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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B65H 27/00, F16C 13/00 — A1

(11) International Publication Number: WO 91/06499

(43) International Publication Date: 16 May 1991 (16.05.91)

(21) International Application Number: PCT/GB90/01700

(22) International Filing Date: 6 November 1990 (06.11.90)

(30) Priority data:
8925103.7 7 November 1989 (07.11.89) GB

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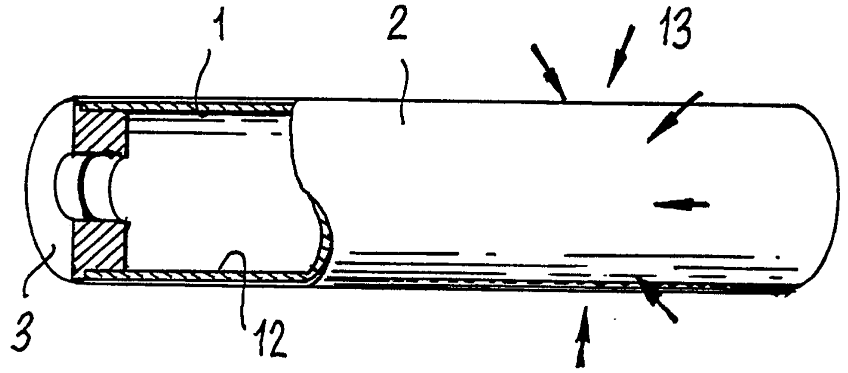
(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GR, GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: IMPROVED ROLLER



(57) Abstract

A roller (e.g. for use in high speed sheet processing) comprises an FRP core (1) and a metal sleeve (2) non-rotatably held on the core by an interference fit caused by hoop tension in the sleeve.

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IMPROVED ROLLER

This invention relates to a lightweight roller (capable of conveying thin sheet material in a high speed processing plant) and to a method of making such a roller.

In certain processes it is necessary to convey sheet material on and/or between smooth-faced circular cylindrical rollers and metallic rollers (e.g. hollow metallic rollers) are a common choice. However in high speed sheet processing it is desirable for the moment of inertia of all components which move with the sheet to be maintained at a minimum value and to this end it is known to replace a substantial proportion of the mass of a hollow metal roller by a lower density core material. Where a metallic surface is required in contact with the sheet material a composite roller must be constructed and the problem then has to be faced of securely retaining an outer layer of metallic material on an inner core of non-metallic material. The present invention addresses this problem.

Various methods have been described for producing fibre reinforced plastic (FRP) rollers, especially carbon FRP (CFRP) rollers, to replace conventional metal rollers. The advantages offered include:

(i) reduction in mass because of the high specific stiffness of FRP compared with metals; this allows higher acceleration and deceleration of sheet material during processing; also handling of lightweight rollers is easier, and

(ii) improved dimensional stability because of the small coefficient of thermal expansion of FRP.

However, the surface properties of FRP are not usually suitable for contact with thin sheet materials being processed, because of, for example, its micro-finish, abrasion resistance and cleanliness. It is thus normally necessary to provide a coating of a metal or other surface material on the outside of the FRP roller. The present invention concerns the manufacture of such a coated roller, and in particular, the method of providing the metal or other coating on the outside of the FRP roller.

Previously described processes to provide a metal coating have mainly involved the gradual deposition of one or more metal layers by, for example, metal spraying, electroless plating or electrolytic plating. These processes all depend critically on adhesion at the FRP/metal interface. This adhesion is dependent on many variables, such as fibre type, matrix resin type, fibre distribution at the surface, surface roughness etc. and on less controllable factors such as contamination. Many solutions have been proposed to this problem of coating adhesion.

According to one aspect of this invention a roller for use in a given operating temperature range comprises a core made of a fibre-reinforced plastics material having an outer surface and a sleeve of a different material having an inner surface engaging the outer surface of the core in such a manner as to place the sleeve material in hoop tension in the vicinity of said inner surface and leave the core non-rotatable with respect to the sleeve within said operating temperature range.

Suitably the core is a hollow tube of FRP and the sleeve is a hollow tube of metal. The core can include end plates (e.g. in the form of metallic discs) which preferably are also contained within the sleeve.

The core can be moulded (e.g. on a supporting mandrel) extruded, pultruded or machined from a solid piece of suitable non-metallic material and may or may not include filament reinforcement. A preferred core would be formed from matrix impregnated filaments applied around a supporting mandrel. The matrix could be a thermosettable or thermoplastic material and the filaments could be mineral fibres (e.g. glass), textile fibres (e.g. polyester or polyamide) or a specialist reinforcing fibre known in FRP techniques (e.g. aramid or carbon).

According to a further aspect of the invention a method of making a composite roller which comprises a cylindrical core of a fibre-reinforced plastics material and an outer tubular sleeve of a second material, characterised in that the method comprises the step of forming an interference fit between the core and the sleeve which leaves the sleeve in hoop tension thereby to retain the core non-rotatable in the bore of the sleeve.

The hoop tensioning of the sleeve is caused by forming an interference fit between the core and the sleeve. One way of doing this is to force the core mechanically into the bore of a sleeve which has a smaller diameter bore than the diameter of the core, but preferably is occasioned by shrink fitting the component parts of the roller together using a temperature difference caused by heating the sleeve and/or cooling the core. An alternative to heat shrinking the sleeve on to the core is to mechanically squeeze the sleeve on to the core, such as for example, by using a swaging technique.

The method according to this invention permits a metal coating to be tensioned around an FRP core without encountering the major problem of FRP/metal adhesion by securing a preformed metal sleeve over an FRP tube by means of the hoop tension generated in the sleeve causing an interference fit. The metal may be, for example, Al or Cu, but other metals may be used. The outer surface of the sleeve may then be polished, etched, electroplated, anodised, electroless-plated, or sprayed with other metals or materials, to provide the final surface properties required for the roller. The interference fit coating principle embodied in this invention may also be applied to other coating materials including, but not limited to, polymers and composite materials, for example.

A particular example of providing a coating held by hoop tension in an interference fit on a core would be to shrink-fit a metal tube over the tubular FRP core.

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

Figure 1 shows the creation of a precursor of an FRP core for a roller in accordance with the invention.

Figure 2 diagrammatically illustrates how a metal sleeve is prepared for engagement with an FRP core,

Figure 3 is a partially sectioned view of the completed roller, and

Figure 4 is a view of a swaged composite roller according to the invention.

Figure 3 shows a completed roller in accordance with the invention which is made up of four parts, an FRP core tube 1, a metal sleeve 2 and two end fittings 3 (only one of which is shown).

The core tube 1 can be formed as shown in Figure 1. A tow 4 of fibres is impregnated with a hardenable liquid matrix material at a station 5 and is wrapped on a mandrel 6 in a series of plies some of which are angle plies 7 and others are hoop plies 8. A drive unit 9 and tailstock unit 10 support the mandrel while it is rotated by a driven chuck 11 of the unit 9.

After winding the fibres on the mandrel to the required thickness, the matrix is hardened to form a rigid tubular core having a precisely sized mandrel-defined internal bore 12 (see Figure 3). After matrix hardening the FRP core tube is removed from the mandrel 6.

In a typical example of CFRP roller manufacture, tows of carbon fibre having a tensile modulus of 230 GPa were impregnated with thermosetting resin, for example a low viscosity liquid epoxy resin, and were filament wound at an angle of 30° to its axis, onto a 100 mm diameter steel mandrel 6 treated with a release agent. To provide a CFRP tube with a calculated balance of properties, other windings were incorporated almost at right angles to the axis. When the required wall thickness of 5 mm had been reached, the resin was cured by rotating the mandrel and CFRP in an oven at 150°C for 4 hours. The CFRP tube, which had a carbon fibre content of some 60% by volume, was then removed from the mandrel.

A section having the required roller length (e.g. of 400 mm) is cut from the tube. The inner surface of a filament wound tube, being a direct moulding of the mandrel 6, is dimensionally accurate and the end fittings 3 (e.g. aluminium alloy end plugs) are bonded into each end of the tube. The outer surface of the CFRP core is then ground to give the required wall thickness (e.g. of 4 mm).

A sleeve tube 2 (e.g. of aluminium) was bored out so that its internal diameter was slightly less (e.g. 0.05 mm less) than the outside diameter of the CFRP core tube at room temperature. This determined the level of hoop tension which would secure the sleeve 2 around the core tube 1.

The sleeve 2 was next heated to 100°C at which temperature a radial clearance of about 0.06 mm existed between the inner surface of the sleeve 2 and the outer surface of the core 1, enabling the sleeve 2 to be slipped over the CFRP core 1. Figure 2 shows the CFRP core 1 and sleeve tube 2 before the shrink-fitting procedure had been effected. The assembly of core 1 and sleeve 2 was allowed to cool to room temperature.

The outer surface of the sleeve 2 can now be machined to the required diameter and surface finish. In one example, the final wall thickness of the sleeve 2 was 0.5 mm. The outer surface of the sleeve 2 can be treated in a variety of different ways and in the case of an aluminium sleeve, anodising can be desirable.

Although carbon fibre would usually be used for the tow 4 (because it can conveniently provide the stiffness of metal with much reduced weight) the roller illustrated could use other reinforcing fibres such as aramid or glass, for example.

Similarly, whilst epoxy resins are widely used as the matrix in CFRP roller manufacture, other thermosetting resins such as phenolic, bismaleimide etc. can be used in the station 5, depending on the material properties required. Thermoplastic matrix materials such as polyetherimide and polyetheretherketone may also be used.

Several processes exist for producing CFRP rollers, such as fabric wrapping, prepreg moulding and filament winding. The present invention is applicable to rollers made by these and other processes. In particular, where high specific stiffness combined with high productivity is required, filament winding (e.g. as shown in Figure 1) is the preferred method.

The filament winding can be performed as an automated process, laying resin-impregnated continuous fibres onto the rotating mandrel 6 at precise angles to its axis, and in patterns which eventually form complete layers of fibre.

Sheet handling rollers in process machinery may be required to rotate very rapidly, and balance is therefore an important characteristic. Accurate machining is therefore required in producing such rollers.

The hoop tensioning of the sleeve on the core can be generated in ways other than thermal shrink fitting. Thus, for example an over-sized sleeve can be swaged down onto a cylindrical core using a rotary hammer- (or ball-) swager. Such a swaging operation is illustrated schematically in Figure 3 by the arrows 13 and in further detail with reference to Figure 4.

In the embodiment of the invention shown in Figure 4 a sleeve tube 22 e.g. of aluminium was bored out so that its internal diameter was slightly more (e.g. 0.05 mm more) than the outside diameter of an FRP core tube 21 at room temperature. In this state the core 21 is a sliding fit in the bore of sleeve 22. To achieve an interference fit between the core 21 and the sleeve 22, the sleeve 22 is mechanically worked down onto the core 21. One way of doing this is to use a rotating hammer swage 23, which is well known per se. Such a hammer swage comprises a die which is split into two or more segments, which cooperate to define a circular opening of the same diameter as the finished size of the outer diameter of the sleeve 22. The segments are assembled around the circumference of the sleeve 22 and hammered radially inwards whilst effecting relative rotation and longitudinal movement between the segments and the sleeve 22. The hammer blows contract the sleeve 22 down onto the core 21 to form an interference fit which places the core 21 in compression and the sleeve 22 in hoop tension.

An alternative swaging process is to use a rotary-ball swage, known per se, which comprises a ball race in which hardened balls are rotated relative to the sleeve 22 and moved along the length of the tube so as to work the metal on a helical line and deform the metal radially inwards to reduce the diameter of the sleeve 22 and form an interference fit which places the core 21 in compression and the sleeve 22 in hoop tension. There are two versions of ball swage that can be used. In one version the balls are equispaced around a fixed common pitch circle diameter to work the sleeve 22 to a preset diameter. In the second version the balls run on the inside of a hardened conical bore which is movable axially to adjust the radial position of the balls relative to the sleeve 22. This second version enables one to reduce the outer diameter of the sleeve 22 in a number of passes if one wishes.

The outer surface of the swaged sleeve 22 can be machined or ground to the required diameter and electroplated as described above.

The hoop tensioning processes described in general, and the shrink-fitting example particularised above, yield a precision lightweight roller comprising a non-metallic core with a surface coating of metal attached by means of hoop tensioning which has the following advantages when compared with previously described processes for production of such rollers:

a) formation of the coating is not dependent on adhesion to the core surface, which is difficult to achieve in the case of FRP cores;

b) the number of manufacturing variables to be controlled can be reduced;

c) the porosity which is always obtained with sprayed coatings (and sometimes with plated coatings) is avoided; and

d) small defects in the outer surface of the core, such as voids, do not affect the outer surface of the roller.

FRP end fittings can be used in place of the metal ones described and can be provided with stub shafts rather than bores to receive a shaft.

Rollers in accordance with this invention have particular utility for the processing of very thin plastics film (e.g. polyester film) and could be made to lengths up to a few metres long.

CLAIMS

1. A roller for use in a given operating temperature range comprising a core made of a fibre-reinforced plastics material having an outer surface, and a sleeve of a different material having an inner surface engaging the outer surface of the core, characterised in that the engagement is arranged in such a manner as to place the sleeve material in hoop tension in the vicinity of said inner surface and leave the core non-rotatable with respect to the sleeve within said operating temperature range.

2. A roller according to claim 1, characterised in that the sleeve is of metal.

3. A roller according to claim 1, characterised in that the sleeve is a polymeric material.

4. A roller according to claim 1, characterised in that the core is reinforced with a fibre selected from the group consisting of glass fibre, polyester fibre, polyamide fibre, aramid fibre and carbon fibre.

5. A roller according to claim 4, characterised in that the sleeve is of metal and has an outer surface treated, to provide the final surface properties required, by a process selected from the group consisting of polishing, etching, electroplating, anodising, electroless-plating and spraying with other materials.

6. A method of making a composite roller which comprises a cylindrical core of a fibre-reinforced plastics material and an outer tubular sleeve of a second material, characterised in that the method comprises the step of forming an interference fit between the core and the sleeve which leaves the sleeve in hoop tension thereby to retain the core non-rotatable in the bore of the sleeve.

7. The method according to claim 6, characterised in that the step of forming the interference fit comprises the steps of forming the core with a predetermined outer diameter, forming the sleeve with a bore having a diameter which is slightly smaller than the outer diameter of the core, and mechanically forcing the core axially into the bore.

8. The method according to claim 6, characterised in that the step of forming the interference fit comprises the steps of forming the core with a predetermined outer diameter, forming the sleeve with a bore having a diameter which is slightly smaller than the outer diameter of the core, subjecting the core and the sleeve to differential thermal treatment which causes the diameter of the bore to exceed the outer diameter of the core, locating the core in the bore of the sleeve, and allowing the core and the sleeve to stabilise at a common temperature thereby to place the sleeve in hoop tension and the core in compression.

9. The method according to claim 6, characterised in that the step of forming the interference fit comprises the steps of forming the core with a predetermined outer diameter, forming the sleeve with a bore having a diameter which is slightly larger than said outer diameter, locating the core in the bore of the sleeve, and working the sleeve down on to the core thereby to place the sleeve in hoop tension and the core in compression.

10. The method according to claim 9, characterised in that the sleeve is worked down on to the core by a swaging technique.

11. The method according to claim 10, characterised in that the swaging technique makes use of a rotary hammer swage technique which hammers the sleeve radially inwards.

12. The method according to claim 10, characterised in that the swaging technique makes use of a rotary ball swage technique which deforms the sleeve radially inwards.

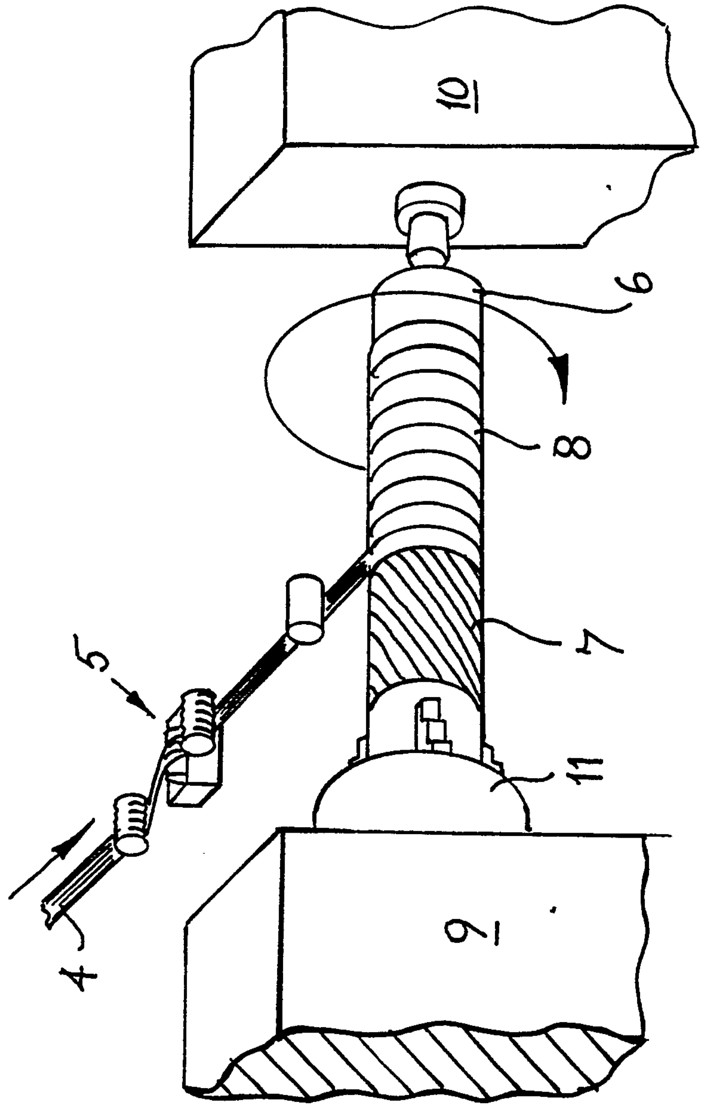
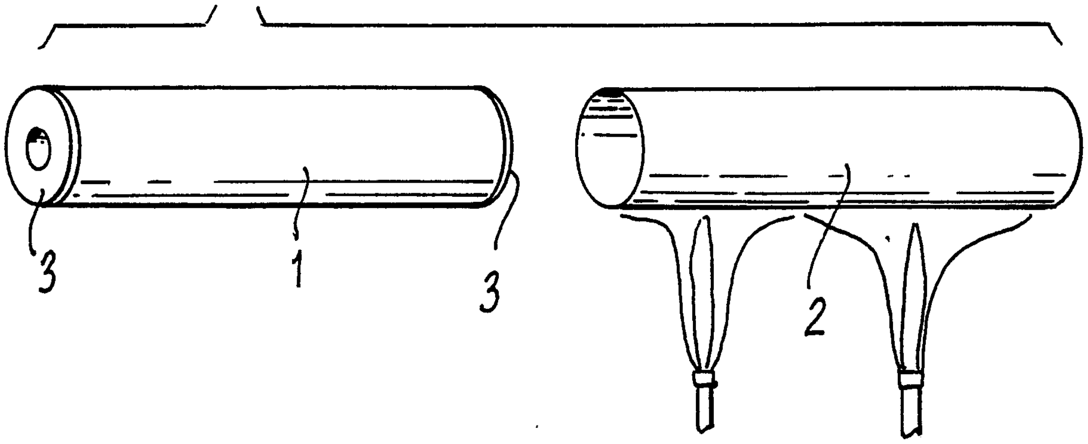


FIG. 1

FIG. 2



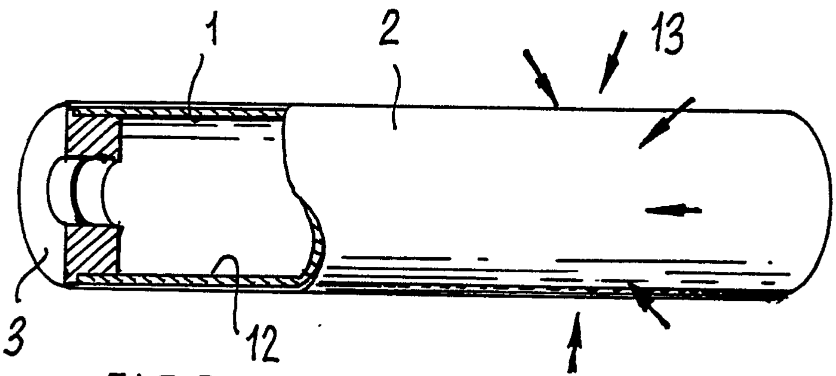


FIG.3

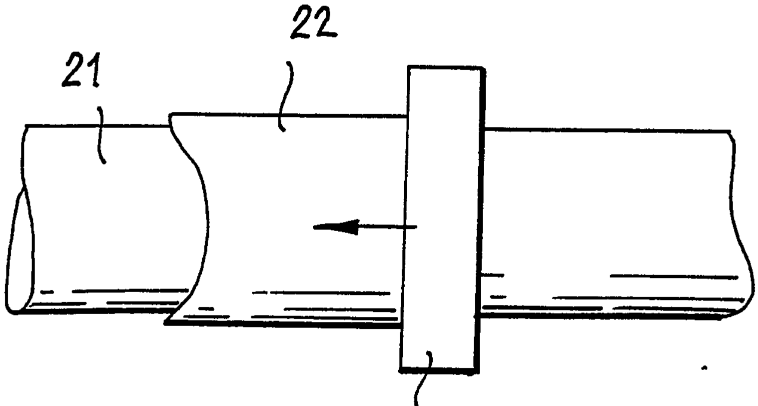


FIG.4

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/01700

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 B65H27/00 ; F16C13/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	B65H ; F16C ; B29D ; B29C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	US,A,4864343 (NELSON) 05 September 1989 see column 4, lines 41 - 48 see column 6, line 53 - column 7, line 29; claims 1-2; figures 3, 9	1-2, 4
Y		3, 5-9
Y	FR,A,2102908 (TAKATA KOJYO CO.) 07 April 1972 see page 7, lines 15 - 26; figure 5	3
Y	US,A,4841613 (BEERY ET AL.) 27 June 1989 see column 3, lines 39 - 44; figure 3	5
Y	PATENT ABSTRACTS OF JAPAN vol. 8, no. 180 (M-318)(1617) 18 August 1984, & JP-A-59 73239 (MICHIO YOSHIKAWA) 25 April 1984, see the whole document	6-9

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° Special categories of cited documents :[10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
19 FEBRUARY 1991	19. 03. 91
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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.
Y	DE,A,1652881 (WEINGRABER EDLER GRODEK) 05 August 1971 see page 1, lines 3 - 8; figure 1 ---	7
Y	DE,A,2165896 (VEREINIGTE DEUTSCHE METALLWERKE AG) 05 July 1973 see page 4, line 28 - page 5, line 12; figure 1 ---	9
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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/GB 90/01700

SA 41548

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 21/02/91
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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