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(71) Applicant *(for all designated States except US)*: GEORGIA PACIFIC RESINS, INC. [US/US]; 133 Peachtree Street, N.E., P.O. Box 105605, Atlanta, GA 30348-5605 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: WILLIAMSON, Bobby, L. [US/US]; Apartment 14, 2209 Briarcliff Road, N.E., Atlanta, GA 30329 (US). HODGE, Carisa, I. [US/US]; 2162 Heritage Heights, Decatur, GA 30033 (US). BRYER, Robert, A. [US/US]; 2840 Livesy Trail, Tucker, GA 30084 (US). DAVIS, William, Cos [US/US]; Suite 489, 3232 Cobb Parkway, Atlanta, GA 30339 (US).

(74) Agents: SKERPON, Joseph, M. et al.; Banner & Witcoff, Ltd., 11th floor, 1001 G Street, N.W., Washington, DC 20001 (US).

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(54) Title: B-STAGED RESIN IMPREGNATED FIBER MAT PLYWOOD GLUE

(57) Abstract

A process for making composite wood products using a B-staged, phenolic resole resin-impregnated fiber mat as a glue line. The fiber mats provide gap filling and are useful for bonding high moisture content substrates. The fiber mats also provide for a reduction in the thickness of individual veneer layers and/or the reduction in the number of veneers used in a composite wood product.

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B-STAGED RESIN IMPREGNATED FIBER MAT PLYWOOD GLUE

Field of the Invention

The invention is directed to a process for making composite wood products using a B-staged resin, such as a B-staged, phenolic resole resin-impregnated fiber mat as a glueline.

Background of the Invention

In preparing wood composites or laminates, resin-impregnated fiber mats have been used to provide fiber reinforcing layers. Typically, the fibers are impregnated with a resin and then allowed to fully cure. A separate resin is then used to adhere the reinforcing layer to other layers, such as veneer in plywood or LVL.

The fiber mat is made of any suitable fiber such as glass fibers, mineral wool, and carbon fibers. Blended fibers have also been used, such as the combination of glass fibers and mineral wool. Fiber mats usually are made commercially by a wet-laid process, which is carried out on modified paper or asbestos making machinery. Descriptions of the wet-laid process may be found in a number of U.S. patents, including U.S. Patent Nos. 2,906,660; 3,012,929; 3,050,427; 3,103,461; 3,228,825; 3,760,458; 3,766,003; 3,838,995; 3,905,067; and 4,129,674.

The known wet-laid process for making glass fiber mats comprises first forming an aqueous slurry of short-length glass fibers (referred to in the art as "white water") under agitation in a mixing tank, then feeding the slurry through a moving screen on which the fibers enmesh themselves into a freshly prepared wet glass fiber mat, while water is separated therefrom.

After the mat is formed, a binder material is used to hold the fiber mat together. The binder material is normally impregnated directly into the fiber mat and set or cured to provide the desired integrity. The glass mats may then be used as layers in shingles and other composite wood products to provide strength. Such composite wood products include plywood, engineered lumber, LVL, and hardboard.

Typically, an adhesive is applied to the glass mat and/or the wood veneer at the time a composite wood product is made. U.S. Patent 4,533,589, for instance, describes a composite material prepared by impregnating at least one layer of reinforcement fibers with a first resin, coating the surfaces of at least one layer of wood veneer with a second resin, stacking the resin impregnated reinforcement fiber layer with the resin coated wood veneer and bonding the layers together under appropriate heat and pressure conditions. U.S. Patent 4,615,936 describes a veneer laminate structure comprising a sheet of processed material sandwiched between two sheets of wood veneer. Resin is interposed between the sheets of the sandwich to firmly bond the sheets together.

Government of India Specification No. 139,241 describes composite laminates reinforced with glass wool or rovings impregnated with resins. The wool or rovings is impregnated with the resin to form a mat and then allowed to dry and cure. The mat is then glued to other layers in the composite such as wood veneers. Government of India Specification No. 139,241 describes composite laminates wherein layers are formed from wood veneer, glass fiber, fabric, paper, and the like, by impregnating the fiber with a resin and curing. The layers are then glued together to form a composite.

Wood adhesives used to prepare wood composites often include urea-formaldehyde resins or phenol-formaldehyde resins. Usually, the resin is prepared under heated alkaline conditions by reacting phenol and formaldehyde, for example, in specific F/P mole ratios to produce phenolic polymers having the desired molecular weight distribution. The cooked resins are then used either in neat form or more usually are mixed with various extenders, fillers and other additives before being applied to the wood substrates by spraying, curtain coating, foam extrusion, roll coating or other methods. After the application of the adhesive to the wooden substrates, e.g. particles or veneer, the substrates are pressed in a hot press typically using high pressure and elevated temperatures to cure the phenolic resin. The minimum time to cure the resin depends, inter alia, on the press temperature, wood moisture content, thickness of the pressed construction, adhesive formulation and the adhesive resin's molecular weight distribution.

The typical wood composite or laminate, made by imposing glass mats between veneer layers using a fluid resin-based adhesive to form the glue line, is difficult to manufacture when the veneer has a high moisture content or is of poor quality, e.g. rough stock, thick or thin veneer. This is particularly a problem in plywood and LVL manufacture. It is therefore desired to provide a way for gluing a wood composite reinforced with a glass mat which can be used for all types of veneer, not just good, low moisture stock.

Summary of the Invention

Applicants have discovered that a resin impregnated fiber mat prepared by impregnating a fiber mat with a B-stageable resin which is then dried to advance the resin to the B-stage can be used as the glue line in preparing a composite wood product. Applicants further discovered that the use of a fiber mat prepared in this manner as the glue line provides for a thicker composite, allowing for a reduction of the thickness of the veneer or allowing for a reduction in the number of veneer layers used to make a given product thickness.

The present invention thus is directed to a method for making a composite wood product comprising the steps of (a) impregnating at least one fiber mat with a B-stageable resin; (b) drying and advancing the resin of the impregnated mat to a B-stage; (c) placing the B-staged, resin-impregnated mat between at least one facing set of a plurality of wood veneers to form an assembly; and (d) consolidating the assembly under heat and pressure to form the composite wood product, and to a composite wood product made by the method.

Detailed Description of the Invention

The present invention is a process for making composite wood products, such as plywood, engineered lumber, laminated veneer lumber (LVL), hardboard and other wood laminates. According to the invention, a fiber mat is impregnated with a B-stageable resin (i.e. an A-stage resin). The resin which impregnates the mat is then advanced to a B-stage. A B-staged resin-impregnated mat is then placed between at least one facing set of a plurality of wood veneers and the assembly is consolidated under application of heat and pressure to bond the wood veneers together.

The B-staged resin-impregnated mat thus functions as a glueline for the wood composite and, after final curing, the mat imparts added strength to the final product. The added strength from the glass mat is a benefit for many products such as plywood, but in particular for products such as LVL which require good flexural strength. It has been found that the B-staged resin-impregnated mat also acts as a gap filler during the bonding process and eliminates many of the veneer problems commonly associated with poor veneer quality such as rough stock and uneven sizes. Further, it has been observed that the B-staged, resin-impregnated mat relaxes the need to dry high moisture content veneer to much lower moisture levels in order to reduce the incidence of blows that are encountered when trying to reduce the press cycle time. This reduced need for drying should lead to lower volatile organic compounds (VOCs) emissions from the dryer and also lower energy costs. The use of the B-staged, resin-impregnated mat minimizes the need for using low moisture content veneer while permitting fast press cycles.

In addition, in the manufacturing of plywood, LVL, or other laminates, a large percentage of the total cost of the composite wood product is associated with the wood actually used to make the veneer. The use of resin-impregnated fiber mats of the invention as a glue line has reduced the amount of wood necessary to prepare a composite wood product of a given thickness. In order to attain the high MOR and MOE values desired in a normal laminated wood composite construction, the surface veneer must be compressed to a high density. This compression reduces the thickness of the raw wood stock during formation of the laminated wood composite. The use of resin-impregnated fiber mats according to the invention, to bond the surface veneers at the front and back side of a laminate wood composite, however, decreases the amount of compression needed during the pressing cycle to maintain the same MOE and MOR values. Thus, the use of these resin-impregnated fiber mats allows for a reduction of the thickness of individual veneers used to make the product, (or a reduction of the number of veneers used) without loss of strength for the wood composite product having a desired thickness, thereby decreasing the cost of the product.

An additional benefit to the present invention is that no additional resin adhesives are necessary between the B-staged, resin-impregnated fiber mat and the veneer and preferably, none is applied. A strong glue line between opposing veneer layers is achieved with only the B-staged resin-impregnated fiber mat. Although it is contemplated that more than one glass mat may be used between opposing veneer layers, only one B-staged resin-impregnated fiber mat is generally required per glue line and preferably only one mat is used.

The fiber mat may be made from any suitable fibers such as glass fibers, mineral wool, asbestos, boron, aramid, metal, or carbon fibers or synthetic or natural fibers such as cotton. The fiber mat may also be made from a combination of fibers such as glass fibers and mineral wool. Preferably the fiber mat is made from glass fibers. The fibers used to make the fiber mat may also be in any suitable form such as random or nondirectional fibers, directional fibers, woven fibers and the like. Preferably the fibers are random or nondirectional. More preferably the fiber mat is prepared from chopped glass. Fiber mats are available commercially and may be made using any suitable process such as wet-laid processes described in U.S. Patent Nos. 2,906,660; 3,012,929; 3,050,427; 3,103,461; 3,228,825; 3,760,458; 3,766,003; 3,838,995; 3,905,067; and 4,129,674. For example, glass fibers may be slurried into an aqueous medium and then dewatered on a formaminated surface to form a mat.

Generally, the fiber mat should be thick enough to hold enough adhesive for a suitable glue line but thin enough so glue is not wasted. The thickness of the mat is chosen based on availability and the thickness of the desired end product and mats would generally be in the range of 1/16 to 1/4 inch. Commercial fiber mats are typically about 1/8 inch thick and are suitable for most applications.

In accordance with the invention, the fiber mat is impregnated with a B-stageable resin using any suitable technique, for example by using a spreader or by dipping the mat into a vat of resin. The resin must saturate the fiber mat, to provide sufficient resin throughout the mat so that when the mat and veneer are consolidated and heated, the resin flows into gaps in the veneer, penetrates the surface of the veneer, and provides a strong bond between the veneer and the fiber mat. Generally, the resin is applied to achieve about 10 to 40 g of dry glue per square foot. Dry glue is the solids part of the glue with the liquid removed.

The resin-impregnated mat is then heated for a sufficient period of time to advance the resin to a B-stage. Heating may be accomplished by passing the resin-impregnated mat through a drying oven where the mat is dried and the resin is advanced to a B-stage. Typical drying temperatures are in the range of about 100 to 180°F, more typically about

140°F. Typical drying times are in the range of about 30 to 90 minutes, typically about 1 hour. Higher or lower temperatures and shorter or longer times may be used provided the resin is advanced only to a B-stage.

An A-stage resin is a resin in a liquid state. Generally, resins used in adhesives that are applied as glue lines are A-stage resins. The viscosity of the resin may be modified by the use of various extenders and other additives to make an adhesive. An A-stage resin, and an adhesive based on an A-stage resin, will flow into the cracks and imperfections of the wood substrates or veneer and make coating of the veneer easier. The flowability of the A-stage resin can be adjusted by adjusting the viscosity and solids content of the resin.

A B-stage resin is a resin that has been partially cured but remains thermoplastic, that is, it will flow when reheated. Thus, in the present invention, an A stage (liquid) resin is impregnated into the fiber mat and then cured to a B-stage. When the B-stage resin-impregnated fiber mat is used as a glue line in a veneer assembly, and pressed under heat and pressure, the B-staged resin will soften and flow into the wood of the veneer to provide a good bond between the wood and the fiber mat. Resins that have been cured beyond a B-stage will not flow when reheated and thus are thermoset. After consolidation of the assembly in the present invention, the B-staged resin has been advanced to a thermoset resin. The temperature and time a resin requires to achieve a B-stage depends on the A-stage resin characteristics.

The A-stage (B-stageable) resin may be a phenol-formaldehyde resole resin, a resorcinol-formaldehyde resin, a phenol-resorcinol-formaldehyde resin, a melamine-urea-formaldehyde resin, a melamine-formaldehyde resin, and other similar resins which can be successfully B-staged. Preferably the resin is a B-stageable phenol-formaldehyde resole resin. The resin may be prepared in any suitable manner well known to those skilled in the art. A typical resin may have about 43% solids, a viscosity of 800-1000 cp, 6% NaOH, a pH about 11.5-12 and a F:P mole ratio of about 2.2. However, these characteristics may be altered depending on, for example, the method of application of the resin to the fiber mat, or the moisture content of the wood veneer. For example, when impregnating the fiber mat by dipping, the resin is diluted to about 20% solids to make dipping easier.

Typically, an A-stage phenol-formaldehyde resole resin is prepared using a two-part reaction whereby formaldehyde and phenol are reacted in the presence of a catalyst and then additional formaldehyde and catalyst are added before the reaction mixture is fully cooked. Acid reaction conditions may be initially employed, if desired, to react phenol with formaldehyde; but the reaction medium preferably is converted ultimately to alkaline conditions by adding a basic catalyst.

More specifically, an alkaline catalyzed phenol-formaldehyde resin suitable for impregnating a glass mat can be prepared by first combining formaldehyde and phenol at an initial formaldehyde to phenol mole ratio between about 0.1:1 to 2.5:1, more preferably between about 0.7:1 to 1.5:1, in an aqueous reaction media and in the presence of an effective catalytic amount of a basic catalyst. The preferred catalyst to phenol mole ratio at the initiation of the reaction is between about 0.1:1 and 0.5:1, more usually between about 0.15:1 and 0.25:1. The reaction temperature is preferably increased to between about 70 to 105°C, more usually between about 80 to 100°C to promote the reaction. This reaction generally takes between about 10 minutes and two hours and is complete after the exotherm of the reaction has subsided.

Additional formaldehyde then is added to provide a cumulative formaldehyde to phenol mole ratio of about 1.5:1 to 2.5:1, preferably about 2.0:1 to 2.2:1. Sufficient additional catalyst also is added to catalyze the reaction of the additional formaldehyde with residual phenol and other methylolated species. Preferably the additional catalyst is added in an amount to provide a cumulative catalyst to phenol mole ratio between about 0.5:1 and 1:1, more usually between about 0.6:1 and 0.9:1. The resulting phenol-formaldehyde resin is then cooked at a temperature of between about 70 to 90°C until the resin (at about 43 % solids) attains a viscosity of about 500-1000 cps (Brookfield). After the resin is cooled, preferably to about room temperature, it is then ready to be used in preparing the resin-impregnated glass mat. Other procedures for making an A-stage (B-stageable) resin are well understood by those skilled in the art.

Additives typically used in preparing adhesive compositions for bonding wood composites may be added to the resin prior to application to the glass mat, for example fire retardants, pigments, extenders, fillers, and the like. It is within the skill of the art to add appropriate additives as required for particular adhesive qualities.

To prepare the laminated wood composite, a B-staged resin-impregnated fiber mat is placed between at least one facing set of a plurality of wood veneers. A plurality of wood veneers is the number of veneers suitable for preparing a wood product of desired thickness. A plurality includes as few as two veneers having a single fiber mat between the veneers as the glueline. Plywood typically has anywhere from 3 to 15 veneers (plies).

After a fiber mat is placed between the layers of veneer, the assembly is consolidated under heat and pressure to form the wood composite product. The temperature and pressure used to bond the veneers depends on many factors such as the moisture content of the wood, the number of veneer layers, and the like. Typical press temperatures range between about 275 and 350°F at press pressures between about 150 and 200 psi. Typical pressing times range between 2 to 20 minutes, and depend on panel thickness, and the temperature and pressure used to consolidate the veneer.

A resin impregnated fiber mat which is used as a glueline prepared in accordance with the present invention provides excellent wood failure and press time results.

Examples

The invention will be further described by reference to the following examples. These examples should not be construed in any way as limiting the invention to anything less than that which is disclosed or which could have been obvious to anyone skilled in the art.

Example 1

A two by one foot sheet of glass mat having a thickness of 1/8 inch was impregnated with a B-stageable 2.2:1 F/P mole ratio phenolic resin by dipping the glass mat in a vat of resin, allowing the resin to saturate the glass mat, and then removing excess resin from the surface. The resin-impregnated fiber mat was dried in an oven at 140°F for one hour to advance the resin to a B-stage. The impregnated glass was then used as the gluelines for preparing 3-ply plywood. A sandwich assembly was prepared with a single mat interposed between each of the opposing veneer layers. The veneer had a 12% moisture content. The assembly was pressed at 315°F for three minutes. The resulting plywood was cut into strips and the modulus of rupture (MOR) and the modulus of elasticity (MOE) values were measured. The MOR increased by 20% and the MOE increased by 11 % over a control 3-ply assembly made without the glass mat using the same resin in a standard glue mix.

In a subsequent experiment, veneer layers were prepared with shims (about 1/10 inch plywood strips that provide gaps to simulate roughness of veneer) to compare bonding of veneer layers using a resin-impregnated glass mat as a glue line in accordance with the present invention and using a standard glue line without a glass mat. When three ply plywood was prepared with the shims-modified veneer layers, the glass mat glue line was better able to handle deviation of the shims than was the standard glue line.

Data from 3-ply Plywood Using Glass Mat

	With Glass	Without Glass
MOR (psi)	21500	16200
MOE (psi)	2434000	2041000

Example 2

A 2.2 F/P mole ratio A-stage phenol-formaldehyde resin and a glass mat prepared from chopped glass were obtained. The glass mat was impregnated with the resin by dipping the mat into the resin and then removing excess resin. The resin impregnated glass mats were then dried in an oven at 140°F for 60 minutes. The treatment levels averaged about 20 g/ft^2 of dry glue per glue line.

In preparing wood billets, the resin coated glass mats were used only for bonding the outer most wood layers to the assembly. The other glue lines in the billet were provided by applying a conventional fluid (A stage) phenolic resole resin-based adhesive to the veneer sheet directly using a standard spreader.

Four sets of billets were prepared: Billets without glass mat (control billets), billets with one sheet of glass mat bonding one face sheet to the assembly, billets with two sheets of glass mat bonding both facing sheets to the assembly, and finally a billet with two sheets of glass mat with extra caustic added to the resin used to impregnate the glass mat.

The billets were then tested for MOR, MOE, and short span bending. Flexural strength was examined on an Instron machine using 24 x 3 sq. in. samples with a span of 23 inches. A short span test was carried out with 5 x 2 sq. in. samples with a span of 4 inches.

Conditions for the Billet Studies	
	Press Speed Study
Veneer	1/8" thick southern yellow pine 12" x 24"
Face/Back Moisture Content	12.4%
Core Moisture Content	6-8%
Panel Construction	7-ply, 7/8" thick, 12" x 24"
Glue Spreads	31-32 g/ft^2, 73 MDGL Equivalent
Lay-up	2 billets per condition
Open Assembly Time	20 minutes
Prepress	4 minutes at 150 psi
Closed Assembly Time	Negligible
Hot Press	315°F, 175 psi, 1 PPO
Time in Hot Press	15 minutes
Hot Stack	2 hours
Test	MOR/MOE: 3 samples per billet Short Span Bending Test: 3 samples per billet

Properties of Billet

Condition	Thickness inches (±about 13%)	Short Span psi (±about 5%)	MOR psi (±about 12%)	MOE psi (±about 10%)
Control	0.711	621	15400	2194000
Two Sheets of Glass	0.756	647	14700	2088000
Two Sheets of Glass, high caustic	0.726	619	16100	2126000
One Sheet of Glass	0.740	679	13600	1933000

The short span test is designed to isolate the stress to the glue line and was used to evaluate the effect a resin-impregnated glass mat had on the bonding compared with the bonding achieved with a normal glue line using a standard resin glue mix. The data indicate that using the glass mat in the panel did not have a detrimental effect on the bonding since there was no loss of strength observed in the panels made with the glass mat. MOE and MOR values were comparable to the control.

A difference in thickness of the billets was observed. The billets with the glass mat were thicker than those without a glass mat by an amount larger than can be attributed to the thickness of the glass mat, possibly due to a higher level of wood adhesive plasticization in samples made without the glass mat. The higher amount of water in the glue in these samples provides better plasticization of the adhesive in the wood and hence higher compression. The billet made with the glass mat with added caustic was the thinnest of the billets containing glass, though thicker than the control. Again, this may possibly have resulted because the caustic increased the plasticization of the wood.

Since the billets made with glass mat retained a greater amount of their original thickness after pressing while still having comparable physical properties to that of the control billets, the use of glass mats may allow for a reduction in the thickness of each veneer and/or a reduction of the number of plies necessary to make a composite wood product of a desired thickness and strength.

It will be apparent to those skilled in the art that various modifications and variations can be made in the compositions and methods of the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A method of making a composite wood product comprising the steps of (a) impregnating at least one fiber mat with a B-stageable resin; (b) advancing the resin of the impregnated mat to a B-stage; (c) placing the B-staged, resin-impregnated mat between at least one facing set of a plurality of wood veneers to form an assembly; and (d) consolidating the assembly under heat and pressure to form the composite wood product.

2. The method of claim 1 wherein the resin comprises a phenolic resole resin.

3. The method of claim 1 wherein the mat comprises nondirectional fibers.

4. The method of claim 3 wherein the fibers are glass fibers.

5. The method of claim 1 wherein in (b) the resin is advanced by heating to about 100 to 160°F for about 30 to 90 minutes.

6. The method of claim 5 wherein the resin is advanced by heating to about 140°C for about 60 minutes.

7. The method of claim 1 wherein the composite wood product is plywood, engineered lumber, LVL, or hardboard.

8. The method of claim 7 wherein the composite wood product is plywood having 3 to 15 plies.

9. The method of claim 1 wherein the fiber mat is placed between the top surface set of wood veneers, the bottom surface set of wood veneers, or both.

10. A wood composite prepared by the steps of (a) impregnating at least one fiber mat with a B-stageable resin; (b) advancing the resin of the impregnated mat to a B-stage; (c) placing the B-staged, resin-impregnated mat between at least one facing set of a plurality of wood veneers to form an assembly; and (d) consolidating the assembly under heat and pressure.

11. The wood composite of claim 10 wherein the resin is a phenolic resole resin.

12. The wood composite of claim 10 wherein the mat comprises nondirectional fibers.

13. The wood composite of claim 10 wherein the fibers are glass fibers.

14. The wood composite of claim 10 wherein the wood composite is plywood, engineered lumber, LVL, or hardboard.

15. The wood composite of claim 14 wherein the laminated wood composite is plywood having 3 to 15 plies.

16. The wood composite of claim 10 wherein the fiber mat is between the top surface set of wood veneers, the bottom surface set of wood veneers, or both.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/07045

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C09J 7/00
US CL :156/313
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)

U.S. : 156/313; 442/326, 413

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	JP, A, 55-114561 (NUKA et al) 03 SEPTEMBER 1980 SEE (IN THE ATTACHED TRANSLATION OF THIS REFERENCE) PAGE 1 FIRST FULL PARAGRAPH, PAGE 3 LINES 9-19, PAGE 5 IN ITS ENTIRETY, AND ALSO NOTE DRAWING FIGURES (a)-(d).	1-16
Y	US, A, 1,299,747 (McCLAIN) 08 APRIL 1919 SEE FIGS. 1-4, PAGE 1 LINES 9-11 AND 64-73, PAGE 2 LINES 30-97	1-16
Y	US, A, 1,960,176 (WEBER et al) 22 MAY 1934 SEE PAGE 1 LINES 1-16 AND 70-72, PAGE 2 LINES 29-65 AND 124-129.	1-16

☐ 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

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