claim 16 The timber drying apparatus as claimed in any one of the preceding claims, wherein the control means includes a modulating valve to regulate the heat source connected to a heat exchanger, wherein the heat exchange is in circuit with the heated platens.

Claim 17 The timber drying apparatus as claimed in any one of the preceding claims, wherein the control means includes a first controller, a second controller, a third controller and a fourth controller, wherein the first controller is adapted to control the vapour pressure within the timber, the second controller adapted to control the enclosure pressure within the vacuum enclosure, the third controller is adapted to control the humidity within the enclosure and the fourth controller is adapted to monitor the moisture content within the timber.

Claim 18 The timber drying apparatus as claimed in claim 17, wherein the first controller includes a first computing means, first valve means, heat exchanger, pump means and temperature sensor in communication with the heated platens to regulate and monitor the temperature of water being circulated through the platens so as to set and control the vapour pressure of the water within the timber.

Claim 19 The timber drying apparatus as claimed in claim 18, wherein the second controller includes a second computing means, second valve means, vacuum pump, and pressure sensor in communication with the vacuum enclosure to set, monitor and control the enclosure pressure within the vacuum enclosure.

Claim 20 The timber drying apparatus as claimed in claim 19, wherein the vacuum pump is adapted to be connected to a condenser which is connected to a collection means for collecting liquid condensed vapour from the vacuum enclosure.

Claim 21 The timber drying apparatus as claimed in claim 20, wherein the third controller includes a third computing means, third valve means, condenser and humidity sensor in communication with vacuum enclosure to monitor and control the humidity within the vacuum enclosure.

Claim 22 The timber drying apparatus as claimed in claim 21, wherein the fourth controller includes a fourth computing means and sensors in communication with the collection means to monitor the quantity of water removed during drying of the timber in order to calculate moisture content of the wood so as to determine the drying rate.

Claim 23 The timber drying apparatus as claimed in claim 22, wherein the computing means are microprocessors.

Claim 24 The timber drying apparatus as claimed in claim 23, wherein the first valve means are modulating valves.

Claim 25 The timber drying apparatus as claimed in claim 24, wherein the second and third valve means are actuated valves.

Claim 26 The timber drying apparatus as claimed in any one of the preceding claims, wherein the timber drying apparatus is suitable for drying freshly harvested timber.

Claim 27 The timber drying apparatus as claimed in claim 27, wherein the timber drying apparatus is suitable for drying timber that has been harvested within two weeks.

Claim 28 The timber drying apparatus as claimed in any one of the preceding claims, wherein the timber drying apparatus dries timber to the desired level of

dryness within three days to three weeks of being placed in the vacuum enclosure depending upon thickness and species of the timber.

Claim 29 The timber drying apparatus as claimed in any one of the preceding claims, wherein the timber drying apparatus is adapted to dry all types of timber including softwoods and hardwoods.

Claim 30 The timber drying apparatus as claimed in claim 29, wherein the timber drying apparatus is adapted for drying hardwoods, such as New Zealand Beech and similar species of hardwood.

Claim 31 The timber drying apparatus as claimed in any one of the preceding claims, wherein the timber drying apparatus is adapted to alter the drying conditions within the vacuum enclosure from rapid drying for easy to dry timber species to slow drying for difficult timber species.

Claim 32 A method of drying timber in a controlled environment, wherein the method includes:

a) loading pre cut wet timber onto and in between heating platens to form a layered stack of timber to be dried;
b) loading the stack of timber into a vacuum enclosure; and
c) controlling the environment within the vacuum enclosure by constantly monitoring and/or controlling the vapour pressure of water in the wood, the enclosure pressure, humidity and timber moisture content to thereby precisely control the rate of vaporization of moisture from the timber so as to avoid drying defects in the timber.

Claim 33 The drying timber method as claimed in claim 32, wherein the drying timber method prevents cell collapse, internal checking, warp and misshaping, loss of dimension and external cracking of the timber.

Claim 34 The drying timber method as claimed in claim 33, wherein the method includes balancing the vapour pressure and enclosure pressure so that the rate of vaporization of water within the timber can be controlled.

Claim 34 The drying timber method as claimed in claim 33, wherein when the vapour pressure and enclosure pressure are balanced, hysteresis of the enclosure pressure occurs to allow vaporization of water within the timber to vary cyclically resulting in affecting the heat transfer between heating support means and the timber and equalising of the moisture gradients in the timber.

Claim 35 The drying timber method as claimed in claim 33, wherein the heating support means are heated platens, such that in use, timber is supported and layered between the platens, and wherein the platens are adapted to transfer heat to the timber.

Claim 36 The drying timber method as claimed in any one of claims 33 to 35, wherein the method includes varying enclosure pressure cyclically over a pressure set point such that the pressure set point insures the timber is kept at low temperatures during drying.

Claim 37 The drying timber method as claimed in claim 34, wherein the balancing of the vapour and enclosure pressures lowers the boiling point of the water in the wood.

Claim 38 The drying timber method as claimed in claim 37, wherein the boiling point in the wood is lowered to less than 40^0C.

Claim 39 The drying timber method as claimed in claim 36, wherein the cycling alternates between periods of slower drying and increased timber temperature and periods of rapid drying.

Claim 40 The drying timber method as claimed in claim 35, wherein the vapour pressure is controlled by controlling the temperature of the heated platens.

Claim 41 The drying timber method as claimed in claim 40, wherein, the heating platens are liquid filled platens and are circulated with heated liquid.

Claim 42 The drying timber method as claimed in any one of claims 33 to 41, wherein the method includes controlling the temperature of the liquid filled platens so as to precisely maintain the vapour pressure of the water within the timber and thereby, with precise control the enclosure pressure, maintain vaporization at the desired rate.

Claim 42 The drying timber method as claimed in any one of claims 33 to 42, wherein the method includes controlling the humidity in dependence upon the vapour and enclosure pressures so that the moisture content of wood cells at the surface of the timber being dried, is controlled to avoid premature drying at the surface of the timber.

Claim 43 A timber drying system for the drying of timber in a controlled environment, whereby the timber drying system involves dying wet timber in a vacuum enclosure in which the environment within the vacuum chamber is constantly controlled by a control means that is adapted to balance the vapour pressure and enclosure pressure, monitor and control the humidity within the vacuum enclosure and monitor the moisture content of the timber such that the environment is constantly sensed, controlled and adjusted in accordance to the rate of vaporization of moisture from the timber to avoid drying defects in the timber.

Claim 44 A timber drying apparatus for drying of timber in a controlled environment as herein before described with reference to the accompany drawing.

Claim 45 A method of drying timber in a controlled environment as herein before described with reference to the accompany drawing.

Claim 46 A timber drying system for the drying of timber in a controlled environment as herein before described with reference to the accompany drawing.

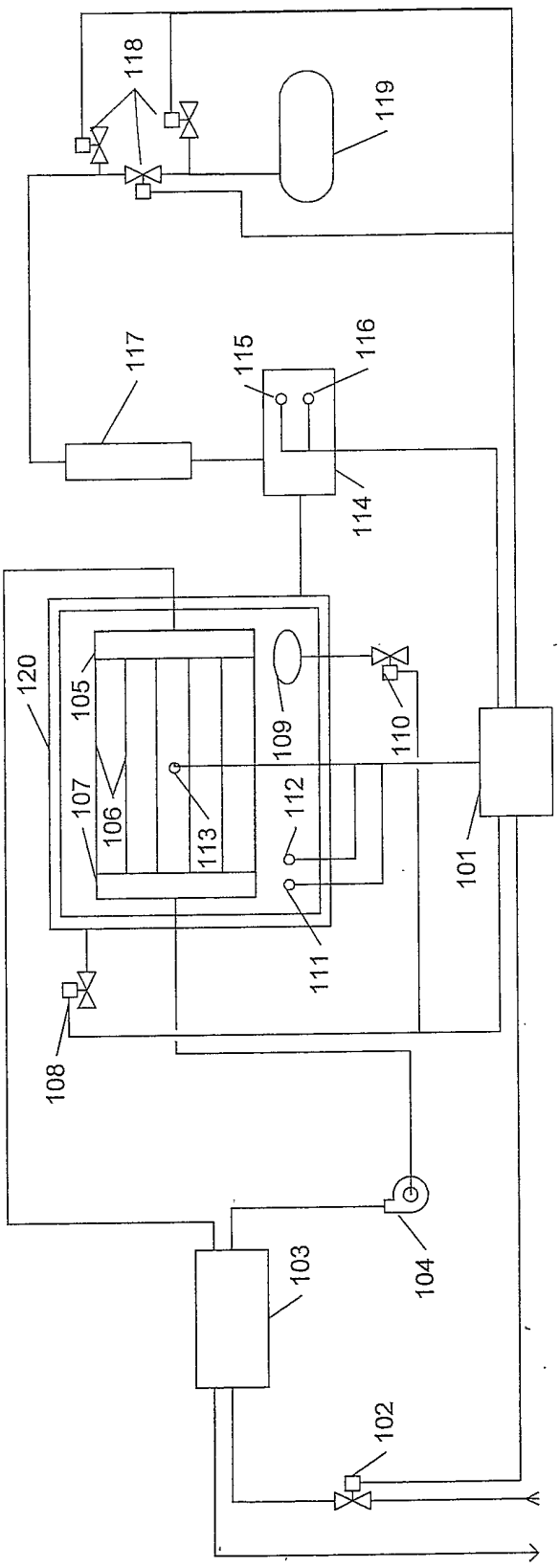

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Figure 1

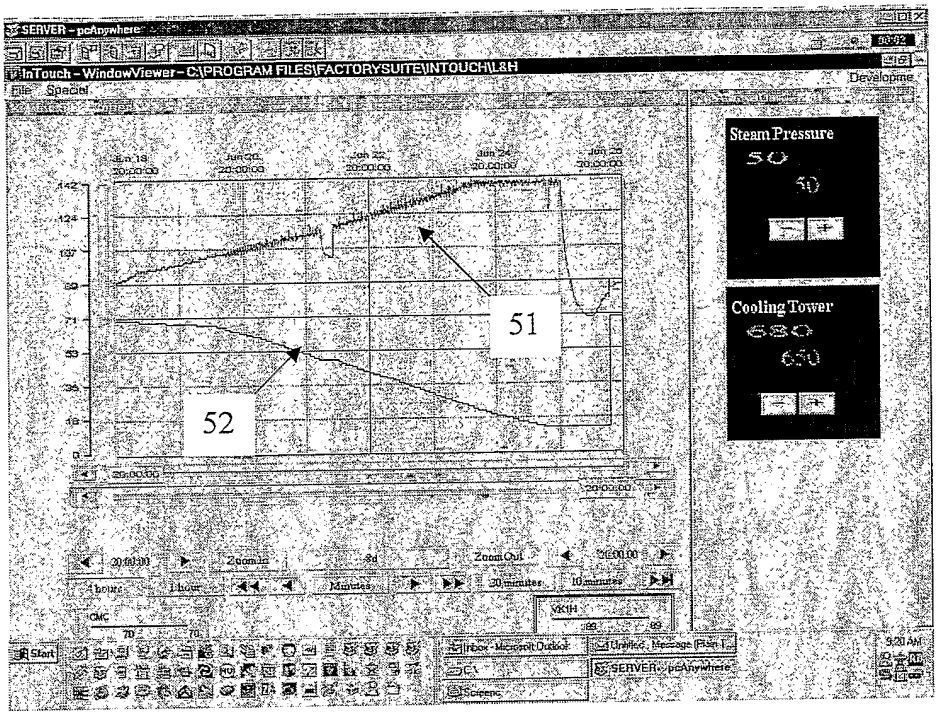


Figure 2

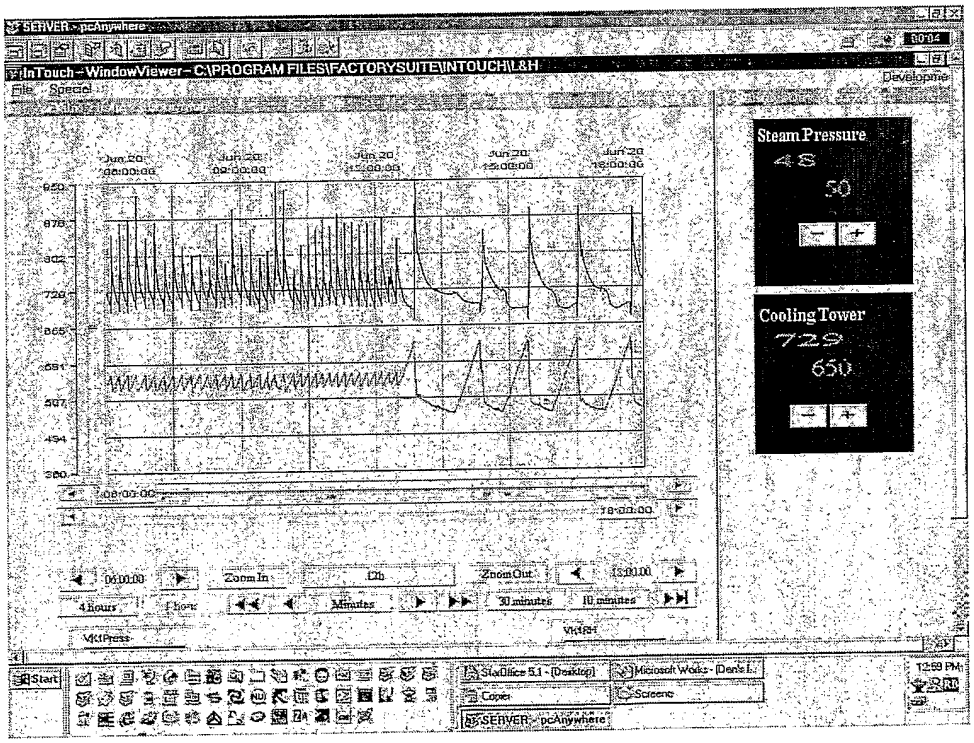


Figure 2a

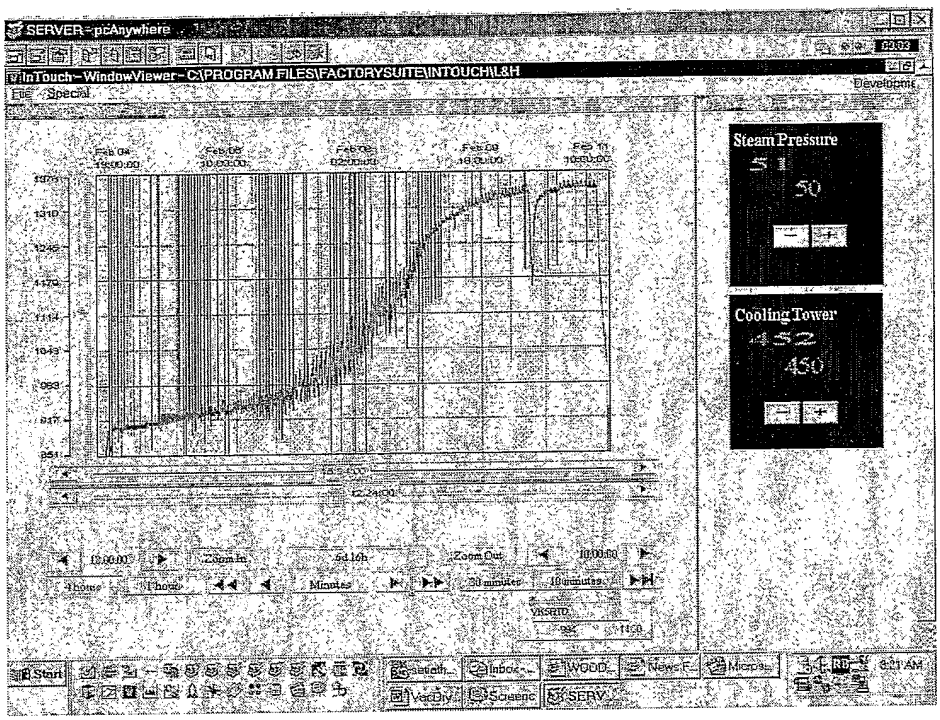


Figure 3

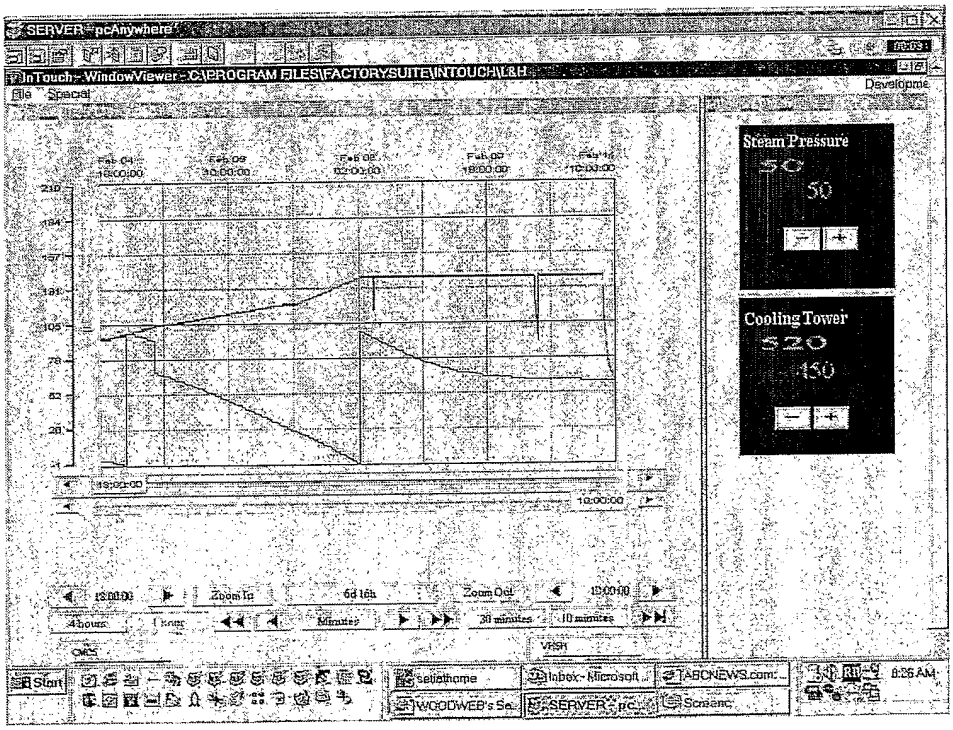


Figure 4

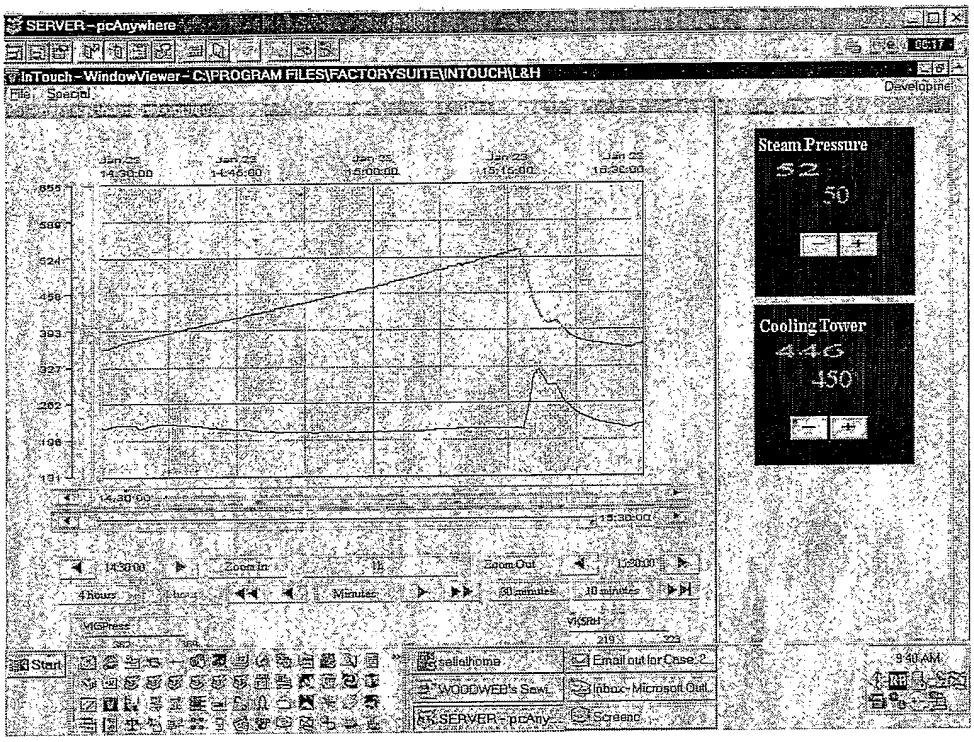


Figure 5

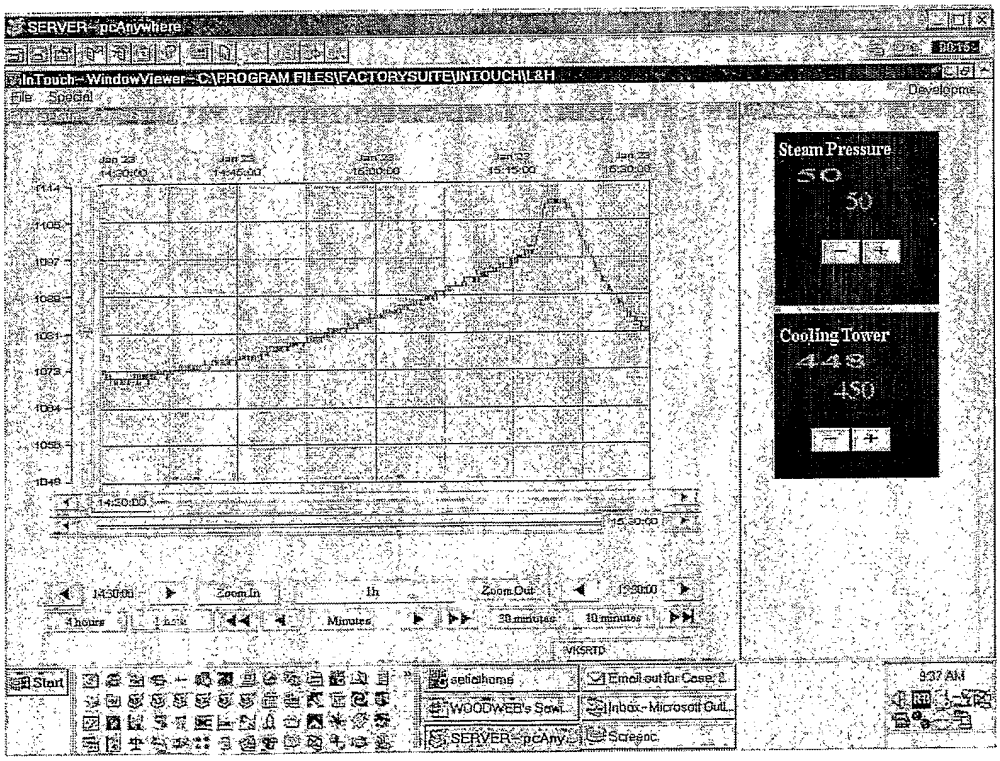


Figure 6

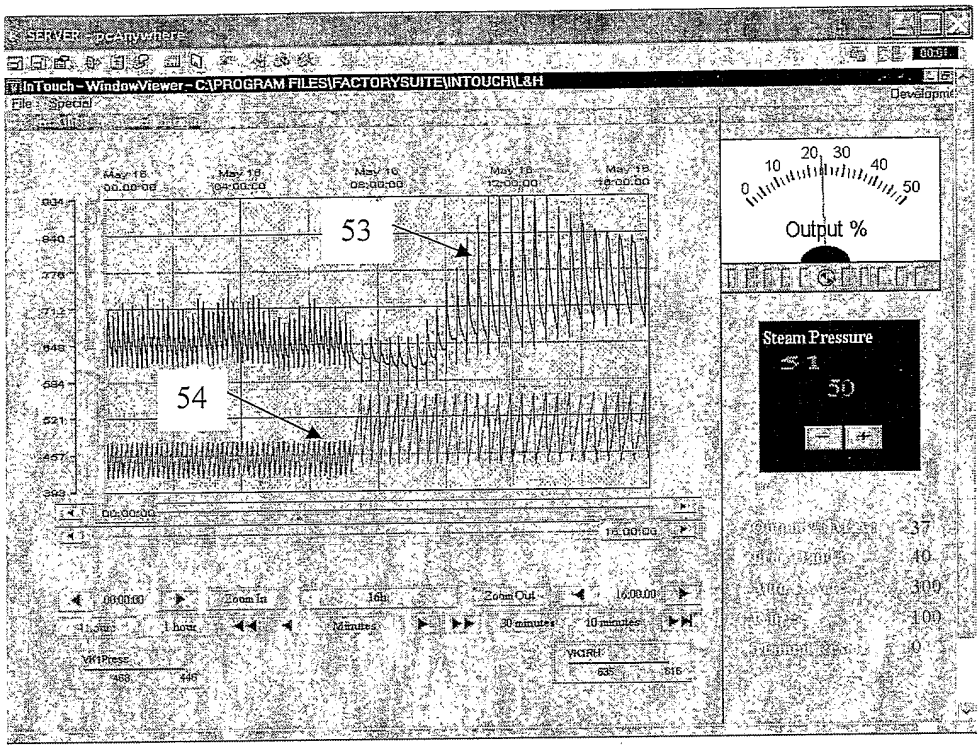


Figure 7

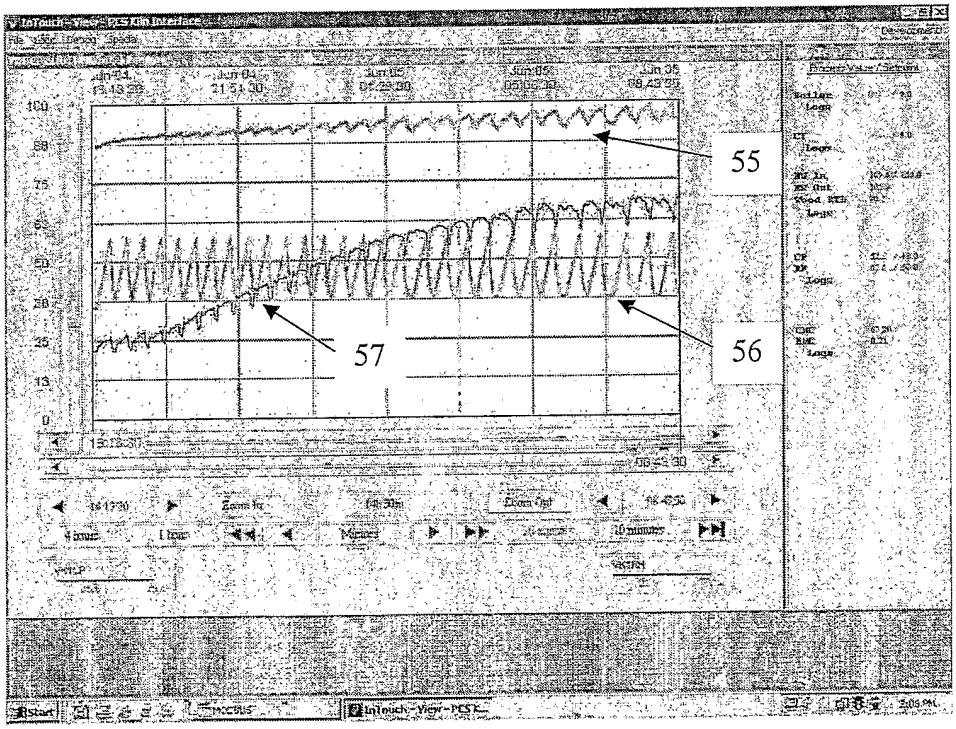


Figure 8

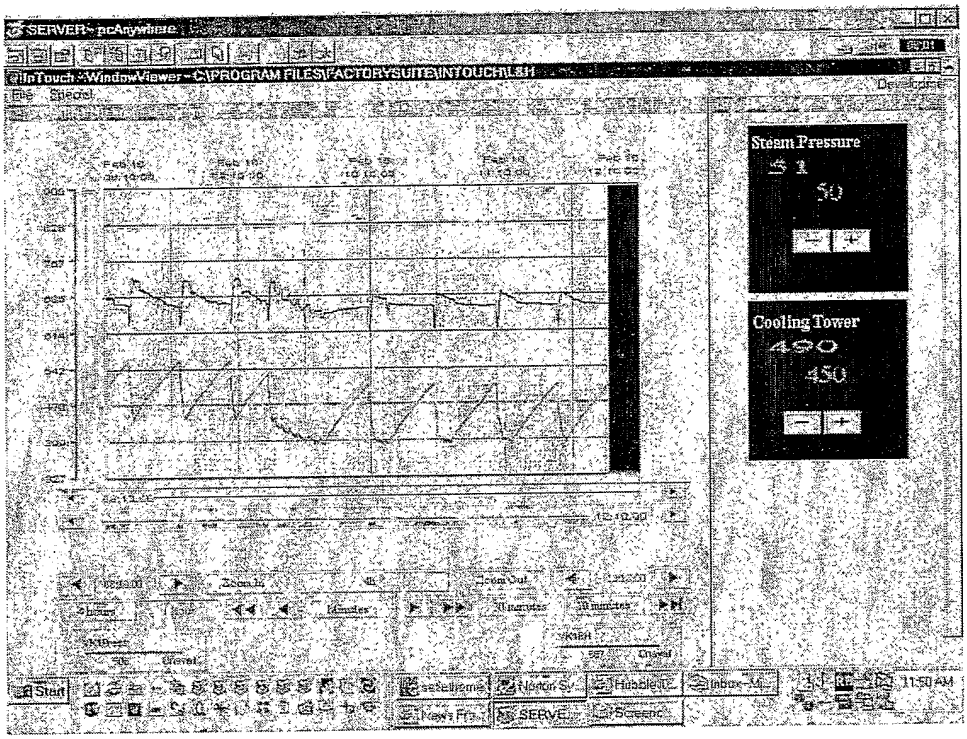


Figure 9

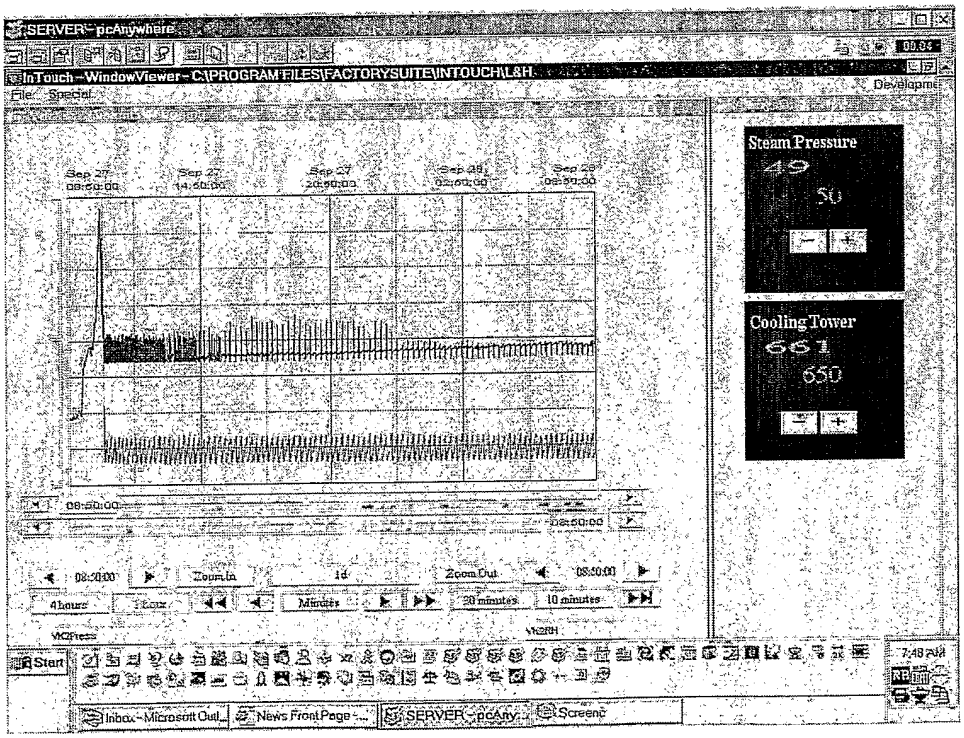


Figure 10

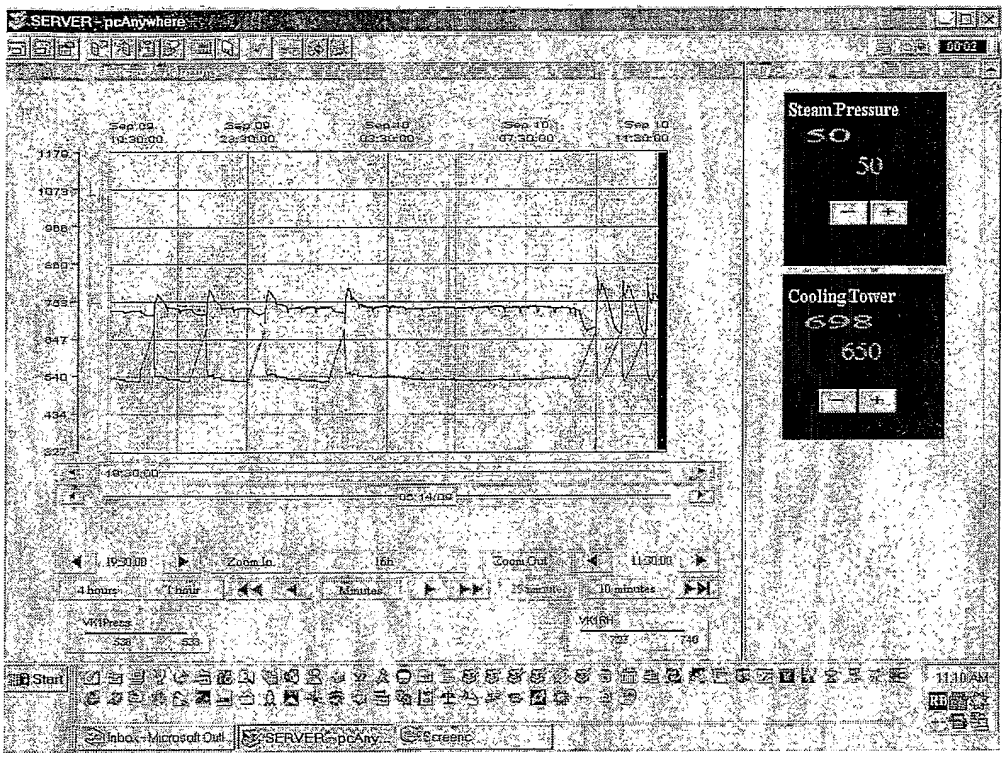
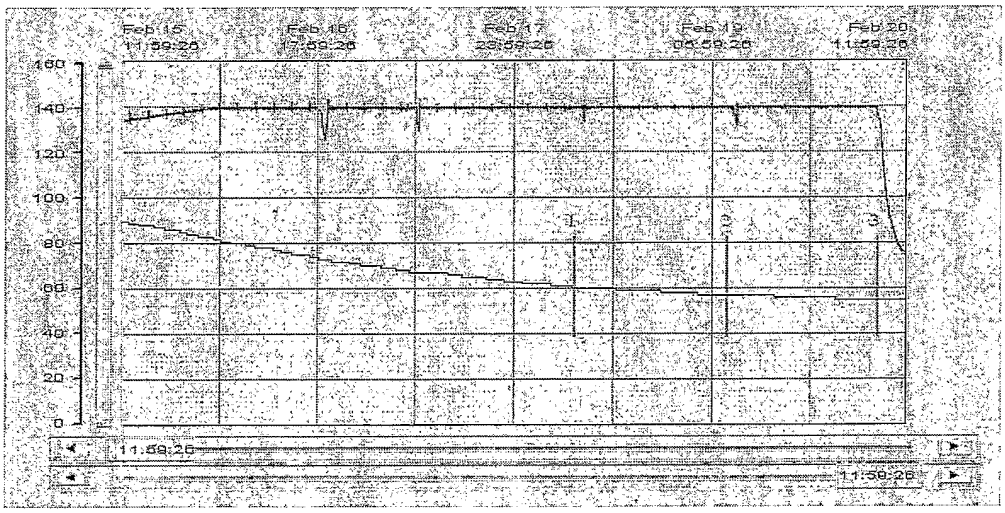


Figure 11



1 Mean: 8.8
Pop. Std. Dev.: 1.33

2 Mean: 7.1
Pop. Std. Dev.: 0.64

3 Mean: 6.5
Pop. Std. Dev.: 0.70

Figure 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ2005/000087

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: F26B 25/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Derwent DWPI: IPC F26B and keywords VAPOR VAPOUR PRESSURE HUMIDITY VACUUM

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2178149 A (H.S. JACKSON & SON (FENCING) LTD) 4 February 1987 See claim 3	
A	Derwent Abstract Accession No. 82-B7155E/07, Class Q76, SU 821880 A (MOSC FOREST TECH) 14 April 1981	
A	Derwent Abstract Accession No. 2002-421265/45, Class P63, JP 2002086407 A (SHINSAI SETSUBI KK) 26 March 2002	
A	Derwent Abstract Accession No. 98-566693/48, Class Q76, RU 2110026 C1 (ENERGY TECHN SYSTEMS DEV CENTRE) 27 April 1998	

☐ Further documents are listed in the continuation of Box C ☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
22 August 2005

Date of mailing of the international search report
26 AUG 2005

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/NZ2005/000087

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member
GB	2178149	NIL
SU	821880	NIL
JP	2002086407	NIL
RU	2110026	NIL

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX