A composite material is manufactured from two spaced stacks (2 and 4) of intermediate fabric material. Each stack consists of a plurality of layers of material placed together face to face. Each layer is formed by embedding high strength fibres having a high modulus of elasticity in a resin matrix. The stacks (2 and 4) are removed from a release film (6), and a film of adhesive is applied to the lower surface of the side portion (8) of the stack (2) and the upper surface of the side portion (10) of the stack (4). These side portions (8 and 10) are placed in overlapping relationship, and are then crimp fastened together by a plurality of fasteners (12). Further layers (14 and 16) of intermediate fabric material are placed over the side portions (8 and 10) to cover the fasteners (12). The crimp fastened stacks (2 and 4) are placed in a mould tool comprising a base plate (18) and a top mould plate (20). A vacuum bag (22) is placed over the top mould plate (20), and an air tight seal is made between the vacuum bag (22) and the base plate (18) by means of a peripheral sealer tape (24). The space inside the vacuum bag (22) is evacuated by withdrawing air through a passage (34) at one edge of the vacuum bag (22). The fastened stacks (2 and 4) are compressed by bringing together the plates (18 and 20), and the mould tool and vacuum bag assembly is then heated in an autoclave to cure the stacks (2 and 4) while they remain under pressure to form the required composite material. After the curing operation has been completed, the mould tool and vacuum bag assembly is removed from the autoclave, the vacuum bag (22) is removed, the mould plates (18 and 20) are separated, and the cured composite material is removed.
FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>Austria</td>
<td>FI</td>
<td>Finland</td>
<td>ML</td>
<td>Mali</td>
</tr>
<tr>
<td>AU</td>
<td>Australia</td>
<td>FR</td>
<td>France</td>
<td>MN</td>
<td>Mongolia</td>
</tr>
<tr>
<td>BB</td>
<td>Barbados</td>
<td>GA</td>
<td>Gabon</td>
<td>MR</td>
<td>Mauritania</td>
</tr>
<tr>
<td>BE</td>
<td>Belgium</td>
<td>GB</td>
<td>United Kingdom</td>
<td>MW</td>
<td>Malawi</td>
</tr>
<tr>
<td>BF</td>
<td>Burkina Faso</td>
<td>GN</td>
<td>Guinea</td>
<td>NL</td>
<td>Netherlands</td>
</tr>
<tr>
<td>BG</td>
<td>Bulgaria</td>
<td>GR</td>
<td>Greece</td>
<td>NO</td>
<td>Norway</td>
</tr>
<tr>
<td>BI</td>
<td>Benin</td>
<td>HU</td>
<td>Hungary</td>
<td>PL</td>
<td>Poland</td>
</tr>
<tr>
<td>BR</td>
<td>Brasil</td>
<td>IT</td>
<td>Italy</td>
<td>RO</td>
<td>Romania</td>
</tr>
<tr>
<td>CA</td>
<td>Canada</td>
<td>JP</td>
<td>Japan</td>
<td>SD</td>
<td>Sudan</td>
</tr>
<tr>
<td>CF</td>
<td>Central African Republic</td>
<td>KP</td>
<td>Democratic People's Republic of Korea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td>Congo</td>
<td></td>
<td></td>
<td>SE</td>
<td>Sweden</td>
</tr>
<tr>
<td>CH</td>
<td>Switzerland</td>
<td>KR</td>
<td>Republic of Korea</td>
<td>SN</td>
<td>Senegal</td>
</tr>
<tr>
<td>CI</td>
<td>Côte d'Ivoire</td>
<td>LI</td>
<td>Liechtenstein</td>
<td>SU</td>
<td>Soviet Union</td>
</tr>
<tr>
<td>CM</td>
<td>Cameroon</td>
<td>LK</td>
<td>Sri Lanka</td>
<td>TD</td>
<td>Chad</td>
</tr>
<tr>
<td>DE</td>
<td>Germany</td>
<td>LU</td>
<td>Luxembourg</td>
<td>TG</td>
<td>Togo</td>
</tr>
<tr>
<td>DK</td>
<td>Denmark</td>
<td>MC</td>
<td>Monaco</td>
<td>US</td>
<td>United States of America</td>
</tr>
</tbody>
</table>
A COMPOSITE MATERIAL

The present invention relates to a method of manufacturing a composite material, such as for example a composite material particularly suitable for forming the outer surface material of an aircraft.

The term "material" includes any suitable component or structure, such as for example a laminate joint, depending on the application of the invention.

A previously proposed composite material has been manufactured by embedding high strength fibres having a high modulus of elasticity within a homogenous matrix. In one example of such a material, the fibres are made of carbon, aramid or boron, and the matrix can be formed of material such as an epoxy, bismaleimide or polyimide resin.

The fibres are supplied in a uni-directional, woven or fibrous mat format which is pre-impregnated with slightly cured resin to form an intermediate fabric material. This intermediate fabric material is flexible and tacky, and the positions of the fibre filaments therein are not fixed. Layers of these intermediate fabric materials are assembled one upon the other in a mould, and then compressed and heated. The heating action accelerates the curing of the resin, and the combination of the heating and compression joins together the intermediate fabric materials to form the composite material.

It is an aim of the invention to provide an improved
method of manufacturing a composite material.

According to the present invention there is provided a method of manufacturing a composite material comprising placing together face to face a plurality of layers of intermediate fabric material, each layer comprising high strength fibres having a high modulus of elasticity in a tacky homogeneous resin matrix, fastening together said layers at spaced locations thereon, and then compressing and heating the layer assembly to cure the resin.

One form of fastening together said layers is by the technique of crimp fastening. In the specification, by "crimp fastening" is meant a process in which each leg of a fastener is forced through at least two overlapping layers by direct pressure when the fastener is either stationary or subject to mechanical rotation. When each leg of a fastener protrudes through the overlapping layers to a required distance it is either crimped or punched in a controlled manner to produce a clamping or fastening action. Crimp fasteners may have any suitable number of legs, such as for example one, two or three legs as illustrated in Figure 8 of the drawings, or may be of a spiral or helical configuration as illustrated in Figure 9 of the drawings. The fastener is made of any suitable material, such as for example metal or plastics material, capable of being crimped or punched to produce the required clamping or fastening action.

If desired, the fasteners may be covered by additional layers of intermediate fabric material before the assembly is heated and compressed.

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

Figs. 1a, 1b and 1c are diagrammatic illustrations of three stages in the manufacture of a composite material;

Fig. 2 is a perspective view showing one stage in the preparation of the composite material;

Fig. 3 is a sectional elevation of the composite material in a mould tool;

Fig. 4 is a detailed sectional elevation of part of the composite material located in a mould tool;

Fig. 5 is a perspective view showing one stage in the preparation of a further composite material;

Figs. 6 and 7 are diagrammatic illustrations of two examples of crimp fasteners for use in the preparation of the composite material;

Figs 8 and 9 are diagrammatic illustrations of further examples of crimp fasteners for use in the preparation of the composite material;

Fig. 10 is a diagram of an operational cycle of the invention;

Fig. 11 is a diagrammatic illustration of examples of skin stiffening configurations which are suitable for the crimp fastening method of the invention;

Fig. 12 is a diagrammatic illustration of examples of composite fasteners of the invention, and
Fig. 13 is a diagrammatic illustration of stages in the manufacture of a composite material using composite fasteners.

Referring to the drawings, and particularly to Fig. 1, in one embodiment transversely spaced stacks 2 and 4 of intermediate fabric material are supplied on a release film 6. These stacks have been compacted or debulked under vacuum at room temperature. This compaction or debulking gives to each stack a degree of structural rigidity which aids assembly of the proposed composite material. Each stack consists of a plurality of layers of the material placed together face to face. Each layer of intermediate fabric material is formed by embedding high strength fibres having a high modulus of elasticity in a homogeneous matrix which may be an epoxy, bismaleimide or a polyimide resin. The fibres may be unidirectional, woven or in the form of a fibrous mat, and the fibres may be made of materials such as carbon, aramid or boron. Each intermediate fabric material layer is supplied with the resin matrix slightly cured to ensure that the fabric layer is tacky and flexible, and at this stage the fibres are not in a fixed position in the matrix. The stacks 2 and 4 are rectangular in shape.

The release film 6 is removed from the stacks 2 and 4, and a film of adhesive is applied to the lower surface of the side portion 8 of the stack 2, and the upper surface of the side portion 10 of the stack 4. These side portions 8 and 10 are then placed in overlapping relationship as shown in Fig. 1b. Each side portion is in the form of a strip running parallel to one edge of the appropriate stack 2 or 4. These side portions 8 and 10 are then crimp fastened together by a plurality of
fasteners 12 which are spaced along the side portions 8 and 10. As shown in Fig. 1c, further layers 14 and 16 of intermediate fabric material are placed over the side portions 8 and 10 to cover the fasteners 12.

Referring to Fig. 3, the crimp fastened stacks 2 and 4 of intermediate fabric material are placed in a mould tool comprising a base plate 18 and a top mould plate 20. A vacuum bag 22 is placed over the top mould plate 20, and an airtight seal is made between the vacuum bag 22 and the base plate 18 by means of a peripheral sealer tape 24.

Fig. 4 provides a more detailed illustration of part of the mould tool of Fig. 3, and for clarity corresponding components in Figs. 3 and 4 have been given the same reference numerals. A release film 26 is located between the crimp fastened stacks 2 and 4 and the top mould plate 20 to prevent the tacky upper surface of the stacks adhering to the plate 20. Similarly, a release agent 28 is located below the stacks 2 and 4 to prevent these stacks from adhering to the mould base plate 18. An edge breather 30 extends round the base plate 18 adjacent to the edge of the vacuum bag 22, and a surface breather 32 of plate form is located near the upper portion of the vacuum bag 22. This surface breather 32 has an area slightly less than the area of the top of the vacuum bag 22. Referring to Fig. 3, the space inside the vacuum bag 22 is evacuated by withdrawing air through a passage 34 at one edge of the vacuum bag 22. The edge breather 30 and the surface breather 32 assist in ensuring that air is withdrawn from substantially the entire region covered by the vacuum bag 22, and that the vacuum bag 22 does not wrinkle or distort unduly during evacuation.
In operation, the space under the vacuum bag 22 is evacuated, the crimp fastened stacks 2 and 4 are compressed by bringing together the mould plates 18 and 20, and the mould tool and vacuum bag assembly is then heated in an autoclave to cure the crimp fastened stacks 2 and 4 while they remain under pressure to form the required composite material. After the curing operation has been completed, the mould tool and vacuum bag assembly is removed from the autoclave, the vacuum bag 22 is removed, the mould plates 18 and 20 are separated, and the cured composite material is removed from between the separated mould plates 18 and 20.

The invention also includes within its scope the above-mentioned method of manufacturing a composite material in which the top mould plate 20 is not used. In this alternative method the required degree of compression is obtained between the vacuum bag 22 and the base plate 18. The top mould plate is used (1) to produce a composite material having a tool finish on both major surfaces, (2) to dissipate the autoclave pressure through the fasteners 12 and the debulked stacks 2 and 4, and (3) to form the integral stiffening or structural element where applicable.

Any suitable form of crimp fastener may be used, and Figs. 6 to 9 illustrate suitable examples of crimp fasteners.

These crimp fasteners can be separably attached to one another in a stack to facilitate loading into a crimping machine similar to a conventional industrial stapler.

Fig. 5 illustrates the various stages of fastening together two stacks of intermediate fabric material. In
the example of Fig. 5 however one stack 36 is in the form of a planar sheet, and the other stack 38 is in the form of a C section stiffener or girder. The debulked C section stack 38 is crimp fastened to the debulked planar stack 36 in order to assist in correctly locating the structure onto the base plate 18.

The method of the described and illustrated embodiment provides a composite structure which is self sealing, and does not require expensive post jigging or drilling of the cured structure.

In a typical cure cycle of a composite material prepared by the method of the invention the maximum cure pressure is in the range from 5.86x10⁵ to 6.89x10⁵ N/m² with a maximum cure temperature of 179 ± 5°C maintained over a period of 120 ± 5 minutes, a heat up rate of 0.5 to 2.5°C per minute and a maximum cool down rate of 2.5°C per minute. By "cure pressure" is meant the pressure inside the autoclave, and hence the external pressure exerted on the vacuum bag 22.

A full vacuum is applied to the interior of the mould tool and vacuum bag assembly. This equates to an external pressure of 1.013x10⁵ N/m² (14.7 psig) which is produced by the column of air acting vertically above the vacuum bag 22. The minimum pressure allowable on a vacuum bagged part placed in the autoclave before commencing the cure cycle is 20"Hg (0.667x10⁵ N/m²). This vacuum serves to maintain the position of the bag, breather, etc. over the crimp fastened stacks 2 and 4.

The vacuum line connecting the bagged part and the vacuum pump which produces the 0.667x10⁵ N/m² minimum pressure is vented to the atmosphere outside the autoclave once the
internal autoclave pressure reaches $1.38 \times 10^5 \text{N/m}^2$ (20psig). The reason for this action is because once the autoclave pressure exceeds $1.013 \times 10^5 \text{N/m}^2$ (14.7psig) there is no longer any advantage in applying a vacuum.

The statement "maintain pressure under vacuum bag of 0 to .345$\times 10^5 \text{N/m}^2$" refers to back pressure. Pressure may be generated under the vacuum bag by volatiles emitted by the curing prepreg and by small leaks in the vacuum bag allowing autoclave pressure through to the vent line. This tolerance of 0 to .345$\times 10^5 \text{N/m}^2$ must not be exceeded since greater back pressure produces inferior components.

The described and illustrated embodiment of the invention possesses the following advantageous features:-

(a)  
(i) Improved impact resistance, tensile, peel, shear strength and improved resistance to crack propagation.

(ii) The structural elements of these fasteners (staple flanges) can be placed to align more closely with the applied loads than the elements of standard mechanical fasteners.

(b) Overcomes the main problems associated with standard mechanical joints, i.e.

(i) Any increase in laminate thickness normally required for mechanical fastening is reduced to an absolute minimum (because any damage to the laminate is minimal and to a degree is self repairing).

(ii) Typical problems associated with
mechanical fastening are avoided, i.e. problems associated with drilling, jigg ing, counter sinking, riveting, etc.

(iii) The joints are self sealing and are therefore ideal for use against the environment and for containing fuel (in a wet wing).

(iv) The joints are more weight efficient than other mechanical fastened joints.

(v) The joints are aerodynamically smooth on the air wet surfaces and therefore any filling/feathering/smoothing countersinking operations are not required.

(c) The joints can be used for local reinforcement, for example, at the "end" of stiffening elements to:-

(i) Act as anti-peel fasteners (used in a similar role for aluminium bonded stiffeners).

(ii) Accurately secure the structural elements in position prior to and during the cure operation.

(d) The fastening of the mechanical elements is more labour efficient than other mechanical fastening techniques because it is completed in one efficient automated operation.

(e) Any complications usually involved with fasteners in a fuel cell environment, e.g. the risk of arc plasma blow by is avoided because
- 10 -

the fasteners can be encapsulated into the structure.

(f) Can be located in areas where extra securement is required and where fasteners would not normally be employed, e.g. blade, stiffener webs.

(g) Crimp fastening may be employed to improve the through thickness structural strength of advanced composites (i.e. prevents delamination of the plies).

Recommended cure cycles for the method of the invention are as follows:-

(a) Simple components:
Apply 700 kN/m² pressure.
Heat to 175°C at 1 to 20°C per minute.
Cure for 1 hour at 175°C.
Cool to below 60°C before pressure removal and components ejection.

(b) Optimum cycle:
Heat under vacuum only to 120°C at 1 to 20°C per minute.
When component reaches 120°C apply 700 kN/m² pressure and vent component to atmosphere.
Continue heating to 175°C.
Cure for 1 hour at 175°C and cool to 60°C before pressure removal and component ejection.

(c) Thick components:
To avoid exotherm on thick components (>10mm) it is advisable to incorporate a dwell of 2 to 3 hours at 130°C
to 135°C in the cure cycle mentioned in (b) above.

The crimp fasteners of the embodiment illustrated in Figs. 1 to 11 are made of any suitable metal or metal alloy.

Referring to Figs. 12 and 13, in a second embodiment, the layers of composite material may be fastened together by means of composite fasteners. In the specification, by "composite fastener" is meant a fastener made of a plurality of layers of woven and uni-directional material. Each layer may be made of a thermosetting or thermoplastic material, including a reinforcement made of Kevlar, carbon or boron. These layers are placed together face to face to form a stack which is placed in a mould tool, and cured to a desired configuration. Fig. 12 illustrates several different configurations of fastener, and Fig. 13(a) illustrates the preparation and curing of a layer stack having a Z configuration.

Referring to Fig. 13(b) and (c) the cured stack is then cut to form a plurality of Z configuration fasteners. The spacing of the cuts in the layer stack will of course define the width of each fastener.

As shown in Fig. 13(d), first and second L-shaped stacks of layered intermediate fabric material are placed back to back on a third generally planar stack of layered intermediate fabric material. The stack combination is placed on a steel base plate. This base plate constitutes the base of a mould tool as illustrated in Fig. 4 and described in the corresponding part of the description. A series of holes are formed in the base parts of the two L-shaped stacks and the coaxial parts of the third stack by means of a punch.
The Z-shaped fasteners illustrated in Fig. 13(c) are
inserted through their respective holes and rotated into
their fastening position as illustrated in Fig. 13(e).
In order to assist the insertion of the fasteners into
the stacks, all or part of the stacks may be lifted from
the steel base plate. The fasteners are inserted
manually using a suitably shaped tweezer type tool.

The three stacks and the inserted composite fasteners are
then compressed and heated as previously described in the
specification.
CLAIMS:

1. A method of manufacturing a composite material comprising placing together face to face a plurality of layers of intermediate fabric material, each layer comprising high strength fibres having a high modulus of elasticity in a tacky homogeneous resin matrix, fastening together said layers at spaced locations thereon, and then compressing and heating the layer assembly to cure the resin.

2. A method according to claim 1, characterised in that the layers are fastened together by means of a plurality of fasteners (12) located at said spaced locations, each fastener having at least one leg.

3. A method as claimed in claim 2, characterised in that each leg of a fastener is forced through at least two overlapping layers by direct pressure exerted on the fastener.

4. A method according to claim 3, characterised in that the fastener is subjected to mechanical rotation during the leg forcing operation.

5. A method according to claim 3 or 4, characterised in that each fastener leg is deformed in a controlled manner when it protrudes through the overlapping layers to a required distance so as to provide said fastening action.

6. A method according to claim 5, characterised in that each fastener leg is deformed by crimping.

7. A method according to claim 5, characterised in that each fastener leg is deformed by punching.

8. A method according to any one of claims 2 to 4,
characterised in that the fasteners are covered by at least one additional layer (14, 16) of intermediate fabric material before the layer assembly is compressed and heated.

9. A method according to any one of claims 1 to 4 further including applying a first film of adhesive to the lower surface of the side portion of a first stack (2) of layers of intermediate fabric material, and a second film of adhesive to the upper surface of the side portion of a second stack (4) of layers of intermediate fabric material, placing said side portions in overlapping relationship, and fastening together said overlapping side portions at spaced locations thereon.

10. A method according to claim 9, characterised in that said stacks (2,4) are located in transversely spaced relationship on a release film (6) which is removed before the adhesive is applied.

11. A method according to any one of claims 1 to 4, characterised in that the layer assembly is compressed and heated under a vacuum.

12. A method according to claim 1, characterised in that holes are made through the assembled layers at said spaced locations, a Z shaped fastener is inserted in each hole, and the fastener is then rotated into its fastening position.

13. A composite material manufactured by the method of claim 2, characterised in that at least one fastener (12) is made of metal and includes at least one leg adapted to pass through at least two overlapping layers.

14. A composite material manufactured by the method
of claim 12, characterised in that each fastener is made of a plurality of layers of woven and uni-directional material.

15. A composite material according to claim 14, characterised in that each layer is made of a reinforced thermosetting material.

16. A composite material according to claim 14, characterised in that each layer is made of a reinforced thermoplastics material.

17. A method of manufacturing a composite material substantially as herein described with reference to the accompanying drawings.

18. Apparatus for manufacturing a composite material substantially as herein described and shown in the accompanying drawings.

19. A composite material substantially as herein described and shown in the accompanying drawings.
completed, the mould tool and vacuum bag assembly is removed from the autoclave, the vacuum bag (22) is removed, the mould plates (18) and (20) are separated, and the cured composite material is removed.
Fig. 7.
6/10

(SINGLE LEG) EXAMPLE 1

(1) AFTER CRIMP

BEFORE CRIMP

FASTENER LOADING LOCATION

(2) AFTER CRIMP

(SINGLE LEG) EXAMPLE 2

(1) AFTER CRIMP

FASTENER LOADING LOCATION

(TRIPLE LEG)

(1) BEFORE CRIMP

AFTER CRIMP

(2) BEFORE CRIMP

AFTER CRIMP

Fig.8.
Fig. 9

- SINGLE LEG SPIRAL ACTION CORKSCREW
- TWIST & CRIMP / PUNCH

- TWO & THREE LEG SPIRAL
- THREE LEG
- TWO LEG

Fig. 11

- TOP HAT
- 'C' SECTION
- 'J' SECTION
- 'Z' SECTION
- 'I' SECTION

DENOTES POSSIBLE LOCATION OF FASTENERS
HOLD AT 18 ±5°C FOR 120 TO 135 mins

HEAT-UP RATE 0.5 TO 2.5°C/min

COOL-DOWN RATE 2.5°C/min

RELEASE AUTOCLAVE PRESSURE BELOW 60°C

TEMPERATURE DEGREES C

APPLY 560 mm Hg VACUUM (MINIMUM) TO VACUUM BAG

APPLY 590 +10^3 KPa - 0 TO AUTOCLAVE

VENT VACUUM BAG TO ATMOSPHERE WHEN AUTOCLAVE PRESSURE REACHES 140 TO 210 KPa

MAINTAIN PRESSURE UNDER VACUUM BAG OF 0 TO 35 KPa

Fig.10.
Fig. 12.
Fig. 13(a). 'Z' type fastener laid-up between matched tools.

Fig. 13(b). 'Z' fastener strip released from tooling.

Fig. 13(c). Fasteners cut to size.

Fig. 13(d). Typical lay-up (blade stiffened skin) in which through plane reinforcement or anti-peel fasteners would be required.

Fig. 13(e).
INTERNATIONAL SEARCH REPORT

INTERNATIONAL APPLICATION No PCT/GB 90/01903

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) *

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC: B 29 C 67/00

II. FIELDS SEARCHED

Minimum Documentation Searched *

Classification System Classification Symbols

IPC: B 29 C

Documentation Searched other than Minimum Documentation

to the Extent that such Documents are Included in the Fields Searched *

III. DOCUMENTS CONSIDERED TO BE RELEVANT *

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of Document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to Claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>GB, A, 2132134 (MESSERSCHMIDT-BOLKOW-BLOHM GmbH) 4 July 1984 see page 1, lines 36-45,53-54,83-103; figures 2,3</td>
<td>1-3,5-7,13</td>
</tr>
<tr>
<td></td>
<td>GB, A, 841371 (AEROPLASTICS LTD) 13 August 1957 see page 2, lines 18-20; page 4, lines 22-32,52-56</td>
<td>1-3</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4808461 (J.S. BOYCE et al.) 28 February 1989 see column 1, lines 29-31; column 2, lines 2-19,31-39,51-53; column 3, lines 17-65; figures 4-8</td>
<td>1,2,11</td>
</tr>
</tbody>
</table>

* Special categories of cited documents: 10
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

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

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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

A document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search 11th March 1991

Date of Mailing of this International Search Report 09.04.91

International Searching Authority EUROPEAN PATENT OFFICE

Signature of Authorized Officer miss T. MORTENSEN

Form PCT/ISA/210 (second sheet) (January 1985)
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of Document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to Claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>FR, A, 2312369 (AVIONS MARCEL DASSAULT-BREGUET AVIATION) 24 December 1976 see page 2, lines 23-32; page 3, lines 18-23; page 4, lines 4-25; figure 7</td>
<td>8,11,15</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4679291 (SHELL OIL CO.) 14 July 1987 see column 1, lines 18-45; column 2, lines 28-35; column 4, lines 35-39, 55-57</td>
<td>1-3</td>
</tr>
</tbody>
</table>
This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 27/03/91. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB-A- 2132134</td>
<td>04-07-84</td>
<td>DE-A- 3246803</td>
<td>20-06-84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR-A, B 2537916</td>
<td>22-06-84</td>
</tr>
<tr>
<td>GB-A- 841371</td>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR-A- 2624426</td>
<td>16-06-89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB-A- 2211142</td>
<td>28-06-89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP-A- 1202444</td>
<td>15-08-89</td>
</tr>
<tr>
<td>FR-A- 2312369</td>
<td>24-12-76</td>
<td>DE-A, C 2623044</td>
<td>08-06-77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB-A- 1541728</td>
<td>07-03-79</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NL-A- 7605534</td>
<td>30-11-76</td>
</tr>
<tr>
<td>US-A- 4679291</td>
<td>14-07-87</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82.