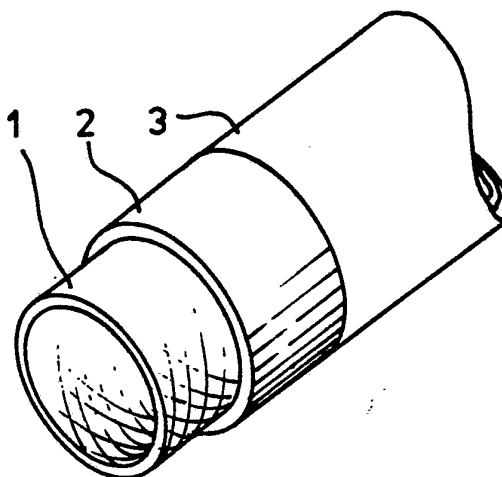




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁵ : F16L 59/08, B32B 15/06</p>	<p>A1</p>	<p>(11) International Publication Number: WO 92/08924 (43) International Publication Date: 29 May 1992 (29.05.92)</p>
<p>(21) International Application Number: PCT/GB91/01996 (22) International Filing Date: 13 November 1991 (13.11.91) (30) Priority data: 9024677.8 13 November 1990 (13.11.90) GB 9113521.0 22 June 1991 (22.06.91) GB (71) Applicant (for all designated States except US): T&N TECHNOLOGY LIMITED [GB/GB]; Cawston House, Cawston, Rugby, Warwickshire CV22 7SB (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): ATKINSON, Alan, William [GB/GB]; 11 Brackendale Drive, Barby, Rugby, Warwickshire CV22 8TJ (GB). BURNETT, Jody, Keith [GB/GB]; 12 The Crescent, Flore, Daventry, Northampton NN7 4NF (GB). JAMES, Allan [GB/GB]; 32 Bracken Drive, Highland Estate, Bilton, Rugby, Warwickshire CV22 6SP (GB).</p>		<p>(74) Agents: CRUX, John, Anthony et al.; T&N plc, Bowdon House, Ashburton Road West, Trafford Park, Manchester M17 1RA (GB). (81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US. Published <i>With international search report.</i></p>

(54) Title: FLEXIBLE SHEET MATERIAL



(57) Abstract

A flexible sheet material suitable for use as a barrier in resisting heat transfer from a source of radiant heat comprises a layer of silicone elastomer (2; 12) which may be foamed, and a metallic foil (3; 14) less than one micron in thickness applied to one surface of the elastomer by transferring the foil from a supporting substrate.

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.

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

⁺ Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.

- 1 -

Flexible sheet material

This invention is concerned with a method of making flexible sheet material suitable for use as a barrier for resisting heat transfer from a source of radiant heat, and with items, eg tubes or clothing, which are made from such sheet material.

In many circumstances, the requirement arises for a flexible sheet material which can be used for resisting heat transfer from sources of radiant heat, namely sources of infra-red radiation. For example, such sheet material may be formed into flexible tubing of the kind commonly used to protect components such as electrical wiring, brake and fuel lines from heat, particularly the heat sources found in automotive engine compartments. Such tubing is often, but not always, a textile product. Important requirements for such tubing are flexibility, which for present purposes includes the ability to bend, ability to stretch circumferentially, shape retention and ease of installation, together with ability to resist heat transfer

- 2 -

to the substrate to be protected. As another example, such sheet material may be formed into articles of clothing for use by fire fighters or others who have to enter hot environments. In this case, flexibility and shape retention are important requirements. Such flexible sheet materials may, in addition to their ability to keep items cool, alternatively be used to keep items warm by resisting heat transfer away therefrom.

Resistance to heat transfer is predominantly a function of reflectivity; the most important heat transfer mechanism is radiation at infra-red wavelengths. Whilst high visual wavelength reflectivity sometime suggests good infra-red reflectivity, this is not necessarily the case, since some materials which appear highly reflective to the eye are in fact good absorbers of infra-red radiation. One known technique, with tubing to protect electrical wiring and brake or fuel lines, is to envelop the tubing in a layer of aluminium foil, by wrapping either spirally or longitudinally with a strip of foil. Typically the foil is at least 20 microns in thickness. The foil is retained in place by adhesive or by stitching. The resultant product has good reflectivity, but suffers from severely impaired flexibility. Another, more recent technique, is to coat the tubing with a layer of flexible polymeric material containing metallic particles, preferably in the form of flakes, for example, of aluminium. Whilst this gives reasonable good flexibility, the infra-red reflectivity is

- 3 -

not as good as might be expected from the properties of an individual flake. It is thought that the reasons for this are the particulate nature of the metal allowing gaps to exist between flakes, allied to absorption by the polymeric material, both before reflection and after, since the particles do not constitute the surface layer, which is predominantly polymeric.

It is an object of the present invention to provide a method of making a sheet material suitable for use as a barrier for resisting heat transfer from a source of radiant heat and which combines good reflectivity with good flexibility.

The invention provides a method of making a flexible sheet material suitable for use as a barrier for resisting heat transfer from a source of radiant heat, the method comprising forming a layer of a silicone elastomer and bonding a metallic foil less than one micron in thickness to one surface of the layer by transferring the metallic foil to the elastomer layer from a supporting substrate.

A sheet material made by a method in accordance with the invention has good flexibility, good reflectivity, and good shape retention.

The metallic foil may be bonded to the elastomer layer by means of adhesive or by making use of the adhesive

qualities of the elastomer before it has solidified.

The elastomer layer may be formed on a knitted, braided or woven fabric support which increases the strength of the sheet material. Where the fabric support is woven and where the sheet material is subsequently formed into a tube, the length of the tube may be arranged to extend at substantially 45 degrees to the direction of the weft of the weave. This has been found to increase the flexibility of the tube. The fabric support may be formed from glass fibre, aromatic polyamide fibre or regenerated cellulose fibre, including blends thereof.

The elastomer is preferably a silicone rubber and may be foamed before or after bonding the foil thereto. The metallic foil is preferably aluminium and may be less than 0.01 microns thick. In practice, thicknesses of from 2 to 4 nanometres have been found to be satisfactory.

It has also been found that the use of a foamed elastomer on a knitted, braided, or woven fabric support tends to smooth out the surface irregularities of the support, thereby ensuring a relatively smooth surface for the foil itself. Surface smoothness is a factor in obtaining a good reflectivity.

Suitable foils of aluminium are available on a thin polymeric support film, usually of a polyester material.

- 5 -

The foil is usually provided with an adhesive coating on the exposed surface of the aluminium. The support film is removed during or after transfer of the foil to the surface of the elastomer layer.

The silicone elastomer layer may be applied to the foil prior to application to a knitted, braided, or woven fabric support. The elastomer layer will usually be applied as a liquid which is dried, cured or otherwise caused to solidify in situ on the support. However, if the elastomer layer is not sufficiently adhesive to retain the foil, then an adhesive interlayer may be applied if one is not already present on the aluminium surface. However, it will normally be more convenient to use the elastomer itself for this purpose.

The silicone elastomer may also be applied to the textile substrate, prior to transferring the aluminium foil thereto, as is further discussed below.

Surprisingly, it has been found that, although the preferred metallic foils are so thin that in some cases they are actually translucent, they are highly effective reflectors of infra-red radiation. Their extreme thinness enables them to stretch or otherwise distort without rupture and without significant effect on the flexibility of the sheet. They provide an essentially unbroken surface which is highly reflective to infra-red radiation.

However, the thinness of the foil does impart some vulnerability to abrasion damage. This may be minimised by at least three methods. The first is to apply a thin protective coating of a polymer having good infra-red transparency. The second is to deliberately conform the foil to the undulating surface of the sheet so that most of it lies in shallow depressions in that surface; it will be appreciated that this is especially applicable to textile fabrics. Thirdly, the elastomeric layer is preferably foamed, as mentioned earlier. This has the effect of imparting some resilience, as well as a degree of thermal insulation, which may be valuable for some end uses.

Where foil is to be applied to a fabric support constituted by tubing formed directly by braiding, circular knitting or by other means, the foil (on its support film) may be applied in several ways. For example, it may be helically wound, using a relatively narrow strip, or strips. It may be applied in a longitudinal direction using one or more strips extending lengthwise of the tube. This method is directly analogous to that used in the manufacture of cigarettes, where a single endless strip is progressively curled about an endless substrate by passage through one or more forming dies. This latter method is preferred, in the interests of simplicity. It has been observed that as long as the overlaps between adjacent helical turns or between adjacent edges of the strip or strips are reasonably narrow, the support film may be removed without significant damage to the foil. Alternatively, the foil may be applied

- 7 -

to a flat sheet and the sheet then formed into a tube, with the edges being sewn, adhesively bonded or otherwise joined.

Where the elastomer layer is formed on a knitted, braided or woven fabric support, it will not normally be significantly thicker than a surface coating and indeed it may not be in contact with (bonded to) much more than the radially outermost yarn surfaces. Otherwise impregnation/coating may tend to affect the flexibility. Whilst the elastomer could be applied to the support in a separate operation prior to application of the foil, it is preferred that it is applied to the foil, so that elastomer and foil layers are applied to the support together.

The invention also provides a flexible, predominantly textile fabric tube and further includes fabrics and articles of clothing made of material made by a method in accordance with the invention.

The invention also provides a flexible tube suitable for use as a barrier for resisting heat transfer from a radiant heat, the tube being formed from a flexible sheet material which comprises a layer of silicone elastomer formed on a woven fabric support, and a metallic foil less than one micron in thickness bonded to the exposed surface of the elastomer layer, the length of the tube extending at

substantially 45 degrees to the direction of the weft of the woven fabric support.

In order that the invention be better understood, preferred embodiments of it will now be described by reference to the accompanying drawings which:

Figure 1 is a perspective view of a first tube made by a method according to the invention, partly cut away to show its construction;

Figure 2 is a perspective, partly cut away view of a second tube made by a method according to the invention;

Figure 3 is a perspective, partly cut away view of a part of a third tube made by a method according to the invention;

Figure 4 is a perspective view of a fourth tube formed from a sheet material made according to the invention;

Figure 5 is a perspective view of a fifth tube formed from a sheet material made according to the invention and

Figure 6 is a perspective view of a sixth tube formed from a sheet material made according to the invention;

Referring to the Figures, Figure 1 shows a tube constituted

- 9 -

by a glass fibre braid 1 with an elastomer coating 2 onto which is bonded a metallic foil 3 less than 1 micron thick.

Figure 2 illustrates one method of applying the foil by helically wrapping with a continuous strip 4, as will shortly be described in relation to Example 1.

Figure 3 illustrates a further method of applying the foil, this time by applying it as a series of longitudinally extending strips, 6.

Figure 4 shows a tube manufactured from a woven glass fibre fabric 10 in which the weft fibres extend longitudinally of the tube. It will be appreciated that the warp and weft structure of the fabric 10 is shown schematically; in ordinary circumstances the warp and weft would be much closer together. A layer of foamed silicone rubber 12 is formed on the fabric 10 and a metallic foil 14 less than one micron thick is bonded to the layer 12. The tube is formed by first forming a planar sheet comprising the fabric 10, the layer 12, and the foil 14 and bending the sheet to bring opposite edges together into overlapping relationship. The edges are then sewn together by stitches 16.

Figure 5 shows a tube which differs from that of Figure 4 in that the warp/weft fibres of the woven fabric 10 extend at substantially 45 degrees to the longitudinal directional

- 10 -

of the tube thereby imparting greater flexibility. Furthermore, the sheet material is bent into the tube in the opposite sense to the tube of Figure 4, with the woven fabric 10 on the outside, and, after sewing through the overlapping edges, the tube is turned inside out to bring the foil 14 to the outside.

Figure 6 shows a tube which is made by helically winding a strip of sheet material. The sheet material comprises a woven fabric 10, a layer of foamed silicone rubber (not shown) and a metallic foil 14 similar to those of Figure 4 and 5. Each turn of the sheet material along the tube overlaps the adjacent turns and is secured thereto by stitches 16.

Example 1

A glass fibre braid, with an outside diameter of 22mm was coated with a two-part silicone elastomer to a thickness of 0.5 to 1mm. To this uncured silicone elastomer coating, a continuous strip of aluminium foil (2-3 nanometres thick and supported on a plastics release film) was applied by helically wrapping with an overlap of typically 1-2mm between successive turns (as shown in Figure 2). Subsequent heat curing at 130 degrees centigrade for about 5 minutes, following by removal of the release film, gave a highly reflective and flexible tubular construction.

SUBSTITUTE SHEET

- 11 -

The product was placed over a rubber tube (as used for automotive brake hose) and the assembly mounted 50mm from a heating element at 900 degrees centigrade (simulating a hot exhaust pipe). The temperature of the inner rubber tube remained below 125 degrees centigrade, thereby avoiding damage.

Example 2

Example 1 was repeated; in this case the elastomer layer was a silicone elastomer foam with a density of about 800kg/cubic metre and a thickness of 1-2mm.

This gave a more resilient coating and made the overlying aluminium foil less susceptible to abrasion.

Example 3

As shown in Figure 3, a silicone elastomer was applied to the glass braid, exactly as in Example 1 or 2. Continuous strips 6 of foil were then applied to the uncured coating in a direction longitudinally of the braid. Four strips were used, giving an overlap of about 2mm between adjacent strips. The silicone elastomer was then cured at 130 degrees centigrade for 5 minutes.

Example 4

Braid and a single strip of aluminium film were combined using a self-foaming silicone elastomer composition, but the latter composition was applied to the aluminium foil (rather than to the braid) prior to curing/foaming of the elastomer. The strip was applied to the braid by passage through forming dies which caused the foil to be progressively folded around the tube. The product was similar to that of Example 3 but employed a single strip.

Example 5

Example 3 was repeated using a knitted glass tube, but with double the quantity of silicone foam. The product was of similar flexibility and reflectivity to those of Example 3.

Example 6

Example 3 was repeated using a rayon braid in place of glass fibre. Flexibility and reflectivity were again similar to those of Example 3.

Example 7

Silicone elastomer employed in Example 2 was used to bond aluminium foil 1 to 4 nanometres in thickness to a flat glass cloth woven from glass fibre. After foaming and

- 13 -

curing of the elastomer and removal of the polymeric support film from the foil, the resulting sheet material was cut into strips 90mm wide. The strips were then joined into tubing as described in relation to Figure 4. The tubing the flexible and reflective with similar properties to the tubing described in Example 2.

Example 8

Example 7 was repeated but the strips were joined into tubing as described in relation to Figure 6. This gave a more flexible tubing than that of Example 7.

Example 9

Sheet material was prepared as described in Example 7, but instead of being cut into strips, was made into a garment. The garment was found to protect a wearer from infra-red radiation while being sufficiently flexible for comfort.

CLAIMS

1. A method of making a flexible sheet material suitable for use as a barrier for resisting heat transfer from a source of radiant heat, the method comprising forming a layer of a silicone elastomer and bonding a metallic foil less than one micron in thickness to one surface of the layer by transferring the metallic foil to the elastomer layer from a supporting substrate.
2. A method according to claim 1, wherein the metallic foil is bonded to the elastomer layer by means of adhesive.
3. A method according to either one of claims 1 and 2, wherein the elastomer layer is formed on a knitted, braided or woven fabric support.
4. A method according to claim 3, wherein the elastomer is applied to a tubular fabric support.
5. A method according to claim 3, wherein the elastomer is applied to a planar fabric support which is subsequently formed into a tube.
6. A method according to claim 3, wherein the fabric support is formed from glass fibre, aromatic polyamide fibre or regenerated cellulose fibre, including blends thereof.

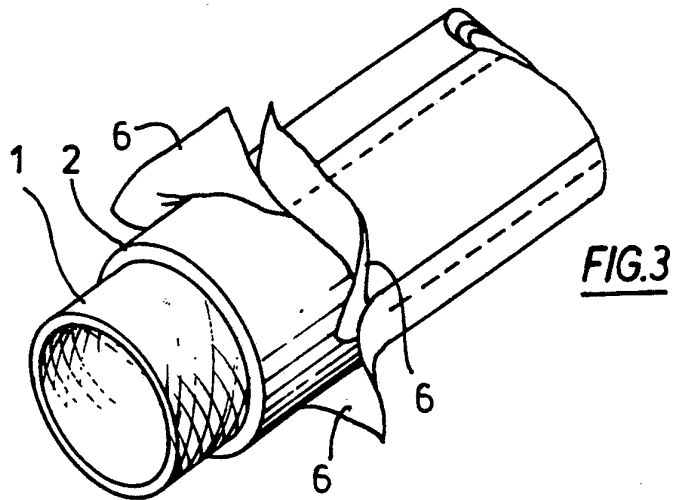
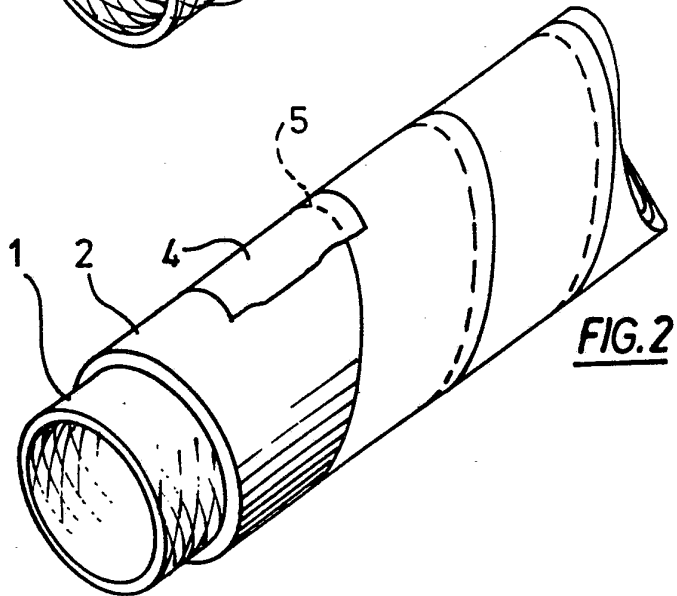
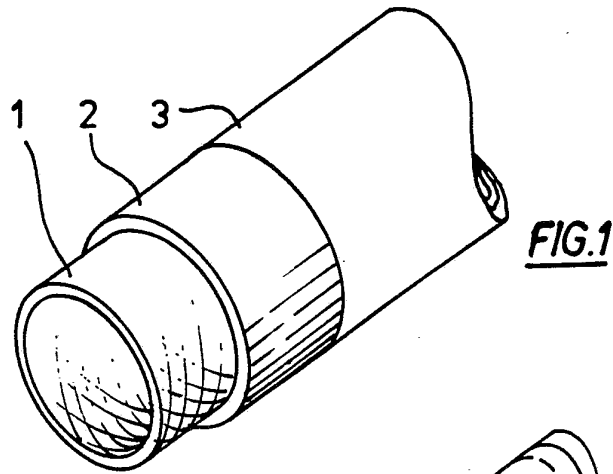
- 15 -

7. A method according to any one of claims 1 to 4, wherein the elastomer is foamed, either before or after bonding the foil thereto.
8. A method according to any one of claims 1 to 5 wherein the metallic foil is of aluminium.
9. A method according to any one of claims 1 to 6 wherein the metallic foil is less than 0.01 microns in thickness.
10. A method according to any one of claims 1 to 7 wherein the metallic foil is from 2 to 4 nanometres in thickness.
11. A method of making a flexible sheet material substantially as hereinbefore described with reference to the accompanying drawings, or as illustrated by the Examples.
12. A flexible tube made of a material made by a method according to any one of claims 1 to 11.
13. A fabric made of a material produced by a method according to any of claims 1 to 11.
14. An article of clothing made of a material made by a method according to any one of claims 1 to 11.

SUBSTITUTE SHEET

15. A flexible tube suitable for use as a barrier for resisting heat transfer from a source of radiant heat, the tube being formed from a flexible sheet material which comprises a layer of silicone elastomer formed on a woven support fabric, and a metallic foil less than one micron in thickness bonded to the exposed surface of the elastomer layer, the length of the tube extending at substantially 45 degrees to the direction of the weft of the woven support fabric.

1/2



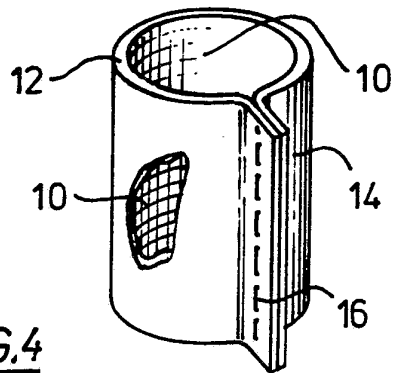


FIG. 4

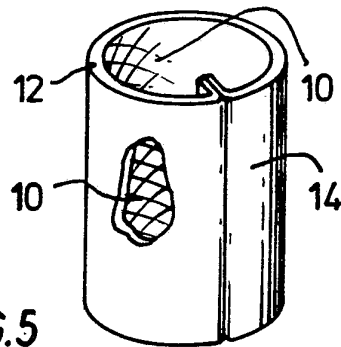


FIG. 5

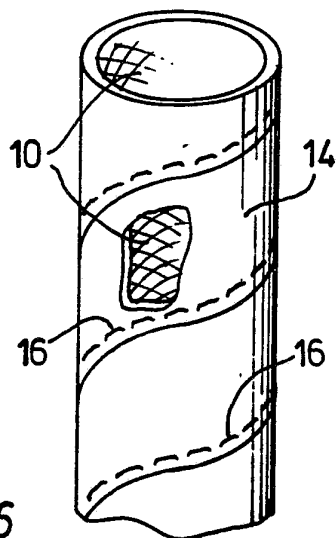


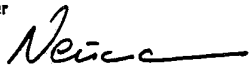
FIG. 6

INTERNATIONAL SEARCH REPORT

PCT/GB 91/01996

International Application No

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC Int.Cl. 5 F16L59/08; B32B15/06		
II. FIELDS SEARCHED Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.Cl. 5	F16L ; B32B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	WO,A,8 903 763 (SNYDER, S.J.) 5 May 1989 see claims 1,3,5,7-9,11	1,3,8, 11,13
A	---	6
X	EP,A,0 243 161 (THE YOKOHAMA RUBBER CO. LTD.) 28 October 1987 see column 1, line 50 - column 2, line 40 see column 3, line 9 - column 3, line 13	1,3,6,13
X	DD,A,213 597 (VEB ASGLATEX OHORN) 19 September 1984 see page 3, paragraph 3 - page 5, paragraph 2; claims	1,3,6,8, 11,14
A	US,A,4 452 279 (ATWELL) 5 June 1984 see column 1, line 51 - column 2, line 9; claims 1-3; figures	1,3-7, 11-13

	---/---	
¹⁰ Special categories of cited documents : <ul style="list-style-type: none"> "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. "&" document member of the same patent family 		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
05 FEBRUARY 1992	26. 02. 92	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	NEUMANN E. 	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US,A,4 068 034 (SEGAWA ET AL.) 10 January 1978 see column 1, line 1 - column 1, line 12; claims; figure 2 see column 2, line 52 - column 3, line 3 ---	1,2,7,8, 13

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

GB 9101996
SA 53170

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 05/02/92

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-8903763	05-05-89	US-A- 4848514	18-07-89
		EP-A- 0391935	17-10-90
		JP-T- 3501402	28-03-91
		US-A- 4947958	14-08-90
		US-A- 4926963	22-05-90
EP-A-0243161	28-10-87	JP-C- 1586188	31-10-90
		JP-B- 2009477	02-03-90
		JP-A- 62248299	29-10-87
		JP-C- 1578315	13-09-90
		JP-B- 2000866	09-01-90
		JP-A- 62265799	18-11-87
		EP-A- 0243162	28-10-87
		US-A- 4960633	02-10-90
		CA-A- 1273087	21-08-90
		US-A- 4923736	08-05-90
DD-A-213597		None	
US-A-4452279	05-06-84	None	
US-A-4068034	10-01-78	None	

EPO FORM P0479

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