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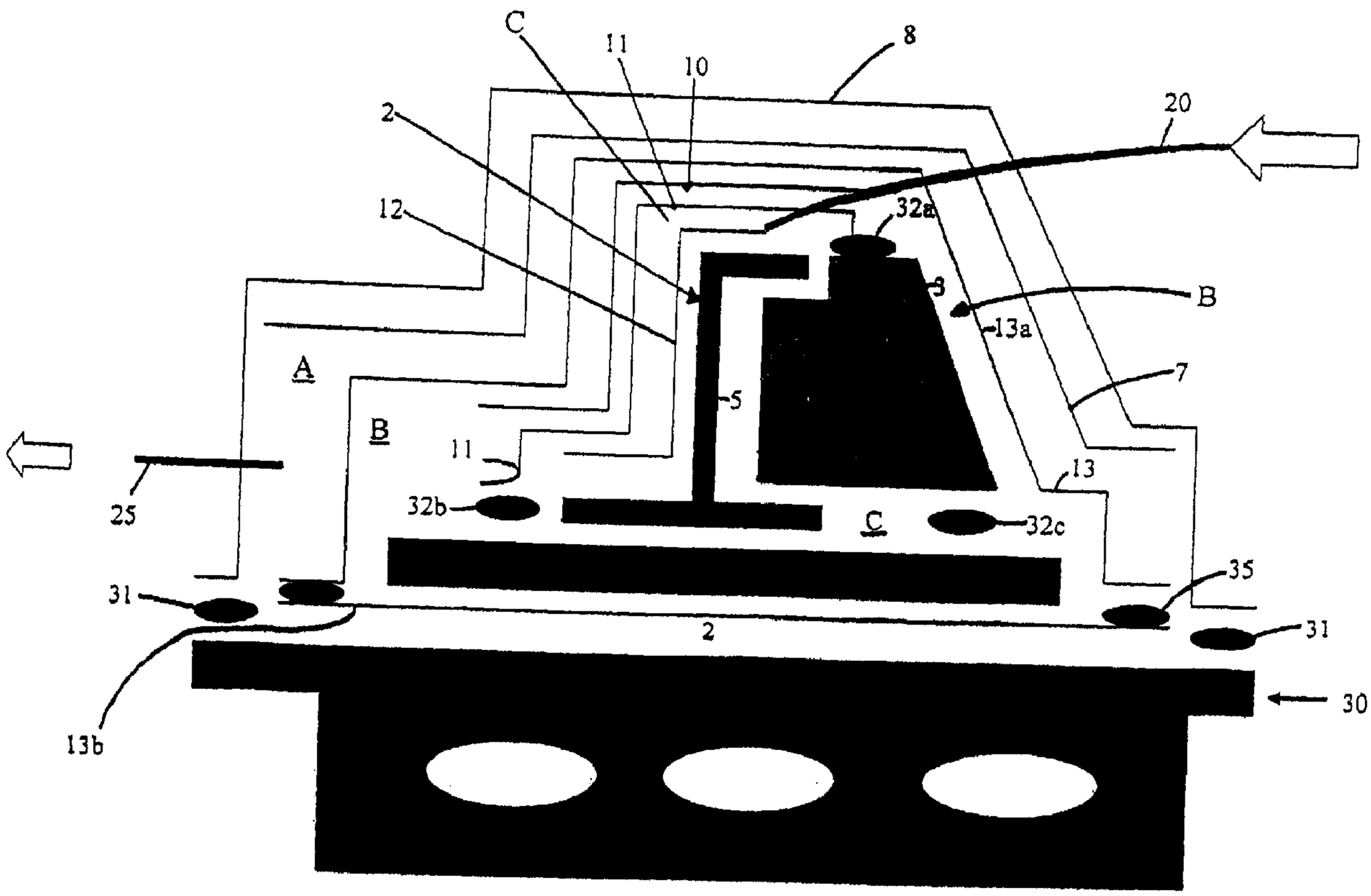
(54) Title: METHOD AND DEVICE FOR PRODUCING FIBER-REINFORCED PLASTIC COMPONENTS



(57) Abrégé/Abstract:
Production device and method for producing fiber-reinforced plastic components comprising a semi-finished prepreg product and a dry semi-finished textile product with an aeration and deaeration chamber (A) and an exhaust line (25) opening into the same for producing a vacuum and a semi-finished textile product chamber (C) to receive a dry semi-finished textile product (1), into which semi-finished textile product chamber an injection line (20) for inserting resin opens, whereby a prepreg chamber (B) for receiving a

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(57) Abrégé(suite)/Abstract(continued):
semi-finished prepreg product (2) is provided, whereby the prepreg chamber (B) is located against the aeration and deaeration chamber (A) in an air-permeable manner and the semi-finished textile product chamber (C) is located against it at least in areas in an air-impermeable and resin-permeable manner by means of a membrane, whereby due to the air-permeable membranes a vacuum in the aeration and deaeration chamber (A) generates a vacuum both in the prepreg chamber (B) and in the semi-finished textile product chamber (C).

Abstract

Production device and method for producing fiber-reinforced plastic components comprising a semi-finished prepreg product and a dry semi-finished textile product with an aeration and deaeration chamber (A) and an exhaust line (25) opening into the same for producing a vacuum and a semi-finished textile product chamber (C) to receive a dry semi-finished textile product (1), into which semi-finished textile product chamber an injection line (20) for inserting resin opens, whereby a prepreg chamber (B) for receiving a semi-finished prepreg product (2) is provided, whereby the prepreg chamber (B) is located against the aeration and deaeration chamber (A) in an air-permeable manner and the semi-finished textile product chamber (C) is located against it at least in areas in an air-impermeable and resin-permeable manner by means of a membrane, whereby due to the air-permeable membranes a vacuum in the aeration and deaeration chamber (A) generates a vacuum both in the prepreg chamber (B) and in the semi-finished textile product chamber (C).

(Fig. 2)

P25158.S01

Method and Device for Producing Fiber-Reinforced Plastic Components

[0001] The invention relates to a method and a device for producing fiber-reinforced plastic components. In particular a semi-finished textile product for producing a planking field and a semi-finished prepreg product for producing a stiffening element for the planking field can thereby be provided.

[0002] It is known to produce fiber-reinforced plastic components by a so-called prepreg technique. A large-surface skin field is used as a planking field and stiffening profiles are used as integral reinforcement thereby. The skin field can thereby be produced by automatic placement. However, the method according to the prepreg technique is disadvantageous in the production of stiffening profiles with non-windable geometry, since they have to be laminated manually. Such a process that needs to be carried out manually increases production costs.

[0003] Furthermore, a resin film infusion technique (RFI) is known, e.g., from US 5,281,388, in which a dry fabric is covered with a pre-impregnated resin film in a curing device, and the curing device thus loaded and evacuated is subjected to suitable temperature and pressure treatments in an autoclave to cure the fiber-reinforced plastic component.

[0004] Furthermore, methods are known in which fiber-composite components are completely prepared as dry semi-finished fiber products at first and are filled with resin and cured in closed or open curing tools through liquid resin injection with vacuum and/or pressure.

[0005] A method for producing fiber-reinforced plastic components with incompletely windable geometry is known from DE 199 15 083 C1 in which the plastic components are formed with the joining of a semi-finished prepreg product and a semi-finished textile product by means of a resin. The semi-finished prepreg product and the semi-finished textile product are jointly arranged in a flexible vacuum hood thereby and a resin film

arranged on the semi-finished textile product is brought to melting under temperature and pressure treatment, which resin film then impregnates and joins the semi-finished textile product and the joint between the semi-finished textile product and the semi-finished prepreg product. In this known method both the semi-finished prepreg product and the semi-finished textile product are jointly and completely enclosed by the flexible vacuum hood and pressurized through evacuation of the same.

[0006] Furthermore an arrangement for producing a component comprising a fiber-reinforced material by means of resin impregnation of a semi-finished fiber product is known from DE 201 02 569 U1, in which the semi-finished fiber product positioned on a mold is pressurized by means of a vacuum foil with the evacuation of the same and liquid resin is fed through the vacuum foil to the semi-finished fiber product.

[0007] The object of the invention is to create an improved and cost-effective method for producing fiber-reinforced components.

[0008] This object is attained according to the present invention in terms of a method for producing fiber-reinforced plastic components composed of a semi-finished prepreg product and a dry semi-finished textile product, the method comprising:

enclosing the semi-finished prepreg product and the dry semi-finished textile product within an air-impermeable foil to form an aeration and deaeration chamber;

enclosing the dry semi-finished textile product and at least a part of the semi-finished prepreg product to be joined to the dry semi-finished textile product in a semi-finished textile product chamber limited at least in part by a gas-permeable and resin-impermeable membrane; and

enclosing at least a part of the semi-finished prepreg product not enclosed by the semi-finished textile product chamber in a semi-finished prepreg product chamber limited at least in part by a second gas-permeable and resin-impermeable membrane. This object is also obtained in terms of a device for producing fiber-reinforced plastics components from a prepreg semi-finished product and a textile semi-finished product, comprising:

an arrangement of the prepreg semi-finished product and the dry textile semi-finished product, in which the semi-finished products adjoin one another in places;

a chamber around the prepreg semi-finished product by means of a first gas-permeable membrane, which at least partially surrounds the chamber;

a chamber around the dry textile semi-finished product by means of a second gas-permeable membrane, which at least partially surrounds the chamber and which at least partially adjoins the chamber containing the prepreg semi-finished product, wherein an injection line for injecting resin leads into the chamber around the dry textile semi-finished product; and

a venting chamber, which is sealed off in a gas-tight manner from the surrounding environment by means of a film and which is surrounded in part by the first membrane, wherein a gas discharge line leads into the venting chamber and a resin injection line leads into the chamber around the textile semi-finished product, so that, when air is drawn off from the venting chamber, air is extracted from both the chamber containing the prepreg semi-finished product and the chamber around the textile semi-finished product.

[0009] One particular advantage of the present invention lies in the possibility of a simultaneous use of two resin systems during the cocuring process. In particular liquid resin systems can be used for the stiffening profiles and prepregs for the planking, in contrast to methods according to the prior art in which only one resin system and only one of the methods cited can be used during the joint cocuring.

[0010] In the method according to the invention, in the case of a planking field a dry semi-finished textile product can be embodied in a large-area manner compared to the semi-finished prepreg product. The semi-finished prepreg product is usually a dry textile fabric provided with resin films. The semi-finished prepreg product, which should

preferably be applied to the dry semi-finished textile product for integral stiffening, can be placed in a production device as a dry fabric and positioned on the semi-finished prepreg product. A suitable vacuum development can be provided with a vacuum chamber for the subsequent resin injection for the dry textile fabric. After the joining of the semi-finished prepreg product and the dry textile fabric, the chamber is evacuated. Subsequently a curing takes place according to a predetermined temperature and vacuum sequence. The curing can additionally be carried out under pressure in an autoclave, in particular depending on the material combination that has been used in the method for the prepreg resin and injection resin.

[0011] Another advantage of the method according to the invention is that almost any desired combination of resin materials can be selected provided that if the maximum temperature limit for any material, e.g., to avoid a decomposition, is not exceeded during the process. In particular very viscous prepreg systems can also be used. In this manner cost-effective materials can be used by which means production costs can be reduced.

[0012] Exemplary embodiments of the method and device according to the invention are described below on the basis of the drawings. They show:

- Fig. 1 A diagrammatic representation of three chambers for producing a combination of a planking field with a stiffening element according to one exemplary embodiment of the invention;
- Fig. 2 An exemplary embodiment of a vacuum device according to the invention for carrying out the method;
- Fig. 3 An example of a temperature and vacuum sequence for carrying out the method according to an exemplary embodiment of the invention.

[0013] Fig. 1 shows in diagrammatic form an aeration and deaeration chamber A provided in the production device according to the invention or the method according to the invention, a semi-finished prepreg product or curing chamber B to receive a semi-

finished prepreg product and a semi-finished textile product chamber or injection chamber C to receive a dry semi-finished textile product.

[0014] The spatial arrangement of the chambers shown in Fig. 1 is by way of example and can also be embodied differently. For example, the injection chamber C can also be arranged inside the curing chamber B. The aeration and deaeration chamber A can also extend further around the chambers B or C than shown in Fig. 1. The aeration and deaeration chamber A can also be formed of several chambers or spaces. In any case, the curing chamber B is located next to the semi-finished textile product or injection chamber C separated in sections only by a membrane 11. The curing chamber B also has a common boundary with the aeration and deaeration chamber A in the form of a membrane 13. Optionally the injection chamber C can also feature a common boundary with the aeration and deaeration chamber A in the form of a membrane 15 (not in the embodiment of Fig. 2). The membranes 11, 13, 15 are made of gas-permeable but resin-impermeable material.

[0015] In sections the surface of the semi-finished textile product or the semi-finished prepreg product can also form the boundary of the aeration and deaeration chamber A, the curing chamber B or the injection chamber C.

[0016] To summarize:

- The prepreg chamber B is located at least in some areas against the semi-finished textile product chamber C in an air-permeable but not necessarily a resin-permeable manner, and
- The semi-finished textile product chamber C is located against the aeration and deaeration chamber A by means of a membrane, whereby means are provided for feeding the resin into the semi-finished textile product chamber C through an air-impermeable area of the chamber.

[0017] Alternatively or additionally a wall with openings or valves can also be provided in the membrane between the semi-finished textile product chamber C and the aeration and deaeration chamber A.

[0018] The chambers A, B and C are vacuum sealed, thus sealed in a gas-impermeable manner from the surroundings either by means of foils 8, 8a, 8b, 8c or, in some sections are separated from the surroundings by the sealed application of the corresponding foils 8, 8a, 8b, 8c on a sealed application device.

[0019] The aeration and deaeration chamber A is a chamber that is used to receive air and volatile process constituents from the semi-finished prepreg product chamber B and from the semi-finished textile product chamber C. The air from the semi-finished textile product chamber C can be brought directly into the aeration and deaeration chamber A via the membrane 15 or via a membrane 11 and the semi-finished prepreg product chamber B.

[0020] The semi-finished prepreg product chamber B is provided to receive a semi-finished prepreg product, thus a semi-finished fiber product pre-impregnated with resin, e.g., for producing a planking field. According to the invention no resin is injected into this chamber B, since resin is already present in the prepreg. In contrast, an injection line 20 opening into the semi-finished textile product chamber C is provided for the introduction of liquid resin. An assigned resin storage chamber and conveying means for feeding the resin are not shown in the Figs.

[0021] Furthermore, a means for producing a vacuum or a vacuum pump is provided that can produce an adjustable vacuum in the aeration and deaeration chamber A via an exhaust line 25 opening into the aeration and deaeration chamber A.

[0022] According to the invention resin is injected into the semi-finished textile product chamber C. During or after the resin injection, a vacuum is adjusted in the aeration and deaeration chamber A via the vacuum pump. The amount and time-course of the vacuum

depend on various factors. In particular the material combination provided for the prepreg resin and the injection resin is influential.

[0023] Due to the vacuum in the aeration and deaeration chamber A, a suctioning off of gas takes place on the one hand from the semi-finished textile product chamber C through the membrane 15 and on the other hand from the semi-finished prepreg product chamber B through membrane 13 or 11 and 15.

[0024] Furthermore, due to the application of the vacuum in the aeration and deaeration chamber A, a degassing of the semi-finished prepreg product located in the semi-finished prepreg product chamber B and thus a curing of the same is effected.

[0025] In order to support the injection of resin into the semi-finished textile product chamber C and the curing of the semi-finished textile product then impregnated with resin and of the semi-finished prepreg product in the semi-finished prepreg product chamber B, defined time-dependent or constant temperatures can be adjusted in one or both chambers B, C. The vacuum in the aeration and deaeration chamber A and the temperatures in the chambers B, C can also be adjusted via an automatic control loop.

[0026] Fig. 2 shows an embodiment of the chambers A, B, C with an at first dry semi-finished textile product 5 and a semi-finished prepreg product 2 in order to produce a planking element with a stiffening from the semi-finished products 5, 2 by means of the production device.

[0027] In the embodiment of Fig. 2, the aeration and deaeration chamber A is surrounded in areas by a vacuum foil 8 that seals the aeration and deaeration chamber A from the surroundings. To this end a sealing band 31 is provided through which the vacuum foil 8 is tightly sealed to corresponding support surfaces of a workpiece support 30.

[0028] In the representation of Fig. 2 the semi-finished textile product chamber C is enclosed by the membrane 11 and a section of a support profile 3 for the semi-finished textile product 5 and situated within the semi-finished prepreg product chamber B. The membrane 11 is made of one part thereby and closed by means of sealing elements 32a, 32b, 32c after insertion of the dry semi-finished textile product 5. The sealing elements 32a, 32b, 32c thereby rest against parts of the semi-finished textile product 5, the semi-finished prepreg product 2 or the support profile 3, so that these elements in some sections form a delimitation of the semi-finished textile product chamber C. Alternatively the membrane 11 can also completely enclose the semi-finished textile product chamber C or be sealed in another way by means of corresponding sealing elements on surfaces of the semi-finished textile product 5, the semi-finished prepreg product 2 or a support profile 3 or other auxiliary devices.

[0029] In the embodiment according to Fig. 2, the membrane 13 for enclosing the prepreg chamber B is formed in two parts 13a, 13b that are tightly joined by means of a sealing element 35. In the representation of Fig. 2, the membrane 13b is located on a tool support 30.

[0030] The sealing of the chambers A, B, C *per se* and relative to adjacent chambers can be achieved in various ways. It is essential

- that the prepreg chamber B is located against the semi-finished textile product chamber C, at least in some areas, in an air-permeable and not necessarily a resin-permeable manner, and
- that the semi-finished textile product chamber C is located against the aeration and deaeration chamber A by means of a membrane whereby means are provided for feeding the resin into the semi-finished textile product chamber C through an air-impermeable area of the chamber,

whereby due to the air-permeable membranes a vacuum in the aeration and deaeration chamber A generates a vacuum in the prepreg chamber B as well as in the semi-finished textile product chamber C.

[0031] Alternatively or additionally to the membrane between the semi-finished textile product chamber C and the aeration and deaeration chamber A, a wall with openings or valves can also be provided.

[0031a] In one or more of the chambers A, B, C a flow promoter 7, 10 or 12 can be arranged in sections. This flow promoter runs in the chamber A in sections between the foil 8 and the membrane 13 as well as optionally between the foil 8 and the membrane 15. A flow promoter can also be located in sections between the prepreg semi-finished product 2 or the textile semi-finished product 5 and a respective membrane running along the corresponding semi-finished product surface. At points at which membranes (11 and 13 in Fig. 2) run along towards one another, a flow promoter (10 in Fig. 2) can be located between these membranes. In principle, a flow promoter can be located in sections on a surface of the textile semi-finished product or the prepreg semi-finished product.

[0032] The semi-finished prepreg product can also be used for a stiffening element and the dry semi-finished textile product can also be used for a planking element.

[0033] Fig. 3 shows a typical temperature and vacuum sequence. The sequence is composed in principle of four phases: an injection phase 101, an intermediate curing phase 102, a curing phase 103 and a tempering phase 104.

[0034] The vacuum is preferably constantly applied over phases 101 through 103, whereby the vacuum is typically applied in the order of magnitude of 20 mbar.

[0035] The vacuum is no longer necessary in the phase 104, but an applied vacuum can be advantageous for the component quality.

[0036] In the injection phase 101 in which typically temperatures of approx. 85°C are adjusted depending on the viscosity of the injection resin, a vacuum is produced in chamber C through the vacuum applied in chamber A. The air escapes from the chamber A through the exhaust line 25. The semi-finished textile products in chamber C are impregnated with the injection resin (e.g., RTM 6). Through the vacuum applied in chamber C the fiber materials in chambers C and B are compressed.

[0037] Optionally from this stage onwards an excess pressure (e.g., 2.5 to 10 bar) can be applied up to the end of phase 103 or 104 by means of an autoclave.

[0038] A heating of the chambers B and C to temperatures of, e.g., 100 to 140° C occurs in phase 102. A chemical reaction is thus started in the two resin systems (chamber B = prepreg, chamber C = liquid resin). Determined by the chemical behavior

of epoxy resins the viscosity now drops again, so that an ideal distribution of the resin systems within the fiber materials occurs in particular in chamber B.

[0039] After a time determined by the resin systems (typically 1 to 2 hours) a heating of chambers B and C takes place in phase 103 that has to be designed so that the temperatures are sufficient for the final curing of the resin system (typically 160 to 180° C, approx. 1-2 hours). If it is advantageous for one of the resin systems, an additional tempering (thermal aftertreatment) takes place at, e.g., 180-210° C. Neither a vacuum nor an autoclave pressure is absolutely essential hereby, but can be provided.

[0040] The method makes it possible to meet typical requirements for component quality of aviation components, such as, e.g., lack of pores, fiber volume content at 60%, component dimensions and interior laminate qualities.

[0041] The method parameters cited above are given by way of example for a typical 180° C prepreg system in combination with a liquid resin system. With other permissible and conceivable material combinations, they have to be respectively adjusted. The size of the components to be produced is virtually limitless, if an excess pressure is not necessary with a certain material combination.

Claims

1. A method for producing fiber-reinforced plastic components composed of a semi-finished prepreg product and a dry semi-finished textile product, the method comprising:

enclosing the semi-finished prepreg product and the dry semi-finished textile product within an air-impermeable foil to form an aeration and deaeration chamber;

enclosing the dry semi-finished textile product and at least a part of the semi-finished prepreg product to be joined to the dry semi-finished textile product in a semi-finished textile product chamber limited at least in part by a gas-permeable and resin-impermeable membrane; and

enclosing at least a part of the semi-finished prepreg product not enclosed by the semi-finished textile product chamber in a semi-finished prepreg product chamber limited at least in part by a second gas-permeable and resin-impermeable membrane.

2. The method according to claim 1, further comprising:

curing the semi-finished prepreg product and the dry semi-finished textile product to join the semi-finished prepreg product to the dry semi-finished textile product.

3. The method according to claim 1, further comprising:

injecting resin into the semi-finished textile product chamber; and

evacuating the semi-finished textile product chamber and the semi-finished prepreg product chamber through the aeration and deaeration chamber.

4. The method according to claim 1, wherein the semi-finished textile product chamber is evacuated through the aeration and deaeration chamber through the semi-finished prepreg product chamber.

5. The method according to claim 1, further comprising:

evacuating the semi-finished textile product chamber and the semi-finished prepreg product chamber directly through the aeration and deaeration chamber.

6. The method according to claim 1, wherein the semi-finished textile product chamber is arranged within the semi-finished prepreg chamber and is enclosed by the semi-finished prepreg chamber, and that the semi-finished prepreg product chamber is arranged within the aeration and deaeration chamber and is enclosed by the aeration and deaeration chamber.

7. The method according to claim 4, wherein the semi-finished textile product chamber and the semi-finished prepreg product chamber are respectively limited at least in part by the aeration and deaeration chamber.

8. The method according to one of claim 1, wherein the semi-finished textile product chamber is limited in part by the semi-finished prepreg product.

9. The method according to claim 1, wherein the fiber-reinforced plastic component is integrally stiffened by the dry semi-finished textile product.

10. The method according to claim 1, wherein the fiber-reinforced plastic component is integrally stiffened by the semi-finished prepreg product.

11. The method according to claim 1, further comprising:
curing the resin under pressure in an autoclave.

12. An apparatus for producing fiber-reinforced plastics components from a prepreg semi-finished product and a textile semi-finished product, comprising:
an arrangement of the prepreg semi-finished product and the dry textile semi-finished product, in which the semi-finished products adjoin one another in places;
a chamber around the prepreg semi-finished product by means of a first gas-permeable membrane, which at least partially surrounds the chamber;

a chamber around the dry textile semi-finished product by means of a second gas-permeable membrane, which at least partially surrounds the chamber and which at least partially adjoins the chamber containing the prepreg semi-finished product, wherein an injection line for injecting resin leads into the chamber around the dry textile semi-finished product; and

a venting chamber, which is sealed off in a gas-tight manner from the surrounding environment by means of a film and which is surrounded in part by the first membrane, wherein a gas discharge line leads into the venting chamber and a resin injection line leads into the chamber around the textile semi-finished product, so that, when air is drawn off from the venting chamber, air is extracted from both the chamber containing the prepreg semi-finished product and the chamber around the textile semi-finished product.

13. The apparatus according to claim 12, wherein one or more of the membranes is impermeable to resin.

14. The apparatus according to claim 12, wherein one or more of the membranes is permeable to resin.

15. The apparatus according to any one of claims 12 to 14, wherein the chamber around the dry textile semi-finished product is arranged within the chamber containing the prepreg semi-finished product and enclosed thereby.

16. The apparatus according to either one of claims 14 or 15, wherein the chamber around the dry textile semi-finished product is partially bounded by the prepreg semi-finished product.

17. The apparatus according to any one of claims 12 to 16, wherein the film is air-impermeable.

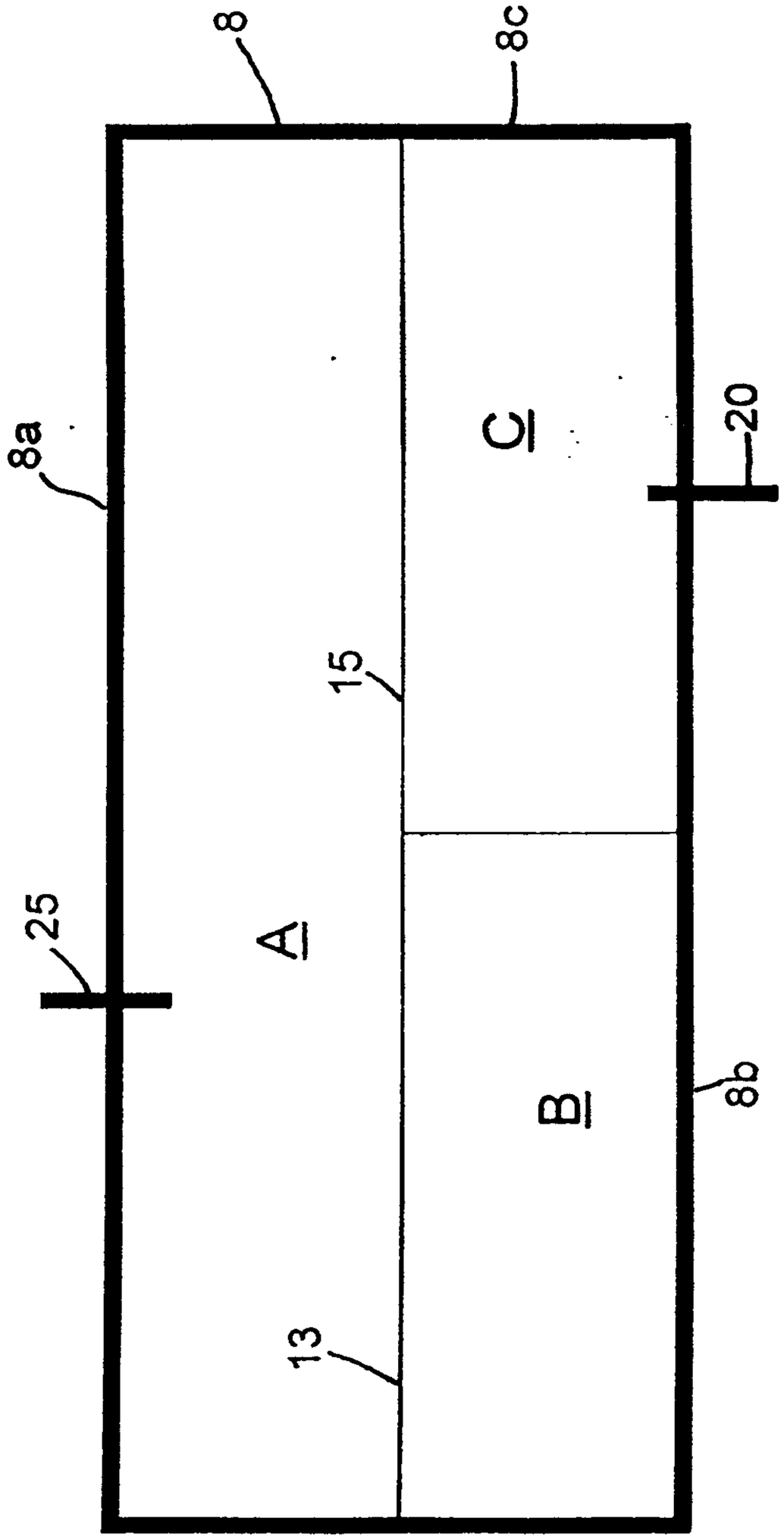


FIG.1

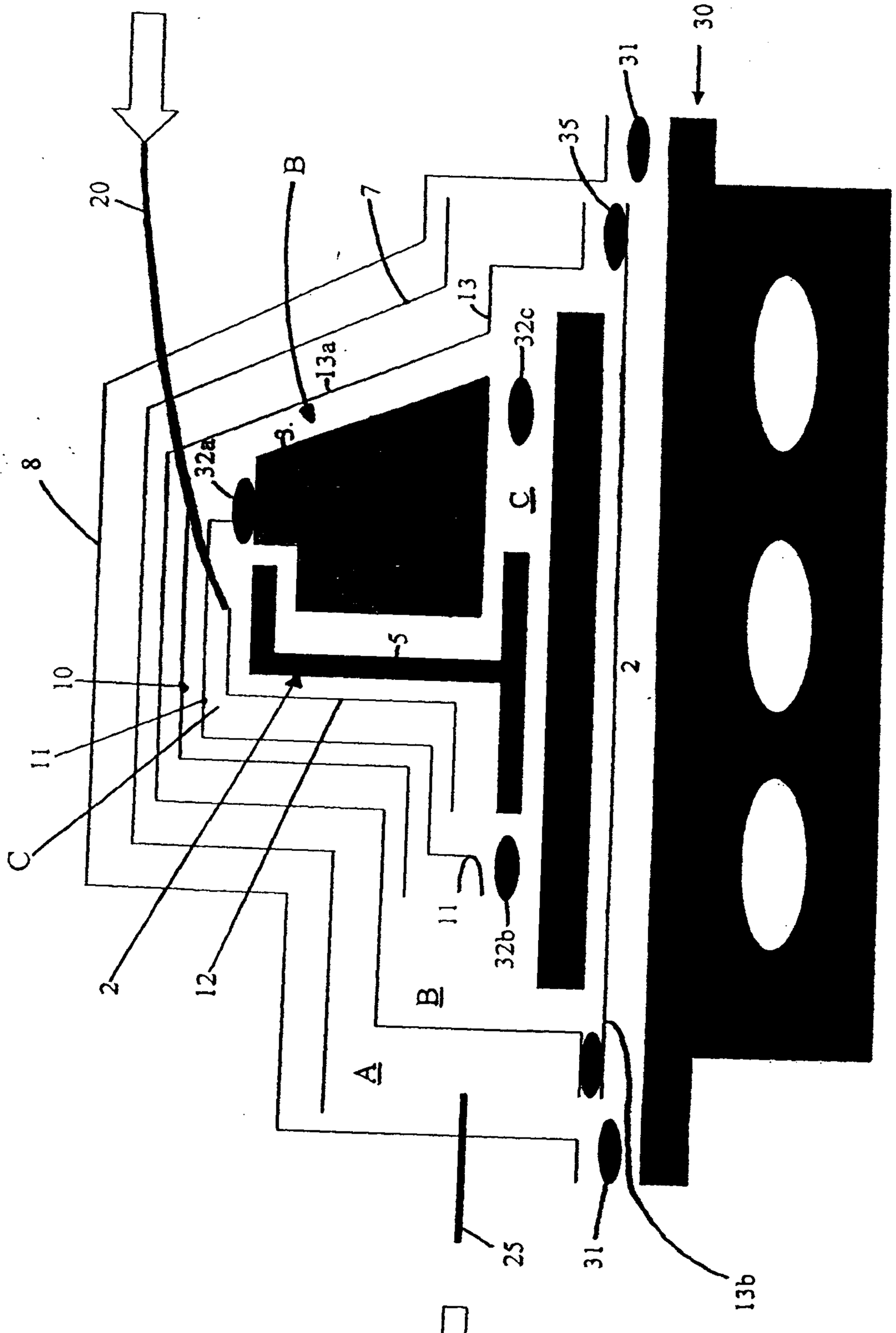


Fig. 2

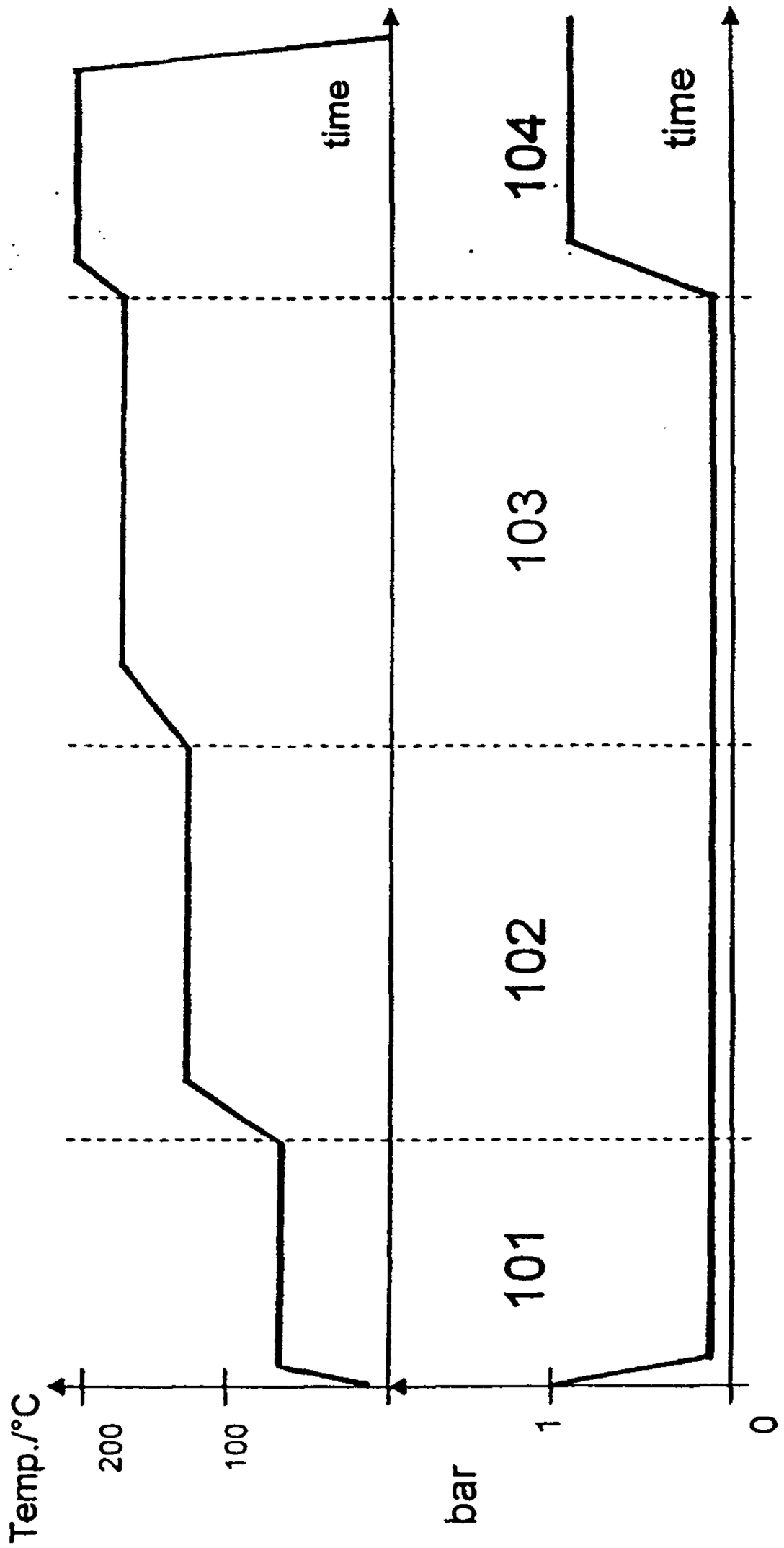
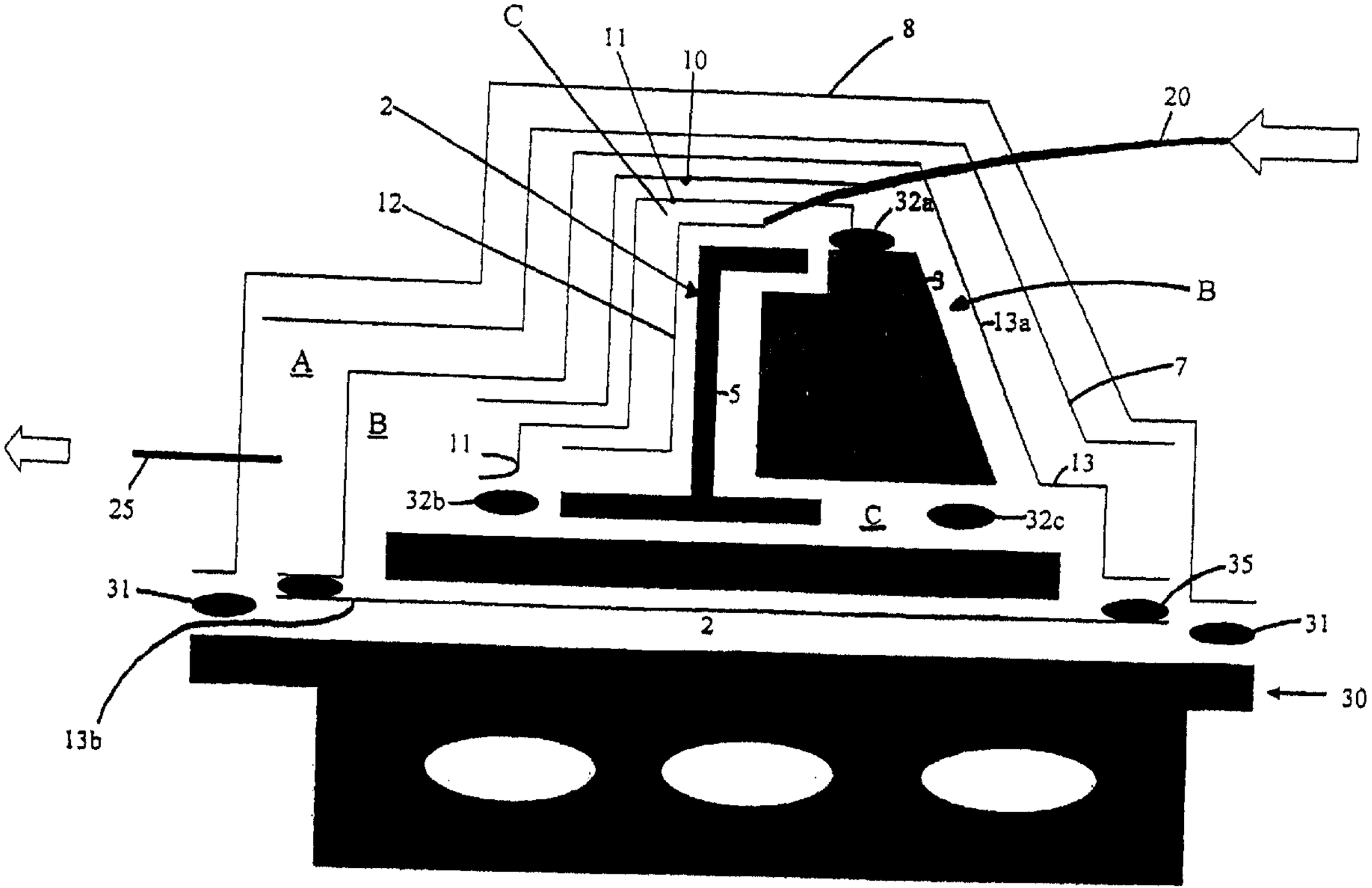


FIG. 3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