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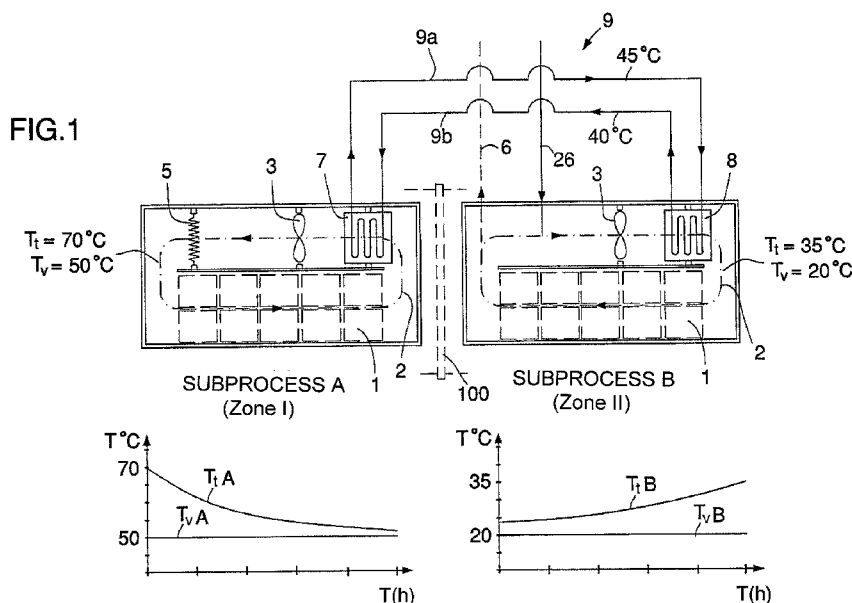
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- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
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(54) Title: METHOD FOR DRYING OF TIMBER USING WARM AIR



(57) Abstract: The invention concerns a method of drying of material, in particular timber, using warm air, where the drying process is divided into at least a first and a second subprocess (A, B), in series with each other, and the circulating flows (2) of the two subprocesses in the relevant drying chambers are conditioned to significantly different wet temperatures (TvA) and (TvB), respectively. In order to achieve a reduced energy input, the circulating air (2) in the first subprocess (A) is given a higher wet temperature (TvA) than the circulating air (2) in the second subprocess (B), and that heat in the circulating air (2) in the first subprocess (A) is re-covered and transferred to the second subprocess (B).



## METHOD FOR DRYING OF TIMBER USING WARM AIR

The present invention concerns a method for drying of material, in particular timber material collected in stacks, through flushing with a circulating flow of air, the condition of which is caused to adopt wet and dry temperatures that are suitable for the quality of the material through the supply of heat to the circulating flow of air and the withdrawal of moisture from the same by ventilation. The invention concerns also a progressive dryer working with a drying channel that is outwardly closed through which timber in the form of batches of stacked timber is fed forwards at regular intervals known as “draft intervals”.

Air is used as a drying medium to transfer heat and transport moisture, which air is circulated with a specific temperature, moisture content and rate of flow through the material with the aid of fans. The drying air is heated with the aid of an air-heating arrangement that comprises heating coils. The drying air is caused to pass through the material such that moisture and water evaporate from the material and are absorbed by the drying air. In order for the drying air that is circulated in the drying chamber, which air eventually becomes saturated with moisture, to be able to absorb more water from the material, it must be dehumidified, which normally takes place through ventilation, whereby the air is diluted with cold, relatively dry outdoor air – fresh air.

For the drying of timber either batch dryers or progressive dryers are used. The drying in a batch dryer takes place in batches in closed chambers. The dryer is filled with timber and the drying subsequently continues until the complete batch is fully dry. In progressive dryers one stack of timber at a time is fed forwards stepwise through the dryer. The drying climate varies in zones along the drying channel. The drying climate varies all the time and the drying process is adapted according to the timber to be dried, the desired final moisture content and the desired final quality. The climate in the drying chamber is controlled through regulation of pre-determined parameters such as, among other things, dry and wet temperatures. The dry temperature is controlled with the aid of regulation of the heat emitted from a heating coil, while the wet temperature is controlled through regulation of the degree of opening of ventilation openings, and possibly also watering or steam-treatment equipment. The difference in temperature between a dry thermometer and a wet thermometer reflects the relative air humidity, whereby a relatively small difference in temperature corresponds to a relatively high air humidity. In order for the wood to dry, it is necessary that the water that is bound in and around the cells is transported out of the wood. The rate of this process depends primarily on the temperature and the prevalent psychrometric difference, i.e. the difference between the dry and wet temperatures, the moisture content of the wood and the rate of flow of the air.

It is known that the energy consumption of a dryer facility during drying can be reduced by dividing the dryer facility into a number of zones and by recovering as far as is possible the heat content from one zone to another zone that has a larger requirement for heat at that moment. A heat exchanger is normally used in this case in which the ventilation is carried out in such a manner that the exhaust air (with a higher temperature) that is output from one zone is allowed to transfer part of its enthalpy to the supply air (with a lower temperature) that is input to another zone. It is known to arrange the drying channel of progressive dryers as two drying zones in the form of a preheating zone and a main drying zone, for an efficient use of energy. The heat energy in the exhaust air that is ventilated out from the main dryer is transferred with the aid of heat exchangers to the preheating zone, in which the timber is preheated before it is fed into the main drying zone for a controlled and monitored drying operation. In another case, it is known that exhaust air that is output from the main dryer can be mixed with fresh air from the surrounding atmosphere and that the resulting mixture can be used as supply air in the preheating zone, with the result that the preheating zone works with colder drying air than the main drying zone. The disadvantage of such a method that has a preheating zone with a moderate drying capacity for sawn timber material is that the risk of drying cracks becomes large, since the initial part of the drying process takes place at a relatively low temperature. A high wet temperature is desirable during this phase of the drying process, when large drying tensions in the timber easily give rise to the formation of cracks, since the wood will in this case become more plastic, and drying tensions may in this way be reduced.

Another complication that can arise during the drying of timber is what is known as "thermo tolerant moulds", which can grow on the timber and form spores during the drying process due to relatively low temperatures in the preheating stage. The mould grows and gives a grey-black discolouration of the timber that in the worst case makes it necessary to discard the timber. By maintaining a relatively high temperature of approximately 50 °C during the initial phase, which means that the dry temperature of the air will vary between 55 and 70 °C, it is possible to limit the growth conditions for fungi and moulds. A period of a few hours at these high temperatures is sufficient in this part of the process to control this.

Relatively high energy costs are to be expected in the future and thus the requirement for drying processes with low energy consumption will increase considerably. Furthermore, the requirements on the quality of the timber will increase, whereby timber with surface defects in the form of cracks or discolouration due to mould cannot be accepted.

A first purpose of the present invention, therefore, is to achieve a method for the drying of material using warm air that makes it possible to make the drying process more efficient not only in batch dryers but also in progressive dryers and in this way to achieve a reduced energy consumption.

A second purpose of the invention is to achieve a method for the drying of material using warm air

that makes it possible to avoid timber with surface defects, discolourations and mould. A third purpose of the invention is to achieve a progressive dryer that can carry out the drying process with a low energy input and that makes it possible to avoid timber with surface defects and discolourations.

5 These purposes of the invention are achieved through a method of the type that is specified in patent claim 1 and a progressive dryer according to claim 10.

As a basis for the invention lies the idea to allow a dryer to function inversely with respect to what has until now been the conventional method of drying material, which, particularly when it is a matter of timber, involves moving in a series of process stages that follow one after the other from a relatively cold drying climate to a warm drying climate. According to the principles of the invention,  
10 however, the inverse takes place, i.e. to move during the process stages from a relatively warm drying climate to a cold drying climate. The many advantages of drying material, in particular timber, in this manner will be made clear below.

One interesting application of the invention is constituted by a timber-drying channel with longitudinal circulation that is divided into two limited drying zones, connected in series, by a door  
15 that can be raised and lowered, where the subsequent second zone is regulated at a dry temperature that is lower than the wet temperature in the first zone, and where the heat consumption for the second subprocess is provided by enthalpy, in the form of heat energy from warm, moist air in the first zone, being transferred and delivered to the second zone through a heating coil arranged in the said zone. In addition to its energy efficiency, such an arrangement has considerable advantages that  
20 will be described in more detail below.

Application of the invention in a dryer facility with two processes connected in series with different levels of wet temperature provides – in addition to a considerably reduced consumption of heat – a considerably more important advantage with respect to the drying of high-quality timber in a dryer with longitudinal circulation. The condition of the drying air in a dryer with longitudinal  
25 circulation depends to a large extent on evaporation from the timber in the drying channel. Cracks and mould can be avoided due to a high temperature in the first zone. A large part of the energy can be recovered, transferred and used in the subsequent second drying zone due to the fact that no, or only a very limited, exchange of air takes place in the first zone. Another advantage is that the heat from the first zone that is stored in the timber can be used in the subsequent second drying zone.

30 The invention will be described in more detail below with reference to the attached drawings, of which:

Figure 1 shows schematically a method according to the invention in a first design where the drying process is divided into two subprocesses A, B and the use of a heat recovery system that transfers heat between the subprocesses through a heat-bearing fluid medium, and Figure 2 shows  
35 schematically a method according to the invention in a second design where the drying process is

divided into two subprocesses A, B and a heat recovery system, in which a heat recovery system that transfers heat between the subprocesses by exchanging the different flows of air of the two subprocesses is a component.

Figure 1 shows the present invention in a first design as a schematic arrangement that uses a fluid medium in order to transfer heat between subprocesses. The drying process is divided into two subprocesses A and B whereby the drying in subprocess A takes place at a relatively high wet temperature  $T_{vA}=50\text{ }^{\circ}\text{C}$ , while the drying in subprocess B takes place at a relatively low wet temperature  $T_{vB}=20\text{ }^{\circ}\text{C}$ . According to the invention, the drying in subprocess B takes place at a dry temperature  $T_{tB}$  that is lower than the wet temperature  $T_{vA}$  for the drying in subprocess A, i.e.  $T_{tB}<T_{vA}$ . The material 1 to be dried in the subprocesses is flushed in separate zones, each in a separate chamber, by circulating flows 2 of drying air, which flushing is achieved by means of fans 3. The circulating air in subprocess A is heated in conventional manner by a heating coil 5 fed by hot water. The exhaust air 6 from the subprocess B may be led out from the chamber and replaced by fresh supply air 26 that has been obtained from the surrounding atmosphere. No exchange of air normally takes place in subprocess A or, in relevant cases, only a limited such exchange takes place. Subprocess A proceeds essentially according to the principle of condensation whereby water vapour bound in the circulating drying air 2 is cooled and is condensed out in the drying zone by a condensation process.

Heat can be transferred between the two subprocesses A, B with the aid of a heat recovery system, through a heat-bearing fluid medium, whereby it should be understood that enthalpy is principally transferred from subprocess A to subprocess B. A condensation heat exchanger 7 arranged in the first subprocess A and a heating coil 8 arranged in subprocess B are components of the system. A closed circuit 9 is arranged to circulate with the aid of a circulation pump (not shown in the drawings) a heat-bearing medium between the condensation heat exchanger 7 in subprocess A and the heating coil 8 in subprocess B. The circuit runs in loops 9a, 9b for the exchange of energy between the circulating drying air in subprocesses A and B, whereby the loop 9a absorbs heat from condensed water vapour in the drying air in subprocess A and transfers this heat through the loop 9b to the heating coil 8 in subprocess B. The heat consumption for subprocess B is in this case provided through the enthalpy that has been obtained from the condensed water vapour in the circulating air from subprocess A. As has been mentioned above, normally none, or only a limited, exchange of air with the surrounding atmosphere is required at subprocess A. The combination of these two arrangements gives an extremely low consumption of heat for the drying process as a whole and, as a consequence of the relatively high temperature in subprocess A, problems with discolouration and cracks can be avoided. It should be understood that the second drying zone for subprocess B can, when necessary, be equipped with additional power, which may be constituted by a heating coil.

Figure 2 shows the present invention in a second design as a schematic arrangement that transfers heat between subprocesses by exchanging the different flows of air of the processes in a heat exchanger of, for example, countercurrent flow type or cross-heating type. Just as has been described above, the drying process is divided into two subprocesses A and B whereby the drying in subprocess A takes place at a relatively high wet temperature  $T_{vA}=50\text{ }^{\circ}\text{C}$ , while the drying in subprocess B takes place at a relatively low wet temperature  $T_{vB}=20\text{ }^{\circ}\text{C}$ . According to the invention, the drying in subprocess B takes place at a dry temperature  $T_{tB}$  that is lower than the wet temperature  $T_{vA}$  for the drying in subprocess A, i.e.  $T_{tB}<T_{vA}$ . The material 1 to be dried in the subprocesses A, B is flushed by circulating flows 2 of air that are achieved by means of fans 3. The circulating air in subprocess A is heated in conventional manner by a heating coil 5 fed by hot water. The exhaust air 16 from subprocess A is carried to the heat exchanger 14 in subprocess B and is divided after its passage through this heat exchanger into a saturated air flow 17 and a condensation flow 18. The exhaust air 19 from subprocess B is mixed with the saturated air flow 17 at 20 and the mixture is allowed to pass through an external heat exchanger 21, after which the condensate 22 is separated and the saturated air flow 23 is divided into a subflow 24, which is expelled from the facility, and a subflow 25, which is used as supply air for subprocess A with a high wet temperature. The supply air 26 to the subprocess B with low wet temperature is preheated in the heat exchanger 21. The consumption of heat for subprocess B is supplied fully or partially through the enthalpy in the exhaust air 16 from subprocess A and no separate external supply air (fresh cold air from the surrounding atmosphere) needs to be obtained for subprocess A. The combination of these two arrangements gives an extremely low consumption of heat for the overall process. It should be understood that the second drying zone for subprocess B can, when necessary, be equipped with additional power, which may be constituted by a heating coil.

During the application of the invention in a channel with longitudinal circulation with zones connected in series for the drying of timber, the drying channel is divided by means of a door 100 that can be raised and lowered into two neighbouring zones I and II, which are suggested by dashed lines in Figure 1. As has been described above for subprocess A, zone I is regulated at a high wet temperature, such as  $50\text{ }^{\circ}\text{C}$ , and, as has been described above for subprocess B, zone II is regulated at a low wet temperature, such as  $20\text{ }^{\circ}\text{C}$ . Zone II has been designed as a channel in which circulating air flows through the timber as a countercurrent flow against the direction of transport of the timber, and as concurrent flow in the first zone I. It should be realised that the specified directions of the circulating flows are given solely as examples and may be changed in practice. The circulating air in zone I is heated in conventional manner in heating coils 5. The drying air in zone I is dehumidified by passing through a condensation heat exchanger 7 located in the circulation flow in zone I, where the condensate that is formed emits heat to a heat-bearing fluid medium that passes through the

condensation heat exchanger. The heat that is emitted in zone I is transferred through a fluid medium to the heating coil 8 in zone II. Since the drying process in subprocess B takes place at a dry temperature  $T_{tB}$  that is lower than the wet temperature  $T_{vA}$  of the drying process in subprocess A, i.e.  $T_{tB} < T_{vA}$ , no extra heat supply from an external source is necessarily needed in zone II.

5           It should be understood that it would be possible for one design invention to include a combination of the two embodiments of the invention that have been described above with reference to Figures 1 and 2. That is to say, a heat recovery system that not only transfers heat from subprocess A to subprocess B through a heat-bearing fluid medium, but also a heat recovery system that transfers heat from subprocess A to subprocess B through exchanging the different flows of air  
10 from the two subprocesses, or by mixing them. It should furthermore be realised that the invention can be used at any drying system at all that can be divided into at least two subprocesses A, B, independently of whether the processes are connected to each other in parallel or in series for the transfer of heat. The invention is not limited to that which has been described above and shown in the drawings: it can be changed and modified in several different ways within the scope of the  
15 innovative concept defined by the attached patent claims.

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## CLAIMS

- 5 1. A method for drying of timber using warm air, where the drying process is divided into at least a first and a second subprocess (A, B) each in a chamber arranged in series with each other, where the timber is allowed to pass from the first to the second subprocess and where the circulating air (2) of the two subprocesses in the relevant drying chamber is conditioned to significantly different wet temperatures ( $T_{vA}$ ) and ( $T_{vB}$ ), characterised in that the circulating  
10 air (2) in the first subprocess (A) is given a higher wet temperature ( $T_{vA}$ ) than the circulating air (2) in the second subprocess (B) and in that heat in the circulating air (2) in the first subprocess (A) is recovered and transferred to the second subprocess (B).
- 15 2. A method according to claim 1, whereby the second subprocess (B) is given a dry temperature ( $T_{tB}$ ) that is lower than the wet temperature ( $T_{vA}$ ) in the first subprocess (A).
3. A method according to claim 1, whereby heat in the circulating air (2) in the first subprocess (A) is recovered and transferred to the second subprocess (B) through the circulating air (2) in the two subprocesses (A, B) exchanging heat with each other.
- 20 4. A method according to any one of claims 1-3, whereby circulating air (2) in the first subprocess (A) is dehumidified through water vapour that is bound in the circulating air being cooled and caused to condense in the drying chamber of the first subprocess (A).
- 25 5. A method according to claim 4, whereby the drying chamber of the first subprocess (A) is equipped with a condensation heat exchanger (7) with which the circulating air (2) in the first subprocess (A) can be caused to condense, the drying chamber of the second subprocess (B) is equipped with a heating coil (8) with which the circulating air (2) in the drying chamber of the second subprocess (B) can be heated, and that a heat-bearing medium is caused to circulate  
30 between the condensation heat exchanger (7) in the first subprocess (A) and the heating coil (8) in the second subprocess (B).
- 35 6. A method according to claim 1, whereby heat in the circulating air (2) in the two subprocesses (A, B) is recovered and transferred through exhaust air flows from the two subprocesses being mixed (20) with each other and caused to pass through a heat exchanger (21) that is common to the processes for the preheating of the supply air (26) to the second subprocess (B) and,

after passage through the heat exchanger (21), to constitute supply air for the first subprocess (A).

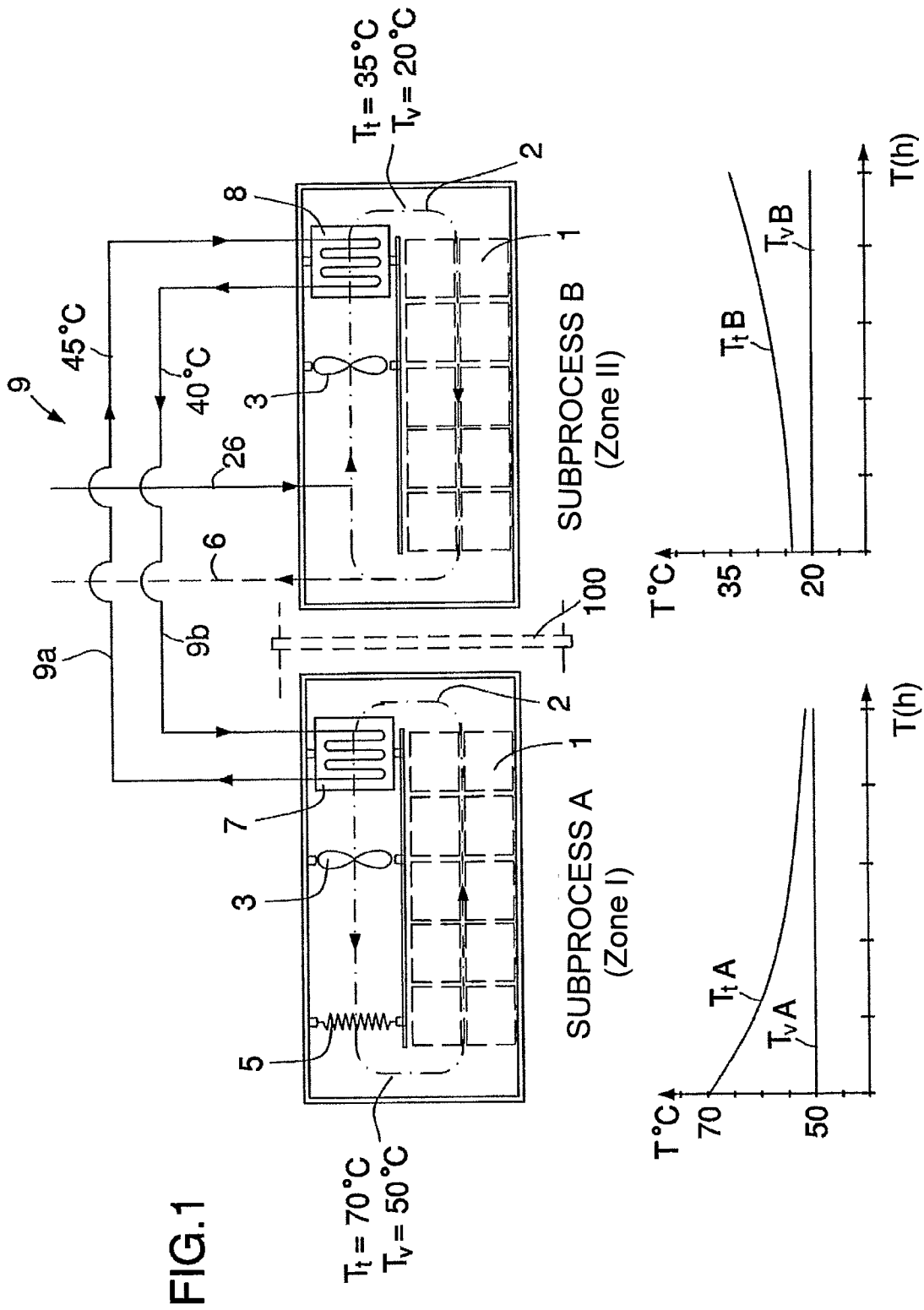
- 5 7. A method according to claim 6, whereby heat is transferred between the two subprocesses (A, B) through the use of a heat exchanger (14, 21) of, for example, countercurrent flow type or cross-heating type, in order to exchange the flows of air that include supply air and exhaust air (25, 26; 16, 19) between the subprocesses.
- 10 8. A method according to any one of claims 1-7, whereby a heat recovery system is used that not only transfers heat from the first subprocess (A) to the second subprocess (B) through a heat-bearing medium of, for example, a fluid in which the circulating air (2) in the first subprocess (A) is dehumidified through water vapour that is bound in the circulating air being cooled and caused to condense in the drying chamber of subprocess (A), but also a heat recovery system that transfers heat from the first subprocess (A) to the second subprocess (B) through  
15 exchanging the different flows of air of the two subprocesses that include supply air and exhaust air (25, 26; 16, 19) between the subprocesses.
- 20 9. A method according to claim 8, whereby heat in the circulating air in the two subprocesses (A, B) is recovered and transferred through exhaust air flows from the two subprocesses being mixed (20) with each other and caused to pass through a heat exchanger (21) that is common to the processes for the preheating of the supply air (26) to the second subprocess (B) and, after passage through the heat exchanger (21), to constitute supply air for the first subprocess (A).
- 25 10. A progressive dryer functioning with an outwardly closed drying channel through which timber in the form of batches (1) of stacked timber are fed forwards at regular intervals, known as "draft intervals", such that a batch of timber with loaded moist timber is fed into the channel at the same time as a batch of timber for which the drying process has been completed is fed out from the channel, whereby the batches of timber are swept over and permeated by drying  
30 air (2) that circulates in the drying channel, characterised in that the progressive dryer comprises a door (100) that can be opened by which the drying channel, when the door is closed, is divided into a first and a second drying zone (I, II) each one of which forms a chamber that works with circulating drying air, whereby batches of timber (1) are allowed to pass from the first to the second drying zone when the door (100) is in its open condition, that each  
35 chamber is provided with equipment (5, 7, 8; 5, 14, 21) that makes it possible to control and

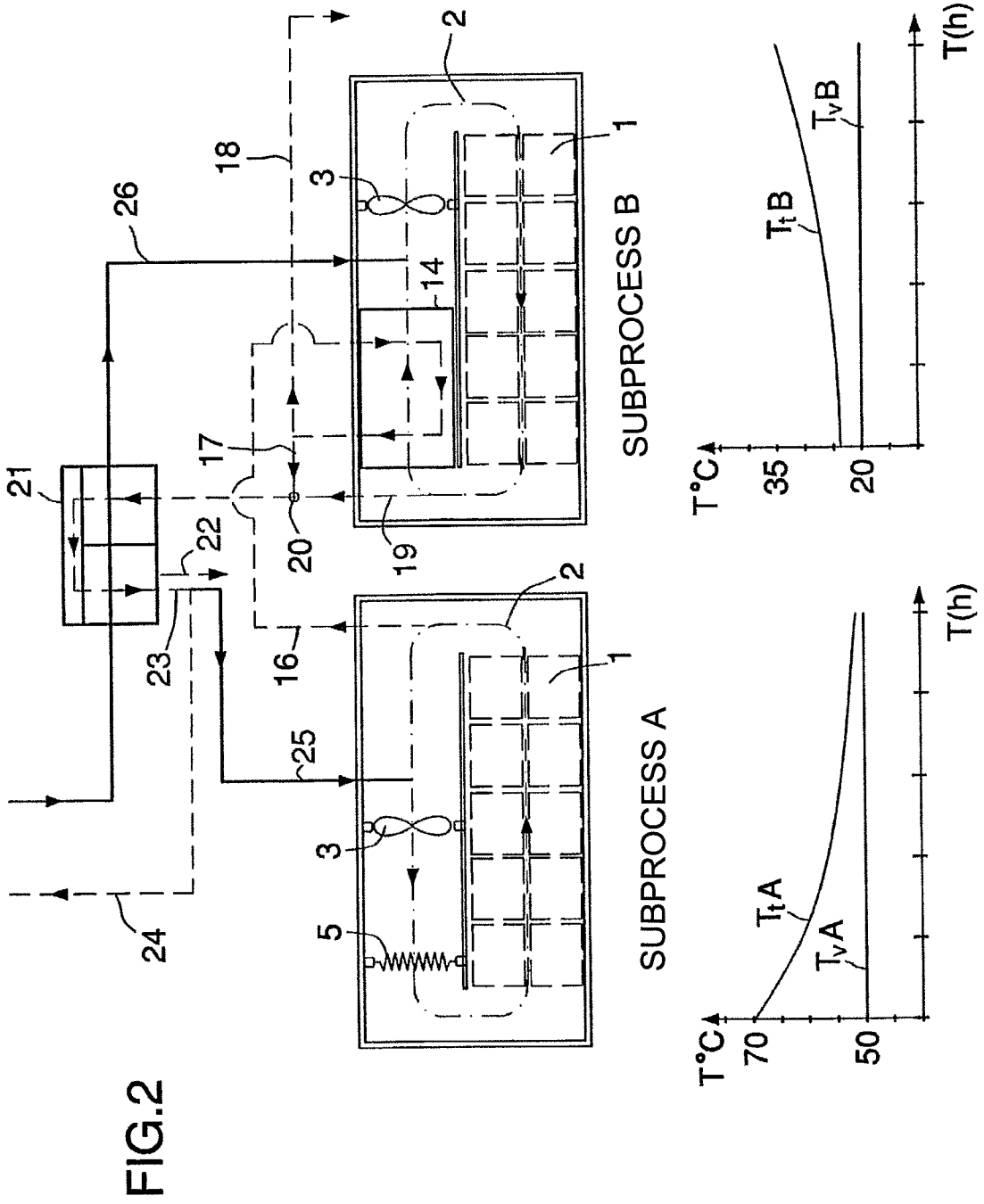
regulate the drying climate in such a manner that the two chambers form a first and a second subprocess (A, B) respectively, and which control and regulatory equipment is arranged not only to provide a higher wet temperature ( $T_{vA}$ ) for the circulating air (2) in the first subprocess (A) than the circulating air (2) in the second subprocess (B), but also to allow heat in the circulating air (2) in the first subprocess (A) to be recovered and transferred to the second subprocess (B).

11. A progressive dryer according to claim 10, whereby the wet temperature ( $T_{vA}$ ) in the first subprocess (A) is higher than the dry temperature ( $T_{tB}$ ) in the second subprocess (B).

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**INTERNATIONAL SEARCH REPORT**

International application No.  
PCT/SE2014/050409

**A. CLASSIFICATION OF SUBJECT MATTER**  
**IPC: see extra sheet**  
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)  
**IPC: F26B**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
**SE, DK, FI, NO classes as above**

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
**EPO-Internal, PAJ, WPI data**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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Y	--	1-11
Y	US 4255870 A1 (MALMQUIST LARS), 17 March 1981 (1981-03-17); column 4, line 28 - line 35; column 4, line 43 - line 46; figure 3	1-11
Y	JP 2000351103 A (ENO SANGYO KK ET AL), 19 December 2000 (2000-12-19); abstract; paragraphs [0006], [0024]; figure 1	1-11
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Further documents are listed in the continuation of Box C.       See patent family annex.

* Special categories of cited documents:	“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
“A” document defining the general state of the art which is not considered to be of particular relevance	“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
“E” earlier application or patent but published on or after the international filing date	“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
“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)	“&” document member of the same patent family
“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	

Date of the actual completion of the international search <b>11-06-2014</b>	Date of mailing of the international search report <b>12-06-2014</b>
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Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer <b>Karin Bengtsson</b> Telephone No. + 46 8 782 25 00
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## INTERNATIONAL SEARCH REPORT

International application No.  
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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**Continuation of:** second sheet

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*F26B 23/00* (2006.01)

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

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