

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
17 October 2002 (17.10.2002)

PCT

(10) International Publication Number
WO 02/081202 A1

(51) International Patent Classification⁷: **B32B 17/10**,
33/00, 27/12

(21) International Application Number: PCT/GB02/01392

(22) International Filing Date: 22 March 2002 (22.03.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0108292.4 3 April 2001 (03.04.2001) GB

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,

CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,
MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG,
SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ,
VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR,
GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent
(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR,
NE, SN, TD, TG).

Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: FORMABLE COMPOSITES

(57) Abstract: A formable composite, usually in sheet form, which has a variable percentage of one or both sides of a formable material covered in key material areas forming discontinuous patterns of keying areas. This discontinuous key material enables the bonding or joining of other materials either as a reinforcing or a form holding structure or a joining method to the formable composite. The formable composites comprising discontinuous keying layers may be vacuum formed.



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FORMABLE COMPOSITES

[001] The present invention relates to formable composites, to their method of manufacture, to their use and to formed and reinforced articles derived from such
5 formable composites.

BACKGROUND OF THE INVENTION

[002] Composite facing or lining materials, which are adapted for bonding to
10 reinforcing materials are known in the art.

[003] United Kingdom Patent No. 1,052,949 describes such a facing material, which comprises a thermoplastic sheet, particularly polypropylene, bonded to a woven or knitted fabric comprising glass fibres and thermoplastics fibres. The
15 thermoplastic fibres provide good adhesion to the thermoplastic sheet whilst the fabric acts as a "key" to which a bulk reinforcement material such as resin reinforced with glass fibres (G.R.P.) will bond.

[004] US 4 228 208 discloses a composite facing material which is adapted for
20 bonding to a reinforcement material. The composite consists of a facing layer of a thermoplastic material and a key fabric layer. The key fabric layer has a base layer, which is bonded to the surface of the facing layer and a fibrous pile layer that is secured to the base layer.

[005] One of the main uses for such a material is in the construction of chemical
25 plant where, for example, the polypropylene provides a highly chemically-resistant lining for vessels, tanks and pipes with the "key" fabric giving the necessary adhesion to the G.R.P. reinforcement. Good adhesion is essential to the overall strength of the structure particularly under conditions of vacuum.

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[006] Apart from providing a "key" surface for bonding to any subsequently applied reinforcing materials the key layer itself may provide reinforcement to the thermoplastic facing material. In this role the key material assists in improving the handling properties of the thermoplastic material, which may be in the form of a relatively thin sheet.

[007] Despite having useful properties these composite materials have limited utility and fields of application. The main reason for this limited utility is their lack of formability. This lack of formability is primarily due to the presence of the woven or felted "key" layer. Layers of this type have two major drawbacks. Firstly, their properties are such that they inherently have limited formability and thus effectively restrict the formability of the thermoplastic layer under forming conditions. Secondly, the warp and weft of the woven "key" materials tend to cut through the base thermoplastic material under forming conditions; this compromises the physical integrity of the thermoplastic facing layer and in some instances may make it functionally useless.

[008] There is a need, therefore, for composite materials, which are formable whilst at the same time retaining the useful properties of for example the conventional thermoplastic facing films and the reinforcing properties and bonding properties provided by "key" layers. The present invention provides formable composites, which meet these requirements.

SUMMARY OF THE INVENTION

[009] The present invention is based on the use of a "key" layer, which is discontinuous; this has been found to allow acceptable formability of the composite whilst retaining all or most of the conventional benefits of the key layer.

[010] The present invention therefore relates to a formable composite, usually in sheet form, which has a variable percentage of one or both sides of a formable

material covered with areas of key material that form a discontinuous pattern or keying area across the surface of the formable composite. This discontinuous key material enables other materials, such as reinforcing materials or form holding materials/structures or joining materials, to be bonded to the formable composite
5 without restricting the formability of the original formable composite.

[011] Therefore, in a first aspect, the present invention provides a formable composite which comprises:(i) a formable material, and (ii) a key material bonded to at least one surface of the formable material, characterised in that the key material is
10 present as a discontinuous layer over the formable material surface to which it is bonded.

[012] There are various methods, which may be used for the manufacture of the formable composites of the present invention.

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[013] Therefore, in a second aspect the present invention provides a method for the manufacture of a formable composite which method comprises bonding onto a formable material a key material in the form of a discontinuous pattern.

20 [014] In a third aspect the present invention provides a method for the manufacture of a formable composite which method comprises bonding onto a formable material a key material in the form of a continuous layer, which comprises a latent discontinuous pattern within its structure.

25 [015] In a fourth aspect the present invention provides a method for the manufacture of a formable composite which method comprises bonding onto a formable material a key material in the form of a continuous layer and then treating the layer of continuous key material to introduce discontinuities. This is the preferred method for the manufacture of the formable material.

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[016] In a fifth aspect the present invention provides a formed composite in the deformed state, which comprises a formable material in contact with a discontinuous key material.

- 5 [017] In a sixth aspect the present invention provides a reinforced formed composite which comprises a formable composite in the deformed state bonded to a reinforcement material, wherein the composite formable material comprises a formable material and a discontinuous key material and wherein a portion of the discontinuous key material is embedded in the reinforcement material.

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BRIEF DESCRIPTION OF THE DRAWINGS

- [018] The present invention will be better understood by reference to the Detailed Description of the Invention when taken together with the attached drawings
15 wherein:

[019] Figure 1 is a schematic cross-section of a prior art composite facing material during its manufacture,

- 20 [020] Figure 2 is a schematic cross-section of a formable composite according to the present invention,

[021] Figure 3 is a schematic cross-section of a reinforced formed composite of the present invention, which comprises a formable composite bonded to reinforcement,

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[022] Figure 4 is a schematic cross-section of a reinforced formed composite of the present invention in which two formable composites are bonded with reinforcing material in a sandwich arrangement,

[023] Figure 5 is a schematic cross-section of two formable composites A and B, which have been formed prior to their engagement into a reinforced formed composite,

5 [024] Figure 6 is a schematic cross-section of the reinforced formed composite resulting from the bonding of the formed composites A and B of Figure 5,

[025] Figure 7 is a schematic cross-section of formable composite, which comprises a metallic layer (a) before and (b) after forming,

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[026] Figure 8 is a schematic cross-section of two formable composites in a sandwich arrangement, (a) before and (b) after forming, a distinct intermediate layer is present between the two formable composites, and

15 [027] Figure 9 is a schematic cross-section of two formable composites in a sandwich arrangement, (a) before and (b) after forming, which comprises an intermediate layer between two formable composites, which enables relative movement of the two layers during forming.

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DETAILED DESCRIPTION OF THE INVENTION

[028] The formable material provides a number of possible functions. It may be selected for its physical properties such as for example impact resistance and/or chemical resistance. Its function may be purely aesthetic. Therefore ideally it is a material, which substantially retains the desired functional property after forming operations.

[029] The formable material may be any material, which is capable of being formed by moulding, by use of an applied vacuum, by the application of pressure, or a combination of all of these. Forming may be undertaken under ambient, sub-ambient

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or elevated temperatures. Preferred formable materials are those that may be used in vacuum forming processes.

[030] One class of suitable formable materials are plastics and polymers, in particular thermoplastic materials that can be formed into sheet or other shapes such as moulded or extruded pipes or vessels. Examples of suitable materials include polyolefins, particularly polypropylene and co-polymers thereof, polycarbonates, polyethers, polyaldehydes, polyvinyls and polystyrene. Other suitable polymers include rubber materials such as silicon rubber. It is preferred that the formable material is a thermoplastic material and more preferably that the thermoplastic material is a polyolefin. The preferred polyolefins are ethylene, propylene, and butylene based polyolefins and most preferred are polypropylene and co-polymers of propylene. It is preferred that the formable material is in the form of a sheet suitable for vacuum forming processes, most preferred are sheet materials which are relatively thin and of the order of 20 mm or less in thickness, preferably 15 mm or less in thickness, more preferably 10 mm or less in thickness and most preferably 6mm or less in thickness. A particularly preferred sheet material has a thickness within the range of 0.1 to 10 mm, more preferably 0.25 to 8 mm, more preferably 1 to 8 and most preferably 2 to 6 mm.

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[031] A further class of suitable materials are metals such as copper, steel, alloys and the like. The metal may be directly bonded to a suitable key layer or it may be present as a metalised surface of a thermoplastic polymer.

25 [032] Other materials not normally associated with forming could be used such as paper/cardboard, wood, chipboard, made formable by soaking in water or other solvent.

[033] The key material has two primary functions although it may have other or alternative functions. The first is to provide a region of the composite, which is capable of interacting effectively with reinforcing materials and therefore bonding the

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composite to them. The region may be a layer of discontinuous key material or it may a number of separate and distinct regions of discontinuous key material located within the same surface plane of the composite or at key points on the composite surface which will be bonded to other materials such as reinforcing materials. When
5 the key material is for example a fabric the fibrous pile of the key fabric provides a large surface area which is highly receptive to bonding to reinforcing materials such as G.R.P., which may be applied in the liquid state and which subsequently cured in situ. The reinforcing material may be needed to provide additional reinforcement to the composite, which is required for its proposed use. The function of the
10 reinforcement may however be primarily to retain the shape of the composite once it is formed.

[034] The second function of the key region is to provide a limited amount of reinforcement to the formable material. This is particularly advantageous when the
15 formable material is to be used in the form of a sheet in vacuum forming operations although it may be advantageous in other applications. Typically, in vacuum forming operations a thermoplastic material in the form of a sheet is first heated to a temperature at which the sheet may be deformed by the application of an applied vacuum when the sheet is applied to a suitable mould. However, at these
20 temperatures the sheet often deforms under its own weight forming a large bubble shaped deformation in the hot sheet. The presence of this bubble is often taken as an indication that the sheet is at the correct temperature for vacuum forming. However, the sheet, deformed in this fashion is often difficult to handle with ease and may result in problems of control during the vacuum forming operation. The formable
25 composites of the present invention do not exhibit such marked bubble deformation effects during use. Surprisingly it has been found that although the key material layer is discontinuous it does impart reinforcement to the formable material during vacuum forming processes. When the formable composites of the present invention are used in the form of a sheet and in a conventional vacuum forming process the sheets of
30 formable composite although at a temperature suitable for vacuum forming, exhibit markedly reduced bubble deformation. This means that the formable composites of

the present invention are easier to handle in a conventional vacuum forming process and are less prone to material control problems in the vacuum moulding operation, especially when used in the moulding of shallow forms. Thus the formable composites of the present invention find particular utility in vacuum forming processes, which is the preferred method of their use in the present invention. It may be advantageous to pre-heat or heat soak the formable composites of the present invention prior to introduction to the vacuum forming process. Such pre-heating or heat soaking may be in addition to any heat that is typically applied to the formable composite in the vacuum forming equipment or it may be used in place of some of that heat to enable lower heat input in the actual vacuum forming equipment.

[035] The key material may be in the form of a woven, knitted, or felted material or a non-woven fabric such as a tufted layer or fleece or stretch fabric. The key material may be the same material as the formable material; it may be a thermoplastic material or it may be a metal material such as a steel fabric or it may be a carbon fibre fabric. The key material may comprise for example glass fibres or natural fibres or a combination of different fibre materials.

[036] An important feature of the key material is that it must be present in the composite as a discontinuous region or layer. By discontinuous is meant that it is deposited onto the formable material in the form of a pattern or distinct areas of deposition or that these patterns of discontinuity are formed after deposition of a continuous key material layer. Alternatively the key material may be deposited physically as a continuous region or layer but within this continuous region or layer of key material there will be present pre-defined areas, which have different material properties from the bulk material. The purpose of these areas of different material properties is to provide a latent discontinuity within the key material. This latent discontinuity may be induced after manufacture of the composite or may be introduced into the key material prior to forming the composite. The latency may be removed prior to use of the composite in a forming operation or may be removed during the forming process. It is preferred that the key material is deposited on the

formable material as a continuous layer and that a pattern of discontinuity is then made in the deposited key material layer.

5 [037] The discontinuities in the key material allow for unrestricted formability of the composite where formability is required, whilst the regions of the key material that remain intact offer selected areas within the composite of greater strength which may be used for bonding to other materials. With the use of discontinuous key materials greater complexity of moulded shapes may be achieved.

10 [038] When the key material is a cut fabric, the cuts to the fabric allow unrestricted formability of the formable material and they should be created in such a manner so as to avoid a 'notch effect' into the base material, when this may be detrimental. This may be detrimental in relatively thin sheets of formable material. On softer materials this may be less important and on harder materials it may be desirable.

15 [039] Rigid materials not normally thought of as formable could be formed by utilising deeper cuts through the fabric key material to create a 'notch' effect weakening of the surface (i.e. squares of chocolate) to allow forming pressures to be applied before fixing in position with a matrix keyed to the key material fibre surface
20 (i.e. reverse of mosaic tiles). Thus, in this embodiment there is a combined use of a discontinuous key layer and notch effect in the formable material.

[040] The key material may be multilayered, for example, as multilayered fabrics. In this embodiment each layer may have different patterns of discontinuity with
25 discontinuities being located at different spacings within each layer. Alternatively or additionally the discontinuous key layer may be covered with an elastic layer, which is able to deform during use of the formable composite. Such additional layers may be useful in avoiding localised thinning of the formable material during forming processes and/or to enable a practical limit to be placed on the extent of deformation
30 of the formable composite.

[041] In the second aspect of the present invention a woven fabric key material may be cut into predetermined shapes, which are then separately or collectively bonded to the formable material. The fabric may be cut using well-known techniques in the art
5 such as hot wire or mechanical cutting.

[042] In the fourth aspect of the present invention the key layer may be cut using well-known techniques in the art such as hot wire or mechanical cutting to introduce discontinuities after deposition of a continuous key material layer. Alternatively, the
10 discontinuities may be introduced by physical or chemical degradation of the key material, introducing discontinuities by removal of the key material before use of the formable composite. The fabric may be cut diagonal to the warp and weft (on the bias) to allow fibre to move more easily than if parallel to warp and weft patterns.

[043] In the third aspect latent discontinuities may be introduced by a number of methods. A wire pattern may be introduced into the key material during its manufacture e.g. it may be introduced by weaving into a fabric key material, to form a latent pattern in the key material. After bonding of the key material to the formable material the wire is physically removed through the surface of the key material to
20 introduce discontinuities in its surface. If the wire is a resistance wire it may be heated with an electric current and removed from the key material via melting of the material to provide a discontinuous pattern. The key material may be selectively chemically treated either before or after deposition on the formable material. This chemical treatment may introduce in the form of a pattern a physical weakness into
25 the selected areas of the key material. These weaknesses would become apparent under forming conditions e.g. elevated temperature, and result in failure of the key material at these locations. A woven key material may be manufactured from a specially spun and weakened yarn (i.e. hot crimped at intervals to produce breaking points, or chemically etched which is especially suitable for metal formable
30 materials.)

[044] In the case of pipe/rod or bar, discontinuous key material could take the form of rings or spirals to allow the product to be bent prior to reinforcement.

[045] It may be desirable to form the discontinuous key material on a further material which is either removed after bonding of the key material to the formable material or is bonded with the key material to the formable material e.g. a bonded layer or removable cover sheet. This may be particularly suitable when the process of forming the discontinuities could result in damage of the formable material.

[046] In this context the key material may be deposited or formed on a base layer. The base layer of the key material may be made from a material e.g. a thermoplastic material which is the same as, or is compatible with, that of the formable material in order to promote bonding of the key material to the formable material. Whilst an intermediate adhesive material may be used, it is preferred to obtain direct bonding between the formable material and the key material with or without the base material by the use of for example heat or solvent action. For example, the formable material may be a sheet of polypropylene, which is calendared to a base layer comprising a polypropylene and glass fibre fabric whilst its surface is still soft immediately after extrusion. This technique is described in British Pat. No. 1,052,949.

[047] The base layer may comprise a woven, knitted or non-woven fabric or simply a thermoplastic film. An example of the latter is a sheet of polypropylene or polyethylene film. A suitable non-woven fabric is a spun-bonded polypropylene fabric such as the fabric sold under the Registered Trade Mark 'Tygar'.

[048] The key material comprising a fibrous pile may be secured to the base layer by any of the known techniques including tufting, pile weaving (terry or plush), sliver knitting, terry knitting, stitch-bonding ("Malipol" machine), and needle punching. In some of these techniques the base layer is formed at the same time as the pile. Tufting is a favoured technique because it lends itself to the use of glass fibre to form the pile without too much damage to the fibre, and provides a good anchorage of the

pile in the base layer, particularly when the base layer is bonded to the formable material. Also, it is a comparatively inexpensive operation. Additional techniques which may be used to make the pile-bearing key fabric include raising or knapping the surface of a fibrous base fabric to partially withdraw some of the base fabric fibres into an integral fibrous pile. The key material may be formed by tufting of a surface of the formable layer.

[049] Prior art formable composites do not have discontinuous keying material. Figure 1 illustrates such a prior art arrangement during its manufacture. This figure illustrates that the key fabric (1) in contact with a woven base layer (2) can be applied to a facing layer (3) either with pressure and heat or by adhesive bonding depending on the material used. The key fabric could be fibrous and/or in the form of bristle.

[050] A specific embodiment of the present invention comprises a polypropylene formable sheet, which is fabric backed to form a composite. The formable sheet may for example be a fleece and/or stretch fabric backed polypropylene or polyethylene or polyvinylidene fluoride. The fabric is tool, heater or chemically cut or weakened to break or allow controlled breaking of the continuous warp and weft (in a grid pattern for instance) of the fabric to form a formable composite and to allow the polypropylene/ to be vacuum formed or forced in a relatively convenient manner to complex compound shapes. Once in this complex shape the formed composite is then reinforced with G.R.P. or similar laminating lay up systems or paper mache or concrete or any form of setting compound /matrix or thermoform materials which attach to the fibrous tufted keying areas. Such an arrangement is illustrated in Figures 2 and 3. Figure 2 shows the type of discontinuous pattern, which could be cut through the key fabric layer (1) and bonding layer (2) to enable efficient forming of facing layer (3). Figure 3 illustrates a reinforced formed composite in which the formable composite of Figure 2 has been formed into a desired shape and then reinforced with a matrix or binding layer (5), which is intimately in contact with the discontinuous keying layer (3) and enables the formed shape to be retained. The discontinuous region (4) and the woven bonding layer (2) are indicated for clarity.

[051] In a further embodiment the formable material is a silicon rubber sheet, which is fabric backed. A pattern is cut into the fabric and the formable composite is vacuum formed and held over a former then G.R.P. backed. This embodiment could
5 be utilised for the manufacture of hot material moulding tools and easy release.

[052] In a further embodiment, polypropylene formable material is fabric backed and disk cut; the cut fabric is then provided with an acrylic cap. This method finds utility in the manufacture of impact and damage resistant decorative panels for use in
10 sign and display work.

[053] In a further embodiment polypropylene formable material is backed with a felted fabric, which is then provided with a discontinuous pattern by cutting. The formable composite is press formed and reinforced with a combination of an uncured
15 butyl rubber plus alloy 20 SWG alloy. These formed and reinforced composites find utility in the manufacture of parts for the automobile, marine and aerospace industries. Figure 7 illustrates such an embodiment. A formable material (1) has a discontinuous keying layer (4) bonded to one surface. A butyl rubber layer (3) is deposited upon the discontinuous keying layer and an alloy/metal layer (2) is
20 deposited on the butyl rubber layer. During forming the keying layer (4) and butyl rubber layer (3) become intimately contacted with each other to form a strong reinforcing layer (5), which holds the formed composite in position after forming.

[054] In the case of materials, other than thermo-plastics, i.e. alloys, steels etc. the
25 key material could be attached with adhesive as tufts or as fabric, then cut. Usually the fabric material would have a higher tensile strength than the formable material to which it is attached, giving improved properties to the finalised component. If desired a shear line may be intentionally introduced between the formable material and the keying material by using a lower tensile strength material, or possibly
30 induced by increase in temperature. Such a shear line would allow replacement of damaged panels.

[055] Differential expansion between the reinforcing media and the tufted material i.e. polypropylene / G.R.P can also be accommodated by wider cut giving larger non-bonded areas allowing ripples to form. This has benefits in ensuring that the facing material remains in intimate contact with the reinforcing material ensuring reduced delamination which can be a problem due to the differential thermal expansion coefficients of the facing material and the GRP which may be used for reinforcement.

[056] Tension webs could be 'spun' inside twin wall structures using rotational movement and a distribution system or CNC point to point wire techniques, followed by foam injection to maintain the formed product shape and aid structural reinforcement. Materials other than foam may be introduced as a binder.

[057] Special multilayered or special weave fabrics could be introduced between twin wall or single wall constructions to create a fibre, 3D web effect to provide binding and torsional stability. Such materials include tow materials which are rolled to unwoven hanks and passed through a spreader to form a web, which may be hot crimped at stages and built up through successive crimping and treatment stages to form a fibrous material which may then be extended into a low density 3D web material, which may then be attached and bonded to the key material of the formed composite.

[058] The formable composites of the present invention could be utilised for the manufacture of complex products which special properties. One such embodiment would find utility in the manufacture of R.F. shielding and the construction of antennae. This embodiment is illustrated in Figures 5 and 6. Two formable composites are prepared (part A and Part B) which have a thermoplastic forming layer (1), which has bonded to its surface a discontinuous metal (or metallized) fabric. Each composite is formed into a shape, which is complimentary to the other (male/female) with the metal keying material or metallized fabric being on opposing surfaces. When the formed composites are pressed together opposing metal fabric

shapes contact each other to effectively form a continuous electrically conductive shape (c) bonded between two thermoplastic layers as illustrated in Figure 6.

[059] Other more complex composite arrangements are envisaged as within the scope of the present invention. These embodiments are illustrated in Figures 4 and 8. There may be present two or more layers of discontinuous material; some of which may function as a key region but other layers may have alternative functions. Thus in one embodiment as illustrated in Figure 8 a formable composite may comprise a formable material (1) having deposited upon it distinct regions of acrylic-fibre islands (3). Two of these formable composites are then brought together in a sandwich arrangement, which comprises a further layer (4) of, for example, a low melt material such as a resinous material. During forming the layer (4) melts and becomes intimately mixed with the two keying regions (3) to form a bonded region (5) in the final formed composite which acts as reinforcement ensuring stability of the formed shape. In the bonded region (5) the two key regions (3) are still discontinuous but they are securely embedded in the material of the further layer (4). In an alternative arrangement as illustrated in Figure 4 the further layer (4) is not a distinct layer but may comprise a resinous region which is deposited during manufacture; such a region due to its properties may allow relative movement of the two opposing keying regions during forming of the composite.

[060] As discussed above the formable composite may be easily formed or if desired reinforced to provide a final formed product. The reinforcement material may be any material which is capable of retaining the shape of the formed composite after forming. For example G.R.P. as mentioned already or indeed any suitable fibre-reinforced resin. Hydraulic cement is another suitable reinforcement material in any of its various forms including Portland cement, high alumina cement, cement fondué and gypsum plaster, all with or without aggregate or fibrous reinforcement and including 'concrete' products. With cement, the preferred pile fibres comprise alkali-resistant glass ("K" glass), for example as manufactured by Pilkington Bros. Ltd. as "Cemfil" (Registered Trade Mark). Other suitable pile fibres, for both cement and

other reinforcement materials, include fibres of polyester or polyamide, including aromatic polyamides such as "Kevlar" (Registered Trade Mark), and acrylic fibres. The reinforcing material may be a thermosetting material or a foamed material. It may be a low melt alloy such as "rose metal" or it may be powdered materials, which
5 can be wet set or sintered. The reinforcing material may be derived from one or more polymers in powder or granule form, which may be placed between the formed composites and fused under heat and/or pressure. The key material or the reinforcing material may incorporate self-extinguishing materials and may incorporate fire resistant properties which are desirable in many applications such as fire brakes for
10 cladding systems.

[061] The reinforcement material may be applied to the fibrous pile surface of the composite facing material by any of the usual techniques. For example, both G.R.P. and cement may be applied by hand lay-up, by spraying, or by moulding or casting or
15 injection.

[062] The formable composites and reinforced formable composites of the present invention may be used in a wide variety of applications including the manufacture of automobile parts such car bumpers, seat mouldings, and door linings.

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[063] In one example concrete back up of formed sections used as permanent or semi-permanent shuttering could be used to create rooms or buildings. Lighter building for use in unstable areas or temporary facilities could be made using a lighter tie matrix than concrete. (i.e. a rigid foam.)

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[064] The reinforced formed composite of the invention may be in the form of a lined pipe, duct, vessel or tank, or may be the wall of a building having an external facing and/or an internal lining. For example, concrete buildings may be faced with decorative and weather-resistant plastics panels by using the composite material of
30 the invention. In this embodiment the discontinuous keying layer may be a point for adhesion to building surfaces which could help to prevent gaps being generated

between the panel and the building surface. This could also afford a panel, which is relatively easy to remove and replace or repair. Another end use is in the lining of rooms where hygiene is important, such as in hospitals or abattoirs.

5 **[065]** The preferred formable composites of the present invention are a combination of a thermoplastic formable material, preferably in the form of a sheet, with a woven fabric bonded to one of its surfaces as the key material layer. The bonded fabric layer preferably comprises a thermoplastic containing fabric and preferably also comprises a polyester material. Preferably the discontinuities are present as a regular pattern of
10 cuts defining continuous areas of key material of preferably regular and uniform shape. The exact dimension of the continuous area will depend on the thickness of the formable composite and the complexity of shape of the final formed article. Typically, larger continuous areas may be accommodated with thicker formable composites and smaller continuous areas may be required for thinner formable
15 composites and/or more complicated formed articles. For relatively thin formable composites with thermoplastics as the formable material of thickness less than 6 mm preferably the continuous regions are of the order of 2 to 20 mm square and preferably 2 to 10 mm square. The formable composites of the present invention are of particular utility in the shallow draw vacuum forming operations. By shallow
20 draw is meant that the overall depth of the internal dimension of the form after vacuum forming is 300 mm or less and preferably 200 mm or less, and most preferably it is no more than 150 mm.

[066] In order to provide a better understanding of the present invention including
25 representative advantages thereof, the following examples are offered.

[067] Example 1 Vacuum Forming of a Formable Composite

A formable composite was prepared using a commercially available composite
30 material sold under the trade name Celmar® by Royalite. This material was supplied in the form of a sheet consisting of a polypropylene layer, which is a thermoplastic,

to which is bonded a woven fabric of polypropylene and polyester to form a continuous layer of keying material. The total thickness of the composite material was approximately 5 to 6 mm with the polypropylene layer being of the order of 4.5 mm. The composite material was treated to produce a formable composite by cutting into
5 the woven key layer with a hot wire knife or with a sharp blade to separate the warp and weft to form a regular pattern of isolated rectangular areas of key material over the whole area of the sheet. The thin lines, due to the cut marks, being regular areas of discontinuity between each area of key material. After this pattern cutting operation the resultant formable composite retained its physical strength and was
10 evaluated in various vacuum forming operations as follows.

Various samples of the formable composite were utilised in a Macc Rotary Indexing type vacuum forming machine, which is a conventional vacuum forming machine known in the art. The mould in this machine was prepared in order to vacuum form
15 thermoplastic shower trays with a large outside turn down.

This machine operates on a three-stage cycle. The first stage is a load/un-load stage. The second stage is a heat up stage where the sheets of formable composite are held horizontally over a bank of ceramic heaters to bring the composite up to the correct
20 temperature for vacuum forming. The temperature of the composite is roughly controlled by the residence time over the ceramic heaters. In the present case the residence times were between 160 and 170 seconds. After heating the hot sheet is transferred to the third-stage, which is a vacuum forming stage where the hot composite is engaged with the mould and a vacuum applied. After forming and
25 partial cooling in the mould the formed composite is moved to the load/un-load stage. The cycle is then repeated.

Firstly, a polypropylene sheet of approximately 1 m² and 4.5 mm thickness was passed through the vacuum former. After the heating stage of 170 seconds it was
30 observed that the sheet had deformed resulting in a deformation bubble of approximately 450 mm in depth. This sheet was passed to the vacuum forming stage

for forming under standard conditions using a rapid vacuum. The formed article was acceptable but did not have any suitable keying means for ease of application of reinforcing materials.

- 5 The formable composite prepared according to the present invention was also passed through the same vacuum forming equipment under the same conditions and was found to have a considerably smaller deformation bubble after the heat cycle. On vacuum forming the sheet formed but was found to have localised extrusion on the long draw down regions of the mould. The moulding was undertaken with the polypropylene surface facing the mould surface. The forming was repeated with the discontinuous key layer facing the mould surface; this was found to transfer the discontinuity pattern through to the surface of the polypropylene. This example proves that the formable composite with a discontinuous keying layer may be vacuum formed. Attempts to vacuum form the commercially available composite had failed.

Example 2 Slow Vacuum and Lower Temperature Vacuum Forming of a Formable Composite

- 20 The forming as undertaken in Example 1 was repeated with the exception that the residence time in the vacuum former was reduced to approximately 160 seconds and the vacuum was applied over a period of 2 to 3 seconds as opposed to the normal instantaneous application of full vacuum. In addition the mould was modified to remove the large external turn down and therefore the tray was a shallow form with a maximum dimension of 150 mm. It was difficult to mould with the standard polypropylene sheet as, due to the large deformation bubble and the presence of too much material for a shallow draw, the sheet folded in the mould during vacuum forming.
- 30 Under these conditions it was possible to vacuum form the formable composite with discontinuous keying layer.

In a further variation the formable composite with discontinuous keying layer was initially heated for 100 seconds and then left to cool in ambient air for a few minutes. After cooling this blank was passed through the vacuum forming cycle with the key
5 layer facing the mould. This blank moulded perfectly with some evidence of the discontinuity pattern being transferred to the polypropylene layer.

This shows that the formable composite may be vacuum formed with either face of the composite in contact with the mould surface.

10

Example 3 Reinforcement of Formed Composite with GPR

A formed composite was fabricated into a reinforced composite by applying a glass fibre (GPR) composition with a low viscosity resin to the discontinuous keying layer
15 of the formed composite. The GPR bonded strongly to the keying surface and provided a final reinforced composite of high strength.

CLAIMS

1. A formable composite, which comprises:
 - 5 (i) a formable material, and
 - (ii) a key material bonded to at least one surface of the formable material,characterised in that the key material is present as a discontinuous layer over the formable material surface to which it is bonded.
- 10 2. A formable composite according to claim 1 wherein the discontinuous layer comprises distinct and separate regions of discontinuous key material.
3. A formable composite according to claim 1 wherein the key material is in the
15 form of a continuous layer with latent discontinuities.
4. A formed composite in the deformed state, which comprises a formable material in contact with a discontinuous key material.
- 20 5. A reinforced formed composite which comprises a formable composite in the deformed state bonded to a reinforcement material, wherein the composite formable material comprises a formable material and a discontinuous key material and wherein a portion of the discontinuous key material is embedded in the reinforcement material.
- 25 6. A formable composite, formed composite or reinforce formed composite according to any of the preceding claims wherein the formable material is a thermoplastic.
- 30 7. A formable composite, formed composite or reinforced formed composite according to claim 6 wherein the thermoplastic is a polyolefin.

8. A formable composite, formed composite or reinforced formed composite according to claim 7 wherein the polyolefin is polypropylene or polyethylene or copolymers of propylene or ethylene.
- 5
9. A formable composite, formed composite or reinforced formed composite according to any one of claims 1 to 5 wherein the formable material is metal.
10. A formable composite, formed composite or reinforced formed composite according to any of the preceding claims wherein the key material is a woven fabric.
- 10
11. A formable composite, formed composite or reinforced formed composite according to claim 10 wherein the woven fabric is a polymer.
- 15
12. A formable composite, formed composite or reinforced formed composite according to claim 11 wherein the polymer is a combination of polypropylene and polyester.
- 20
13. A formable composite, formed composite or reinforced formed composite according to claim 10 wherein the woven fabric is a metal.
14. A method for the manufacture of a formable composite which method comprises bonding onto a formable material a key material in the form of a discontinuous pattern.
- 25
15. A method for the manufacture of a formable composite which method comprises bonding onto a formable material a key material in the form of a continuous layer which comprises a latent discontinuous pattern within its structure.
- 30

16. A method for the manufacture of a formable composite which method comprises bonding onto a formable material a key material in the form of a continuous layer and then treating the continuous layer of key material to introduce discontinuities.
- 5
17. A reinforced formed composite according to claim 5 in which the reinforcement material comprises a fibre-reinforced resin.
18. A reinforced formed composite according to claim 5 in which the reinforcement material comprises hydraulic cement.
- 10
19. A formable composite, formed composite or reinforced formed composite or method as claimed in any one of the preceding claims wherein the formable material is in the form of a sheet.
- 15
20. A formable composite, formed composite or reinforced formed composite or method as claimed in claim 19 wherein the sheet is of 20 mm thickness or less.
- 20
21. A formable composite, formed composite or reinforced formed composite or method as claimed in claim 19 wherein the sheet is of 6 mm thickness or less.
22. An invention substantially as described herein with reference to Figures 2 to 9.
- 25

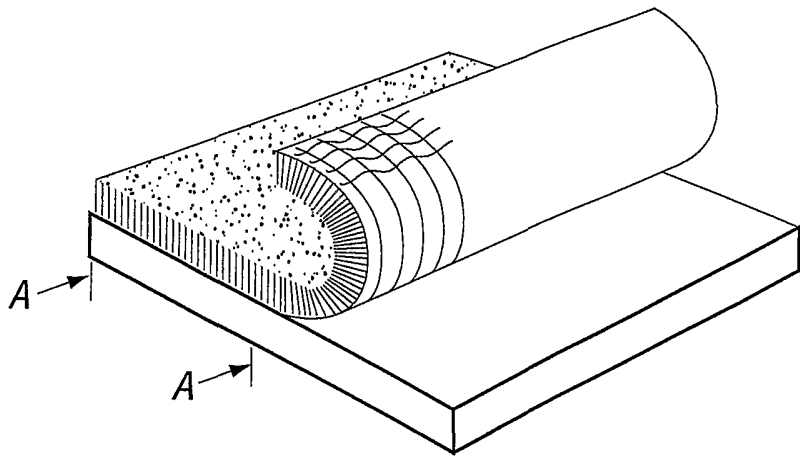


FIG. 1

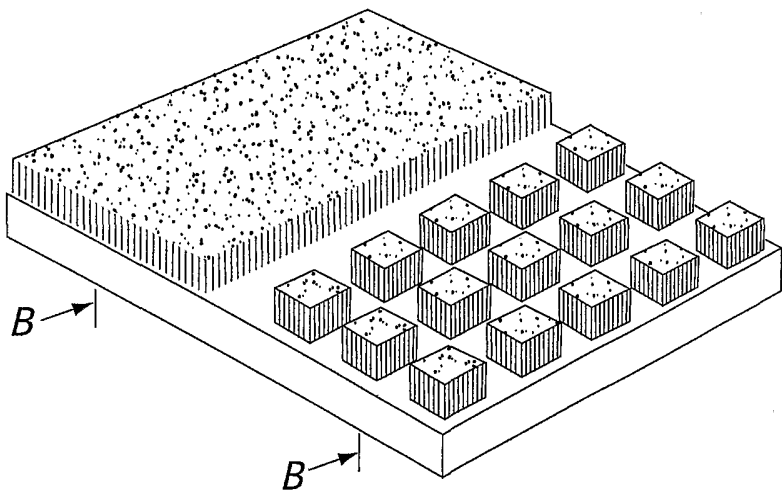
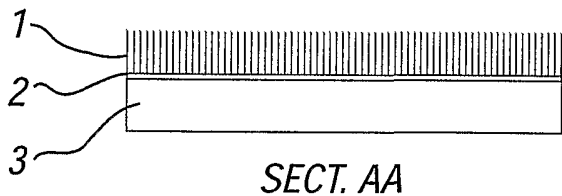
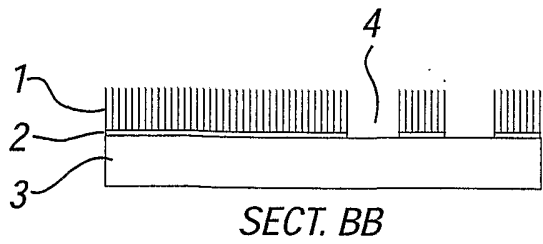
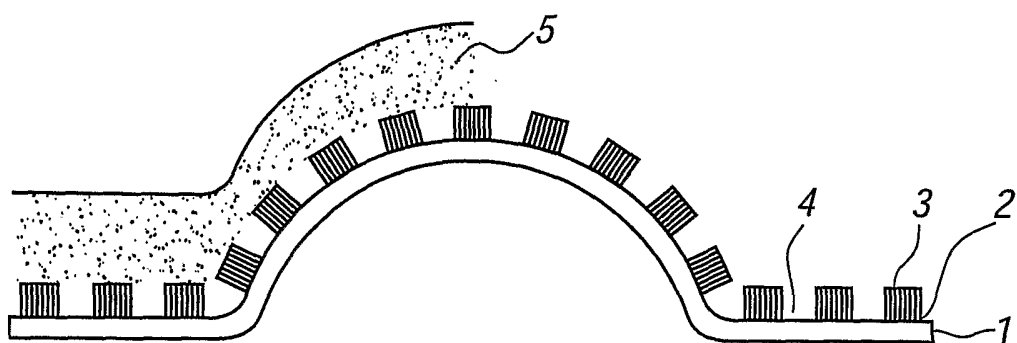
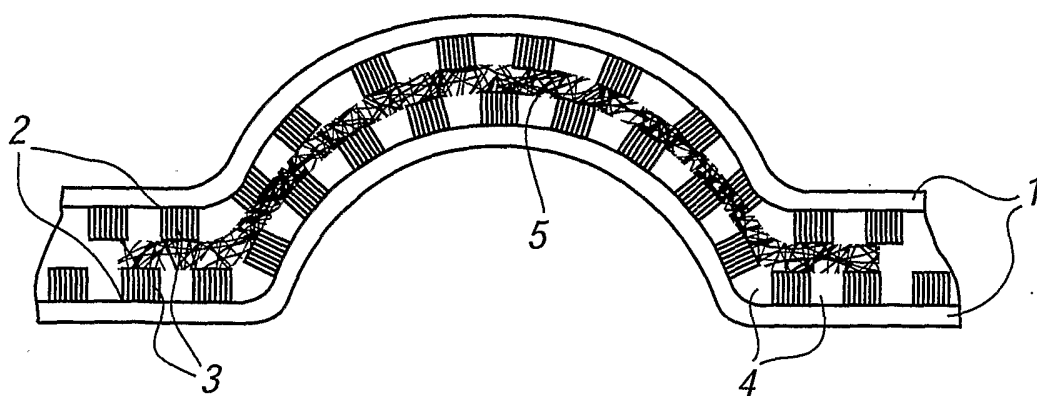


FIG. 2



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FIG. 3FIG. 4

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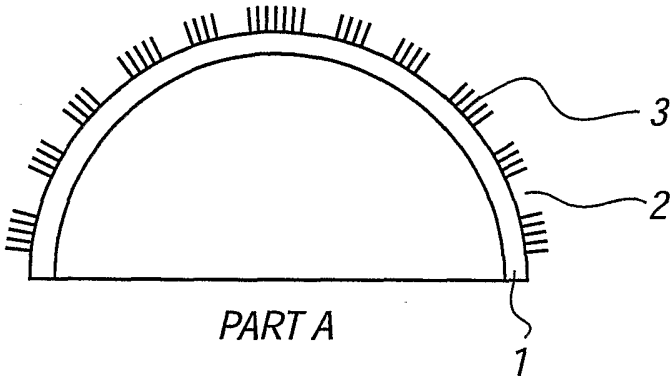
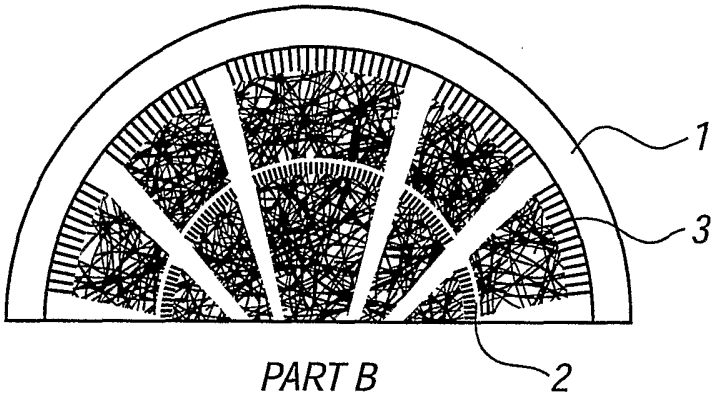


FIG. 5

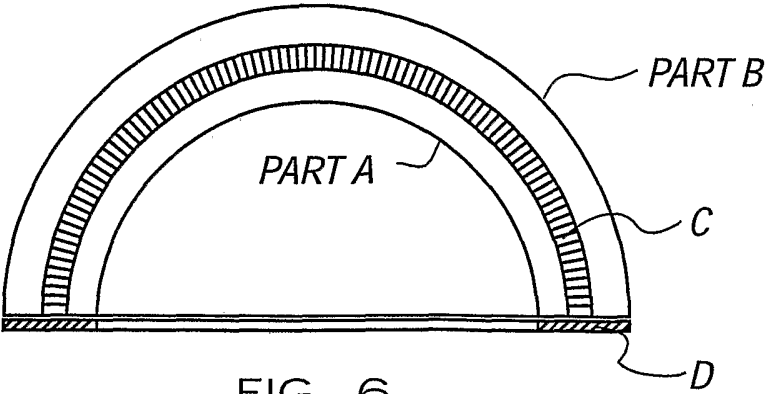
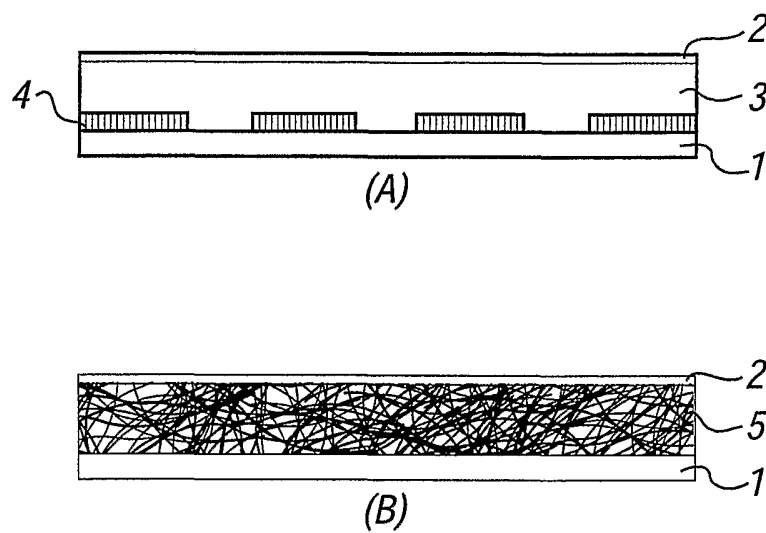
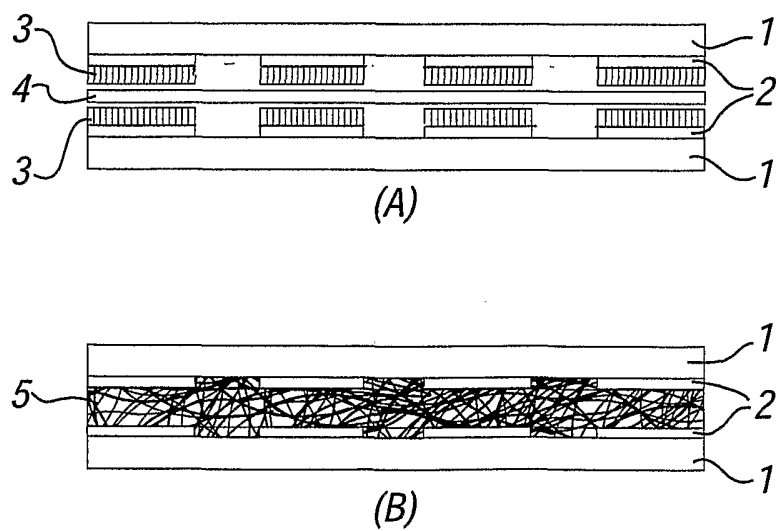


FIG. 6

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FIG. 7FIG. 8

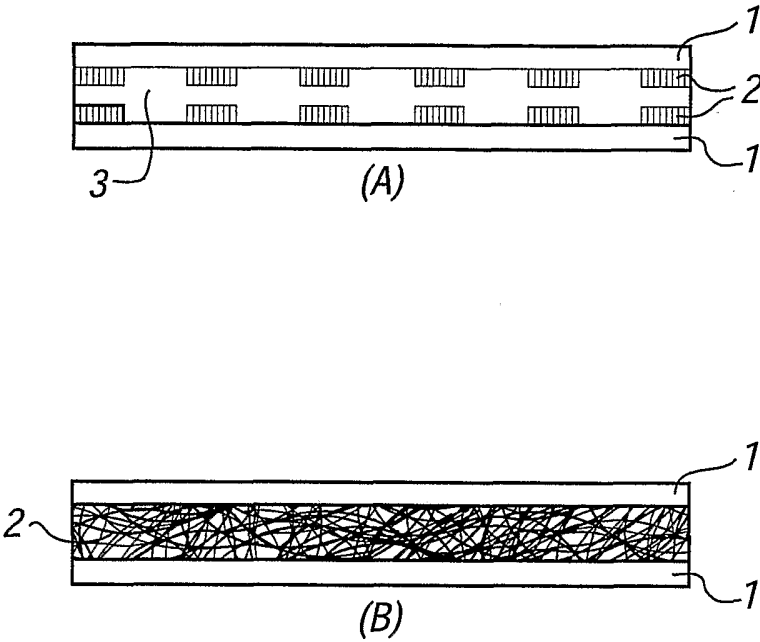


FIG. 9

INTERNATIONAL SEARCH REPORT

PCT/GB 02/01392

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 B32B17/10 B32B33/00 B32B27/12

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 7 B32B

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 practical, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 23 20 239 A (DAINIPPON PRINTING CO LTD) 25 October 1973 (1973-10-25) page 5, paragraph 4 -page 6, paragraph 3; figures ---	1-8, 10-12, 14-22
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

2 July 2002

Date of mailing of the international search report

09/07/2002

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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