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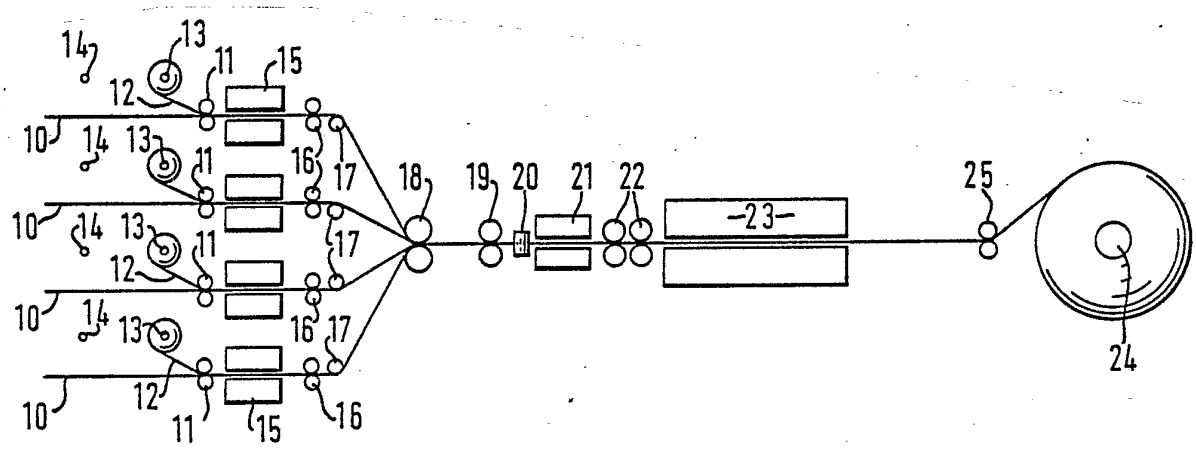
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(54) Title: CONTINUOUS PRODUCTION OF FIBER REINFORCED THERMOPLASTICS MATERIALS AND STRUCTURES MADE THEREFROM




(57) Abstract

The described arrangements provide for the continuous formation of a fiber reinforced laminate or an article made therefrom by impregnating reinforcing fibers with a thermoplastics material/solvent mix, heating the impregnated fibers and then compressing them (e.g. with one or more roller sets). Articles are formed by re-heating the laminate and then moulding the laminate to a desired shape. Different section articles may be produced and description is made of the production of a number of different open and closed sections. The closed sections may be filled with foamed thermoplastics, and fillers (e.g. metallic sheaths or wires) may be interposed between different layers of a multi-layer laminate article.

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Title: CONTINUOUS PRODUCTION OF FIBRE REINFORCED THERMOPLASTICS MATERIALS AND STRUCTURES MADE THEREFROM

# D E S C R I P T I O N

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## TECHNICAL FIELD

The invention concerns the continuous production of fibre reinforced thermoplastics material laminates and the manufacture of articles therefrom and is particularly, but not exclusively, concerned with the production of continuous stocks of fibre reinforced polyethersulphone (P.E.S.) shapes.

## BACKGROUND ART

In the production of fibre reinforced thermoplastics laminates wetting between the reinforcing fibres and the thermoplastics material is improved by impregnating the reinforcing fibres with a thermoplastics solution. To achieve the desired resin/fibre ratio in the final laminate or structure the impregnated thermoplastics material may be supplemented by adding a solid thermoplastics material in the form of film, powder, monofilaments or in any other suitable way.

A problem with producing laminates by such a method is that high temperatures (in excess of 290°C) and high pressures (greater than 75 $kg/cm^2$) are required to produce a finished article.

When making discontinuous laminates (such as plaques) this problem is readily overcome by using conventional compression moulding techniques. However this technique is of little use when making a continuous, moving, stock of laminate, (or an article made from the laminate) as the necessary high temperatures and pressures are more difficult to obtain and sustain. Also, when producing continuous stocks of laminates and articles, problems arise due to the propensity of the thermoplastics material to stick to any parts with which it comes into contact and also due to the high viscosity (and therefore viscous drag) of the resin materials at temperatures above their normal glass transition temperatures.

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DISCLOSURE OF THE INVENTION

According to one aspect of the invention we provide a method of forming a continuous stock of fibre reinforced thermoplastics laminate comprising impregnating fibres reinforcement with a thermoplastics material in solution, drying the impregnated fibres to disperse at least in part the solvent, heating and then compressing the thermoplastics material and fibres reinforcement.

Throughout this specification, and in the claims attached hereto, the term fibres reinforcement encompasses reinforcing fibres or tows of fibres or fabrics woven from such fibres or tows of fibres.

We have discovered that there is a reduction in the glass transition temperature of a thermoplastics material due to plasticisation of the thermoplastics material - in the presence of a low level of solvent and this effect may be used to aid the production of continuous laminate stocks of fibre reinforced thermoplastics materials.

With advantage, the reinforcing fibres are impregnated with said thermoplastics material by passing them through a bath containing a solution of said thermoplastics material.

Preferably the thermoplastics material is polyethersulphone and the solvent is N-methyl-2-pyrrolidone or a mixture of N-methyl-2-pyrrolidone with an aromatic hydrocarbon (such as xylene or toluene).

The thermoplastics material with which the fibres reinforcement are joined is preferably in the form of a film, sheet or layer.

The heating of the thermoplastics material and fibres reinforcement may be effected with short-wave infrared heating

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units in which heating is to a temperature at which the thermoplastics material attains its glass transition temperature.

Another aspect of the invention provides a method of continuously forming a stock of a fibre reinforced article in which a laminate is made in accordance with the method outlined above and the laminate is then heated and moulded to form the desired article.

Moulding to form an article in this way may be effected in any suitable way e.g. with a die mandrel or the like and make use of forming rollers.

In producing articles in accordance with the invention such as pipes, rods or the like fillers (e.g. metal sheathes for reinforcement of electrical screening) may be interposed between different ones of the layers of fibres reinforcements.

## BRIEF DESCRIPTION OF THE DRAWINGS

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

Figures 1 and 2 illustrate a system embodying the invention;

Figure 3 illustrates a modification to one part of the system of Figures 1 and 2;

Figure 4 illustrates a modification to another part of the system of Figures 1 and 2;

Figure 5 illustrates sections of various products which may be made with the system of Figures 1 to 4;

Figure 6 illustrates apparatus for use in effecting the invention;

Figure 7 illustrates sections of products made with apparatus embodying the invention;

Figures 8, 9 and 10 illustrate other modifications which may be made to apparatus embodying the invention; and

Figure 11 illustrates a mobile land system for the continuous production and laying of oil pipe-lines

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embodying the apparatus of the invention.

Figures 1 and 2 show the central section and the pre-impregnation section respectively of apparatus embodying the invention. In Figure 1 woven sheets 10 of fibre reinforcing fabric pre-impregnated with a solution of a thermoplastics material are fed continuously to pairs of pinch rollers 11, at which the sheets 10 are brought into contact with films 12 of thermoplastics material taken from support rolls 13. Back-up rolls 14 of thermoplastics material films are provided for use when any roller 13 is exhausted. When a roller 13 (or 14) is exhausted the other roller 14 (or 13) is arranged to feed film to the rollers 11 enabling the exhausted roller to be renewed. Suitable, commercially available, means (not shown) are provided to ensure that the thermoplastics film 12 is fed to the rollers 11 substantially continuously.

After passage through pinch rollers 11 the pairs of fibre reinforced sheet 10 and thermoplastics film 12 are fed between banks of infra-red short-wave heaters 15 which heat them to a temperature of approximately 340°C and they then pass via a further pair of pinch rollers 16 over a spring loaded roller 17 (which acts to maintain tension in the sheets) to a pair of collection rollers 18. After passage through rollers 18 the stack of sheets of fibre reinforced material 10, now interleaved with films of thermoplastics material, are fed via a pinch roller 19 and guide rollers 20 to a further infra-red short-wave heater 21. Immediately after passing through the heater 21 the stack is passed between sets of high pressure rollers 22 to form the laminate. The laminate formed in the high pressure roller set 22 is drawn therefrom by any suitable device but preferably by a tractor 23 as shown after which the formed laminate is passed via guide rollers 25 for further treatment or for storage (as shown) on a roller 24.

The rollers 16 act as low pressure compression rollers initially tacking each film 12 to its associated

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sheet of fibre reinforcing material 10. These rollers support the feed and tension rollers and are individually synchronised to the line-feed. They are preferably provided with power couplings to keep each fabric/plastic strip under suitable tension.

To ensure safety in operation gas extractor means are provided around the heaters 15 and 21 ensure the safe extraction of the possibly explosive gases from the solvents in which the thermoplastics material is dissolved.

Dust extractor means - preferably water but possibly air - may be provided at the output end of the tractor take-off 23.

Figure 2 illustrates one way in which the sheets of fibre reinforcing material may be pre-impregnated with the thermoplastics material in a continuous process. Rolls 30 carry continuous lengths of fibre fabric 31 which are fed by guide and tensioning rollers 32 and guide rollers 33 to a bath 34 containing a thermoplastics material in solution 35 (for example a bath of P.E.S. in a solution of N.M.P.). Within the solution in bath 34 each sheet of fibre reinforcing material passes round two guide rollers 36 spaced apart beneath the surface of the thermoplastics material solution and is then passed by guide rollers 37 to a drying tower 38 in which each individual fabric reinforcing sheet (now coated with a solution of thermoplastics material) is dried. After passing through the drying tower 38 the impregnated sheets 10 of fibre reinforcing material emmerge, and may be passed continuously to the rollers 11 in the apparatus of Figure 1.

Further support rollers 39 may be provided in the apparatus of Figure 2 on which further rolls 31 of material are located enabling a continuous sheet of fibre reinforced material 31 to be provided for entry to the bath 34. Means (e.g. a sewing machine) may be provided to enable the end of one roll of material 31 to be joined to the start of another roll 31 of material.

The feed of fibre reinforced sheet material from

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the rollers 30 and 39 is so synchronised that no two rollers are exhausted of material 31 at the same time. This aids the operation of the method and allows for the substantially continuous production of thermoplastics impregnated sheets of fibre reinforced laminate material.

An extraction duct 40 may be provided for the exhaust of noxious gases (i.e. from the solvent in bath 34).

Each sheet of fibre reinforcing material passes between two rollers 36 within the thermoplastics material 35 in the bath 34. The path, in practice, each sheet of fibre reinforced material takes within the solution of thermoplastics material and the time any particular part of it takes to pass therethrough may be altered to vary the degree of impregnation of the fibre reinforcing sheets with thermoplastics material.

In the drying tower 41 the different lengths of thermoplastics impregnated fibre reinforcing material are spaced apart by any suitable means e.g. rods 41. The tower itself may be provided with drying means 42 such as aluminum sheet heaters or long-wave infra-red panels with an air moving fan provided at the base of the tower, or simply with a blower/heater unit (not shown).

Modifications may be made to the above described arrangements within the scope of the invention.

The preformed sheets of fibre reinforcing material described above may be replaced by bobbins of single strand fibre or tows of fibres. The number of bobbins may be determined by the width of the strip required.

Other single strand fibres may be laid across the direction of line feed, as weft, to create a "woven" fabric (see for example the description below with reference to Figure 3). The single strand fibres remain straight and thus eliminate the weaker mechanical structure of a woven fabric. This process allows the weft to be laid at any angle to the warp making increased torsional strength available.

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The thermoplastics film loading (from the rollers 13 and 14 of Figure 1) may be eliminated if the ratio of thermoplastics material: reinforcing fibre emerging from bath 34 (of Figure 2) can be made sufficiently high. Alternatively the plastics material can be loaded in other ways (e.g. by ribbon extrusion, fluidised power coating making use of compressed air, liquid powder dipping - in which a powder of the thermoplastics material suspended in a solution of water and water soluble solvent is used - and by a powder curtain.

The high pressure compression rollers 22 may be modified or replaced with high pressure forming rollers. In such an arrangement layers of appropriate width fabric are supplied from auxilary loading units and composite sections may be continuously formed.

A multi-roll forming process may be provided at the outlet from the tractor unit 23 (Figure 1) or alternatively a cut-off unit may be provided there, allowing any desired length of laminate to be produced.

We envisage that the approximate requirement of the apparatus described in Figures 1 and 2 will be between 50 and 74 kilowatts continuous rating.

Figure 3 discloses a modified arrangement of the apparatus of Figures 1 and 2 in which the fibre reinforcing material rather than being preformed in sheets (either flat or woven sheets) is formed directly from single strands of fibre or tows of fibres. In this arrangement the individual fibres or tows of fibres taken to the device shown at 50 are passed first through a pre-impregnation bath in which they are coated with a solution of thermoplastics material and then through a drying tower if it is thought necessary.

The warp fibres 51 are taken from the drying tower to the device 50 and are there provided as an array of generally parallel fibres extending longitudinally of the length of material that is to be formed. The weft fibres 52 however are taken via a spool 53 to a recipro-

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cating shuttle or slider 54 arranged to reciprocate across the width of the warp fibres 51 and to hook the weft fibre 52 over pins of caterpillar tracks 55 arranged at both sides of the fabric making machine 50. The shuttle 54 is driven pneumatically and hooks the weft fibre 52 over each of the caterpillar pin tracks which then act to ensure that the weft threads are applied to the warp threads at a desired spacing. The shuttle 54 lays the weft fibre 52 directly onto the warp fibres 51 (or onto an interposed layer of thermoplastics film 56 which may be provided from a roller 57). After the weft fibre has been laid down the caterpillar tracks 55 carry the fabric in the direction of arrow A between a pair of short-wave infra-red heaters 58 which heats the fabric to a temperature of $\simeq 340^{\circ}C$. Thereafter the fabric is passed between a pair of pressure rollers 60 in which the impregnated weft and warp threads (with possibly the interposed layer of thermoplastics material) are consolidated into a laminate.

After passage through the pressure rollers cutters may be used at the edges of the material to provide an even edge to the laminate. Thereafter the composite laminate may be passed to a loading unit such as is described in Figure 1 in which it is conjoined with other similar laminates to form a composite laminate.

The advantage of the apparatus described with reference to Figure 3 is that we provide that the reciprocating head 54 be carried on a carriage the position of which may be varied in the directions of the arrows B such that the direction in which the weft fibre extends relative to the warp fibres may be varied. For example although Figure 3 shows the weft fibres to extend orthognally of the warp fibres it is possible, by positioning the carriage 61 of the reciprocating slider 54, that the weft fibres run across the warp fibres at any desired angle.

It should be noted that several units such as are described with reference to Figure 3 may provide one after another to enable more than one fabric layer to be

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produced simultaneously. For example several sets of weft fibres may be arrayed, at the same or different angles relative to the warp fibres, interleaved between various arrays of warp fibres.

In this way laminate structures having great strengths may be formed on a continuous basis.

Figure 4 illustrates apparatus by which the thickness of a laminate to be produced may be varied across its width.

In the arrangement of Figure 4 semi-processed laminate taken from the tractor 23 is shown at 70 to be passed between pairs of pinch rollers 71 between which rollers complimentary rolls of fabric 72 and thermoplastics film 73 are located to pass fabric and/or film onto the laminate 70 at positions (and in thicknesses and width) determined by the section it is desired to produce. The laminate 70 and complimentary fabric and/or film passes adjacent one or more guide form plates 74 the quantity, type and positions of which are determined by the desired section of the final laminate to be produced and then between guide rollers 75 to an infra-red short-wave heater 76 which is thyristor controlled. After heating the composite laminate passes between compression form rolls 77 driven in synchronism with the line-feed rate. Thereafter the composite laminate may be further heated (at 78) and/or passed between further compression form rolls (at 79) - the number of times the laminate is re-heated and the number of rolls through which is passes vary in accordance with the complexity of the section which is to be produced.

Various sections which may be formed using the apparatus shown in Figure 4 are shown in Figure 5.

Figure 6 shows an arrangement in which various other section structures may be produced.

Figure 6 provides that the laminate produced at the outlet of the tractor 23 is taken over a set of cutters shown at 80 and then between a set of short-wave

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infra-red heaters 81 arranged on both sides of the laminate in which the laminate is re-heated. After passing heaters 81 the lengths of laminate are passed between form rollers 82 which bend the sections of laminate to any desired shape. The laminate material may thereafter be passed between further short-wave infra-red heaters 83 and forming rollers 85 before emerging at 87, from the machine.

With the arrangement of Figure 6 tubes may be formed and the ends of the laminate - after processing - may be at any desired angle simply by positioning the angle of the cutters 80. If the cutters lie normally of the laminate the cuts they make are right angled forming square ends and butt joints in the final article whereas if the cutters are set at an angle, scarf joins may be achieved and angled ends may be provided for the sections produced.

Examples of the sections which may be produced making use of the apparatus such as is described with reference to Figure 6 are shown in Figure 7A.

It will be appreciated that by making use of a combination of the apparatus shown in Figures 4 and Figure 6 it is possible to produce complicated, closed section laminate structures. In such an arrangement the laminate would be initially treated in apparatus such as is shown in Figure 4 to provide for varying thickness across its width and then treated in apparatus such as is shown in Figure 6 to be bent to the desired shape.

It will be appreciated that with the closed sections shown in Figure 7 it is possible, prior to final closure of the section, to fill the section with any desired material - for example a foamed plastics material. In this way articles with substantially solid sections can be made.

The arrangement of Figure 6 enables structures with complex cross-sections to be produced including aerofoil sections and/or square section tubes. When desired to make simple round section tubes (or even

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section tubes of more complex shape) it is possible to treat the laminate material emerging from the tractor 23 of Figure 1 as shown in Figure 8. In this arrangement the laminate 89 is first trimmed at 90 then heated by a short-wave infra-red heater 91 and passed to a forming die 92 in which it is formed to the desired shape. After coming from die 92 the almost closed laminate may be re-heated - specifically in those areas of laminate which it is desired to join - by means 94, and the laminate then passed to a closing die 95. A further tractor 96 may be provided to pull-off the finished laminate.

An alternative to the arrangement of Figure 8 is shown in Figure 9, in which a flat or variable thickness stock 97 is re-heated and passed to a tube forming spigot or mandrel 98 the temperature of which is kept at a constant level of say 200°C and the laminate is then bent around the spigot by a plurality of forming rolls 101 interspersed by infra-red short-wave heaters. Examples of the shapes which may be formed are shown in Figure 7B.

When the arrangements of Figures 6, 8 and 9 are used to form closed section lengths of stock (for example tubes) other materials may be inserted within the tube as it is produced. Mention has been made of filling of the inside of an aerofoil section with a foamed thermo-plastics material however it will be appreciated that other materials may be inserted within the closed section - for example arrays of conductors if the closed section is to form a sheath for a reinforced electric cable.

Figure 10 shows another way in which closed sections formed with the apparatus of Figures 6, 8 and 9 may be treated.

In the arrangement of Figure 10 a tube 120 (formed with the apparatus of any of Figures 6, 8 and 9) passes through an aperture 121 after being coated with a thermo-plastics film bonding agent 122. The coated tube is then surrounded with another layer of material fed thereto from a series of concentrically located bobbins 124. The

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material from bobbins 124 may be any desired material e.g. a metal wire filler for reinforcing, a fabric thread enabling the wall thickness of the tube to be built up even, a thermoplastics wire for use as a bonding agent - which may eliminate the need for film wrapping as shown at 122. The tube, with its additional coating, then passes a short-wave infra-red ring heater the temperature of which is controlled to operate at $\simeq 340^{\circ}C$, and thereafter passes between a pair of pressure rollers which act to ensure that the added coating on the tube securely adheres to it. It will be seen that a plurality of the devices described with reference to Figure 10 may be arranged to operate sequentially on a tube formed by the apparatus of any of Figures 6, 8 and 9, each of the devices providing an additional layer on a preformed tube. With such an arrangement conductive wire layers may be interleaved with layers of electrically insulating material to build up a coaxial cable of any desired length.

Futher it will be seen that a tube passed to the apparatus shown in Figure 10 may be formed on a mandrel or spigot and need not be produced by the apparatus of Figures 6, 8 and 9. In this way the tube winding unit module of Figure 10 (either alone or with others) may be used to produce tubing of any desired section from scratch or for reinforcing and building up wall thicknesses of pre-formed tubing. It is possible to use such systems to coat any object that may be passed through the bobbin heads with a variety of materials. When producing tubing from scratch the system could be made mobile on land or sea to produce and lay continuous tubing of any diameter (within the limitations of the system size) on site. Continuous tubing could be manufactured by this system at a rate of 4 to 5 feet per minute or one mile per day. Possible uses for tubing produced in this way would be for e.g. gas or oil pipe lines, continuous casing of underground or undersea telecommunication or optical fibre communication lengths, sewage pipes and irrigation

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pipes. For each application which is intended to be used we propose that the particular thermoplastics material, and reinforcing materials and/or conducting materials interleaved therewith, be selected so as not to deleteriously effect the environment or the product which the tube is to carry.

The integrity of stock formed with any of the devices described above may be checked immediately after it is made by passing it through an automatic inspection system, utilising X-rays, visible rays or radio waves enabling the internal inspection of the stock. Additionally a probe may be located within a forming spigot or mandrel when manufacturing tubing from scratch. In this way the production of continuous lengths of material, of any desired length, is enabled without the need for welding or otherwise joining different sections of tubing together. With the arrangements we describe it is possible to rapidly increase the rate at which pipe lines and/or telephone communication links are made and put on site.

Figure 11 shows schematically an arrangement we envisage to be useable to a pipe-line across land.

A digging machine 200 digs a trench 201 in which a pipe is to be laid. The digging machine 200 may also be used to lay tracks on either side of the trench 201 which tracks are in sections 202. Following the digging machine 200, on the tracks 202, is a modified heavy goods vehicle 203 carrying various sections. The first section 204 is a material store feeding directly to a second section 205 in which reinforcing fibres are impregnated with a solution of a thermoplastics material (such as is described with reference to Figure 2). The impregnation section 205 is isolated from the material store 204 and the rest of the vehicle to eliminate fire risks. It is alternatively possible to arrange for the materials to be impregnated with a solution of a thermoplastics material prior to them being loaded on the vehicle although such an arrangement reduces the efficiency of the proposal.

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After impregnation and drying (heat for which would be provided partly by waste heat from the vehicle engine and in the main from a hot air supply burning diesel oil) the impregnated fibre material is passed to a flat stock and tube forming section 206 which may be in accordance with the apparatus of Figure 1 as modified in accordance with the apparatus of Figures 6, 8, 9 or 10. Issuing from the back of the flat stock and tube forming section 206 the completed pipe shown at 210 is laid in the trench dug for it. Sections of the trackway on which the vehicle runs may be lifted from behind the vehicle and placed in front of it.

In each of the above described arrangements the heating is provided by short-wave infra-red heaters which are thyristor controlled to operate at the optimium temperature i.e. for P.E.S. a temperature of $\simeq 340^{o}C$. This temperature may vary if other thermoplastics materials are used.

It is provided that a laminate formed in accordance with the invention is drawn from the rollers (or subsequent heating section) by a tractor haul-off unit, the power requirement of which enabling movement of the reinforcing fibres through the solvent/thermoplastics bath, and of the fibres reinforcements and thermoplastics sheets through the heaters and rollers.

It will be noted that to increase the strength of a laminate we provide that a plurality of layers of fibres reinforcement may be used, the direction of extent of the fibres of various layers being different. If the fibres reinforcing a laminate material all extend in one direction the laminate has a high tensile strength in that direction but a low tensile strength in, e.g. a direction extending transversely thereof. By providing fibres of different layers of reinforcement extending in different directions to one another (for example orthognally) the laminate strength is increased. The way in which we provide this also overcomes a problem of knitted reinforcing

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fabrics i.e. that the individual fibres are bent as they cross other fibres e.g. weft fibres bend as they cross each warp fibres in a woven material, thereby providing individual pockets in the laminate of lower than normal tensile strength at which the thermoplastics material matrix surrounding the fibres may be less thick than elsewhere and at which the fibres may tend to straighten (and therefore elongate) if the material is subjected to a tensile force along the length of the individual fibres.

The present invention also enables the formation of continuous stocks of various articles such as aerofoils, pipes, coaxial cables and the like.

The desired shapes may be, as noted above of complex section, even U or V sections or closed tubes of various section.

With all the above described arrangements we provide preferably the ratio of N.M.P. to aromatic hydrocarbon is not less than 2:1 and that the concentration of P.E.S. in solution is preferably between 15 to 30% by weight.

With the desired solvent or solvent system the reinforcing fibres pass through the solvent until the required resin content is obtained. For high levels of resin content, e.g. greater than 50% by volume, it is desirable to pass the reinforcing fibres through the solution a number of times and to partially dry the reinforcing fibres after each pass. This drying operation is desirably carried out at a temperature slightly below the boiling point of the primary solvent (for example with N.M.P. a temperature of between 70 and 180°C is preferred) so that a small amount of the residual solvent is left in the P.E.S. resin impregnated onto the fibre. Once the required resin/fibre ratio is obtained the material is again desirably partially dried (at similar temperatures) so that some solvent is left in the resin. The residual solvent left in the resin acts as a plasticiser for the resin allowing the layers of impregnated reinforcing

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fibres to fuse together into laminates or articles of the required shape at temperatures below the normal glass transition temperature or softening point of the P.E.S.

Adequate ventilation must be provided in "moulding" the fibres to ensure that the solvent vapours given off are removed.

The rolling or forming operation is as noted above, continued until the desired shape has been achieved and all the residual solvent removed from the polyethersulphone. To achieve the complete removal of the residual solvent it is desirable that the material be heated to a temperature just above its normal glass transition temperature of the resin (with P.E.S. to slightly above 220°C). After the additional heating a final run through a nip roll at a temperature of 220°C may be required to ensure that the laminate section is of the desired shape. Higher temperature thermoplastics resins such as polyetheretherketone (P.E.E.K.), Polyether Ketone (P.E.K.), P.E.S. Copolymers or other compatible materials may be bonded to the laminate surface at this stage if it is desirable so to do.

Although described above with the use of N-methyl-2-pyrrolidone and with Xylene or Toluene it will be appreciated that other solvents and other aromatic hydrocarbons may be used.

It will be appreciated that many modifications may be made to the above described arrangements without departing from the scope of the present invention. For example when forming a pipe for use in conveying viscous fluids (e.g. sewage effluent) the interior of the tube may be coated, as it is formed, with a slippery coating easing passage of the fluid along the pipe. Again the exterior of a pipe or cable may be coated with a material having a low coefficient of friction (e.g. PTFE) if the pipe or cable is to be pulled through an outer hard-material (metal, brickwork) supporting pipe or aperture.

In certain applications pipes for carrying fluids liable to coagulate would be provided with electrically

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resistant elements within their thickness (or on their inner or outer surfaces) through which current may be passed to heat the fluid and maintain its temperature at a desired level at which it flows easily.

Another variation to the described methods is to provide that conductive pathways or coating on (or in) the material of a structure being made, are formed directly on the structure (during or after its manufacture) by metal-ion deposition.

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CLAIMS

1. A method of forming a continuous stock of fibre reinforced thermoplastics laminate comprising impregnating fibres reinforcement with a thermoplastics material in solution, drying the impregnated fibres to disperse at least in part the solvent, heating and then compressing the thermoplastics material and fibres reinforcement.

2. A method according to Claim 1, wherein layers of fibres reinforcement are interleaved with additional thermoplastics material in the form of sheets, films or layers prior to heating.

3. A method as claimed in any one of Claims 1 to 2, in which the reinforcing fibres are impregnated with said thermoplastics material by passing them through a bath containing a solution of said thermoplastics material and are then dried.

4. A method as claimed in any one of Claims 1 to 3, in which the thermoplastics material is polyethersulphone and the solvent is N-methyl-2-pyrrolidone or a mixture of N-methyl-2-pyrrolidone with an aromatic hydrocarbon.

5. A method according to any one of Claims 1 to 4, in which heating of the thermoplastics material and fibres reinforcement is effected with short-wave infra-red heating units and in which heating is to a temperature at which the thermoplastics material attains its glass transition temperature.

6. A method as claimed in any one of the preceding claims in which a plurality of fibres reinforcements are brought into abutment each with an individual one of a plurality of films, sheets or layers of thermoplastics material, the pairs of fibre reinforcements and thermo-

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plastics material are then individually heated and then collated and passed to a pair of rollers by which they are compressed to form a continuous stock of laminate.

7. A method as claimed in Claim 6, in which the reinforcing fibres of different ones of the fibres reinforcements extend in different directions.

8. A method of continuously forming a fibre reinforced article comprising forming a fibre reinforced thermoplastics laminate in accordance with any one of the preceding claims, and then heating and moulding the laminate to form the article.

9. A method as claimed in Claim 8, in which heating of the laminate is effected by short-wave infra-red heating units.

10. A method as claimed in Claim 8 or Claim 9, in which additional layers comprising a metallic sheet and/or metal wire strands are interposed between layers of fibres reinforcement or are provided on the outside thereof.

11. A method as claimed in any one of Claims 8, 9 and 10, in which the laminate is heated and bent around a mandrel to form a continuous length of pipe to form a pipe or a sheath for a cable passing through the mandrel.

12. A pipe or sheath formed in accordance with the method of Claim 11, wherein said additional layers are formed by winding metallic foil or strands onto the surface of said pipe and then winding thereonto further layers of fibres reinforcement impregnated with thermoplastics material in solution.

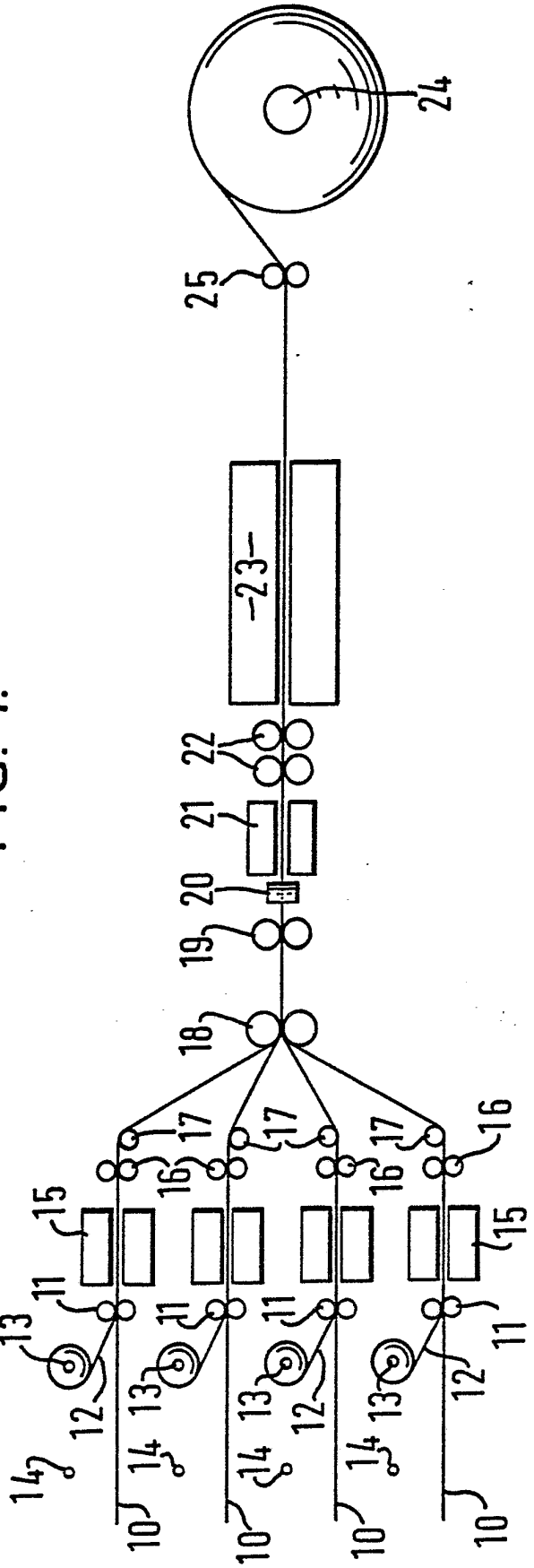
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13. A closed section article formed in accordance with any one of Claims 8 to 12, wherein, before closure, the section is filled with a foamed thermoplastics material.

14. An article formed in accordance with the method of any one of Claims 1 to 13.

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FIG. 1.




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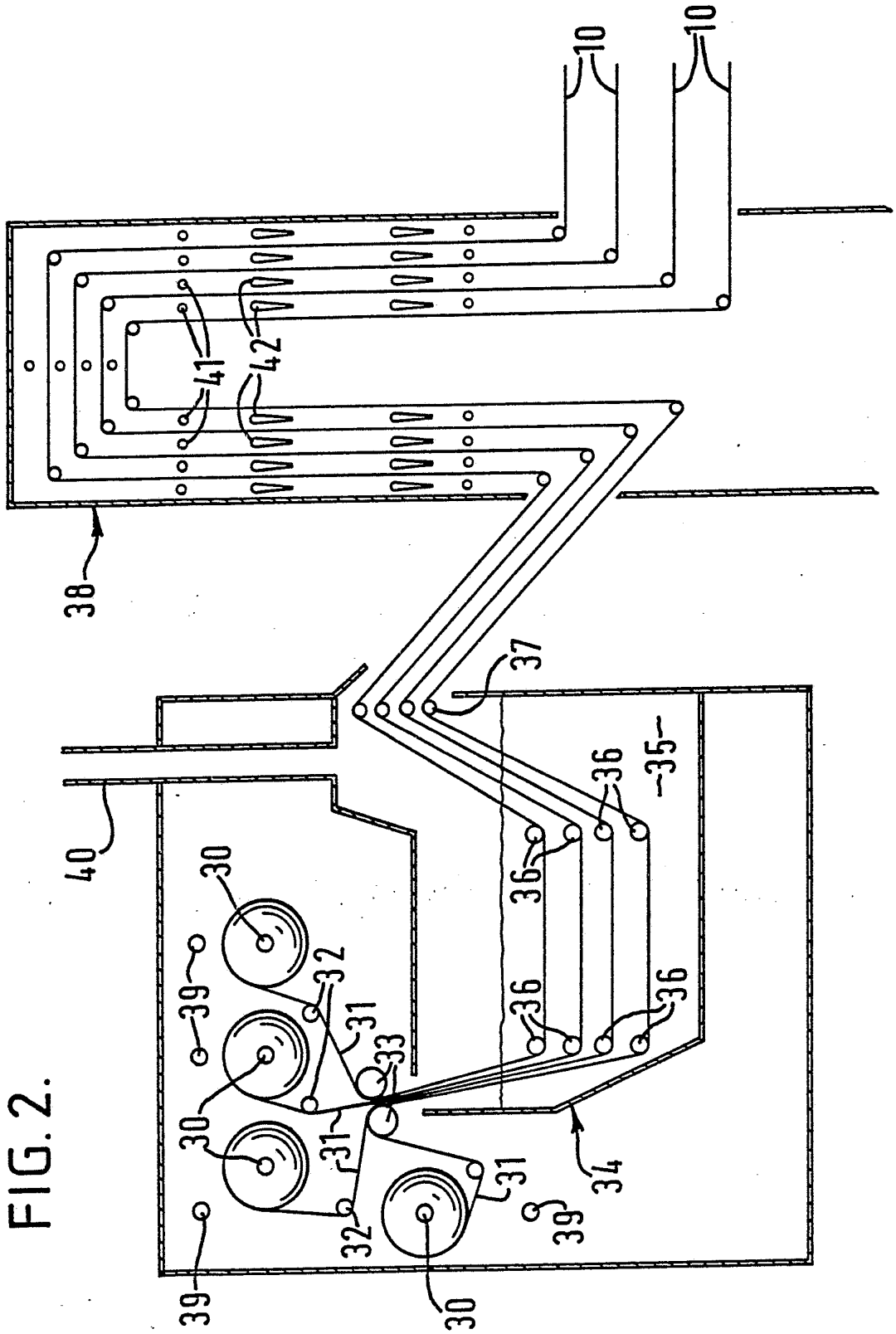



FIG. 2.

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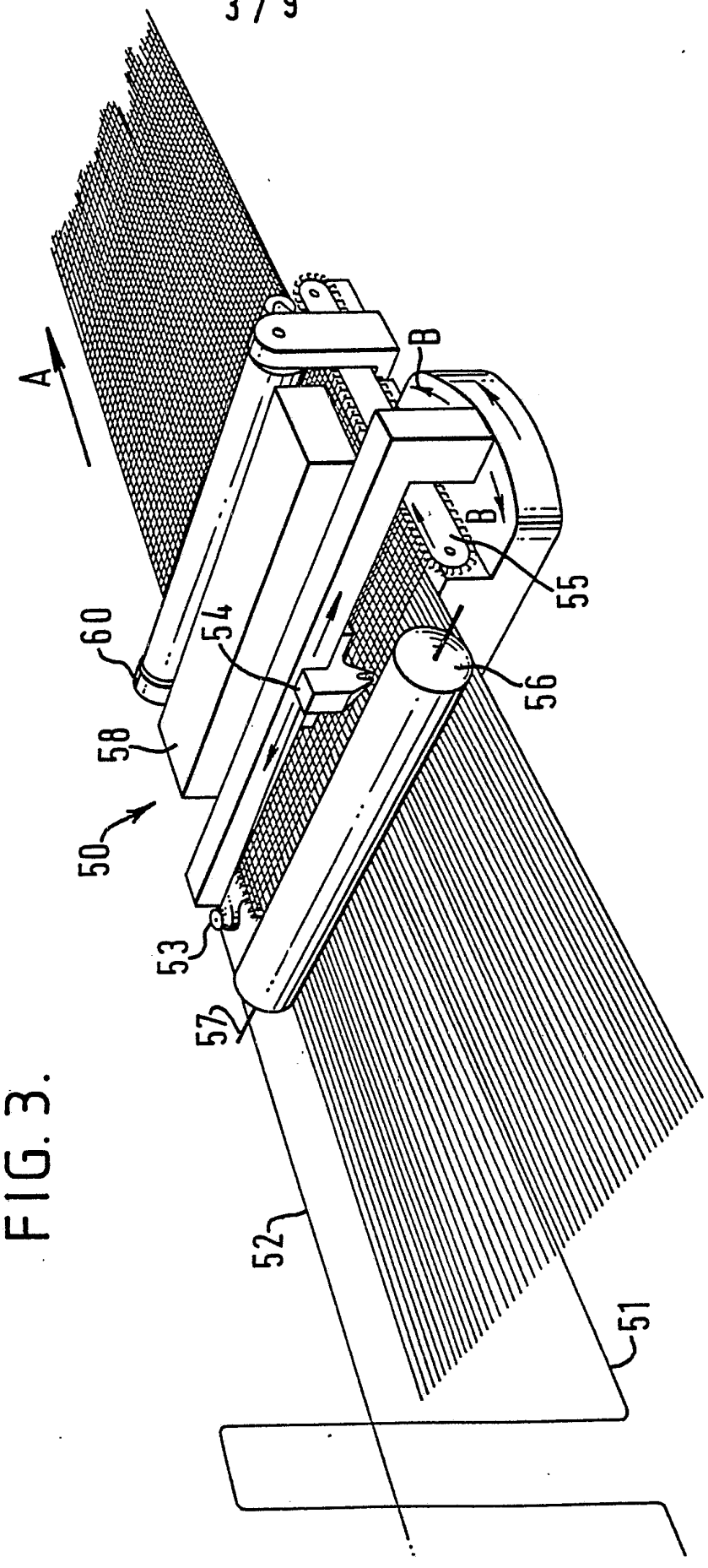



FIG. 3.

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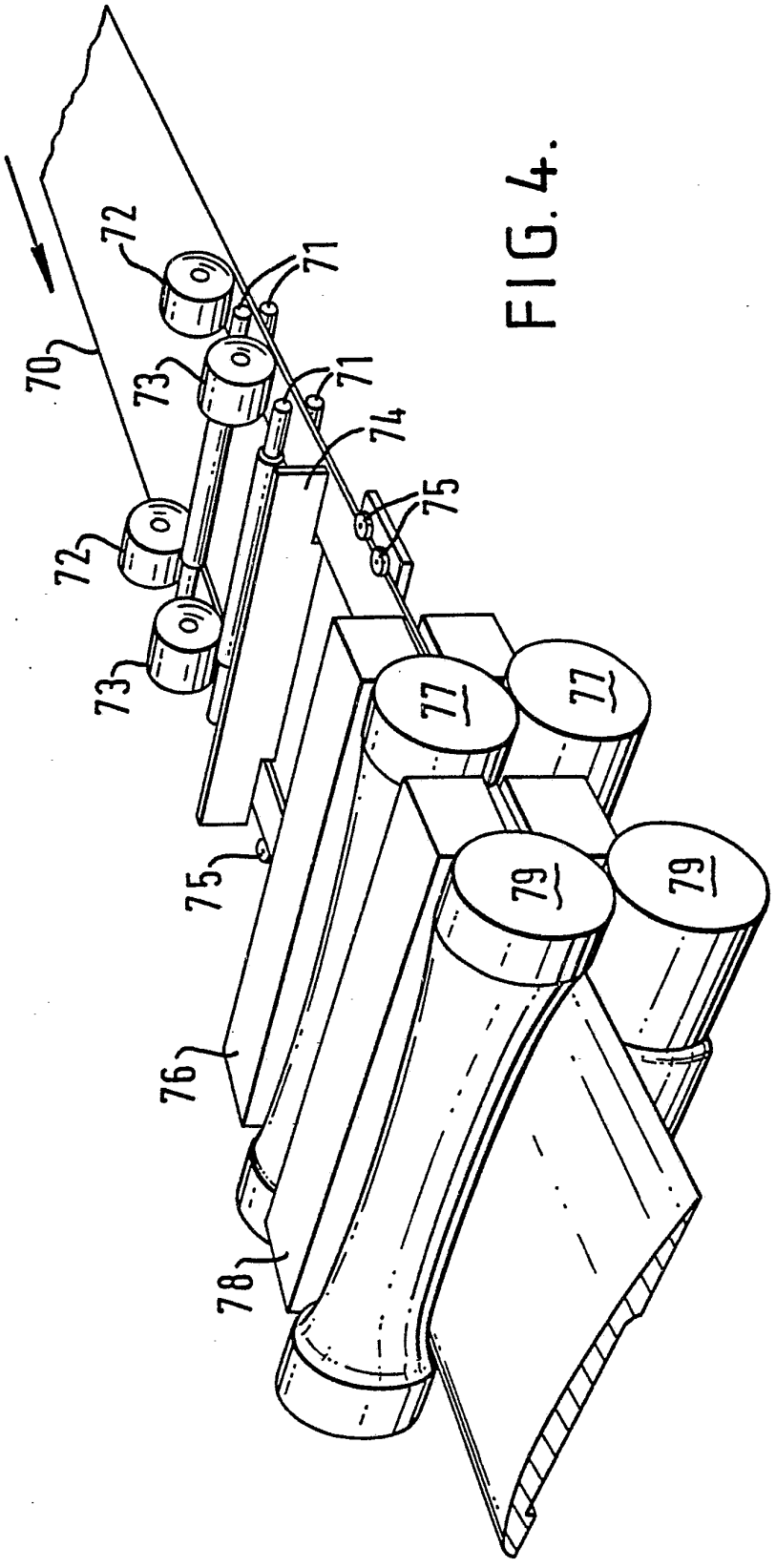
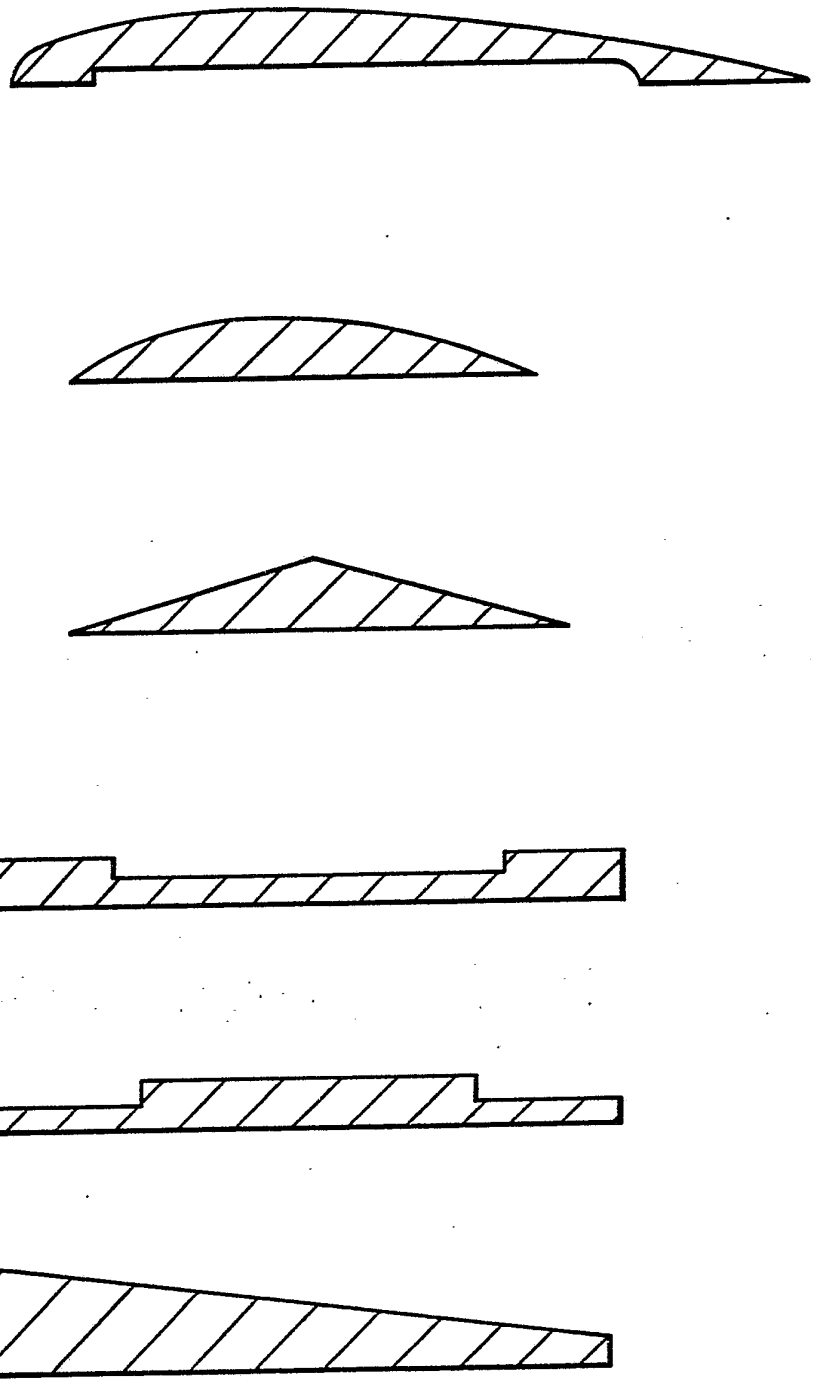



FIG. 4.

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FIG. 5.



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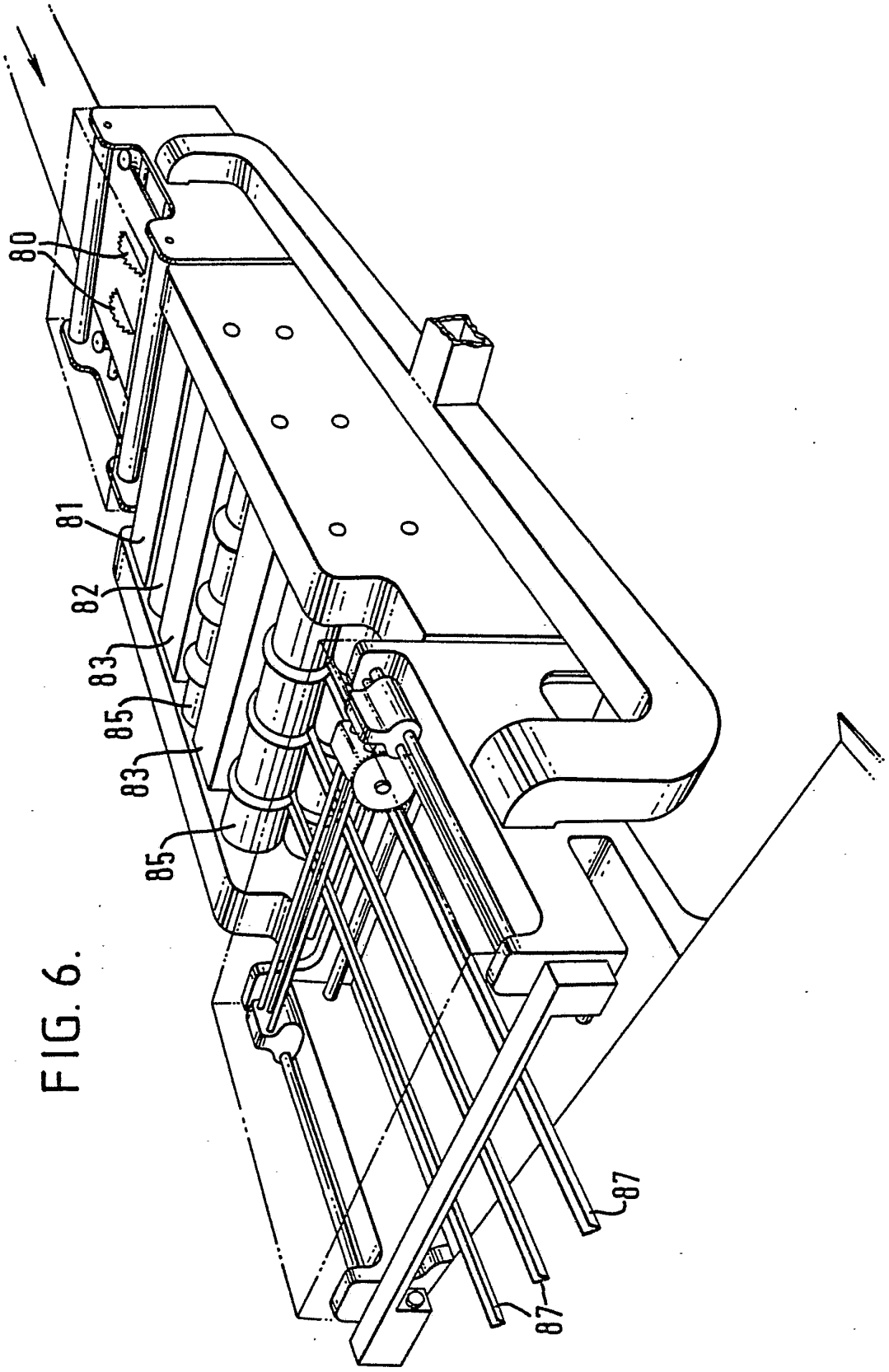
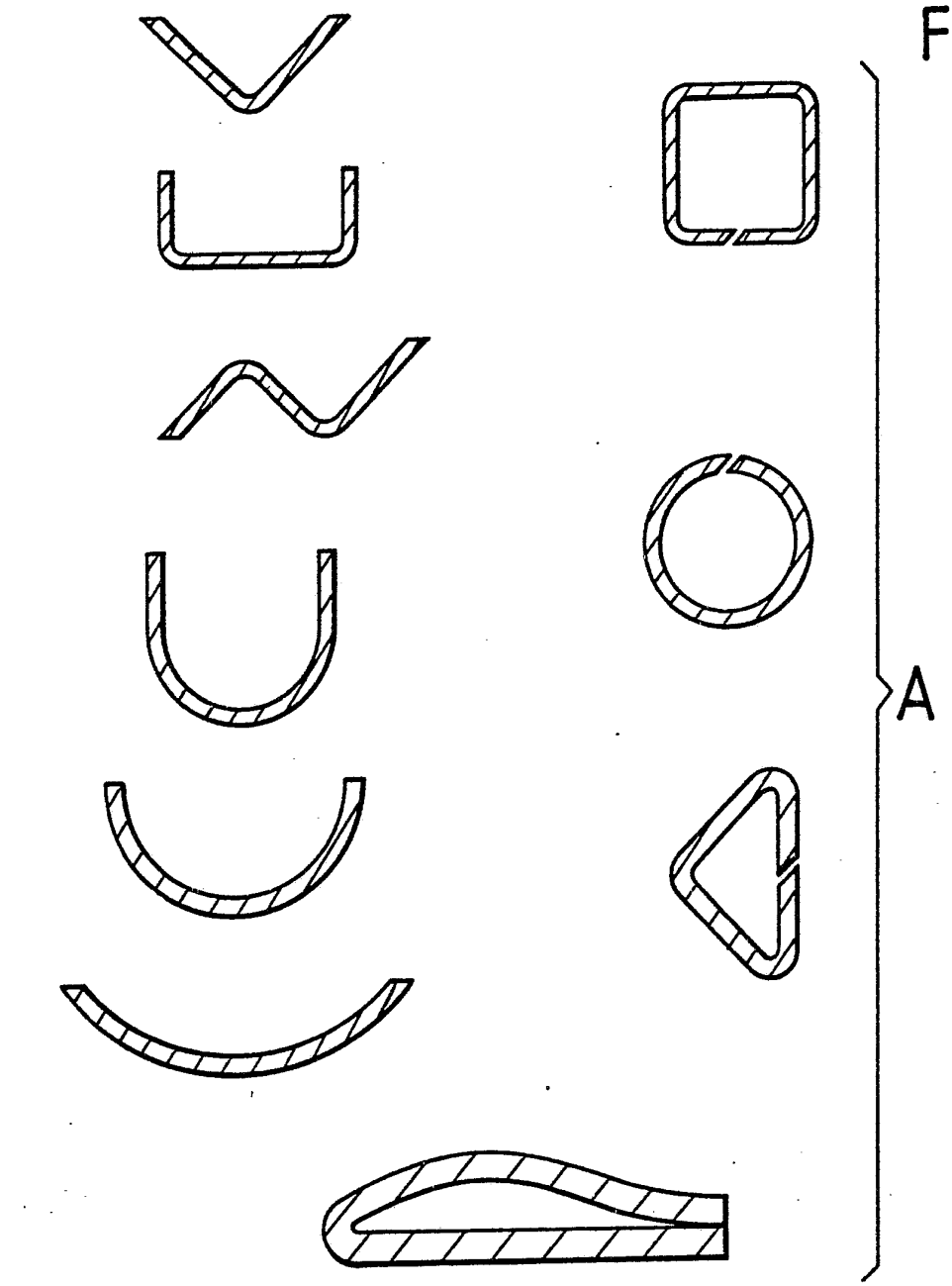
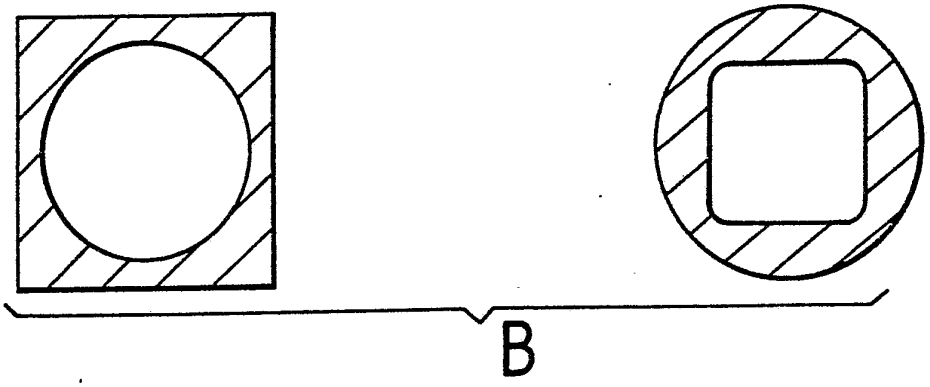



FIG. 6.

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FIG. 7.




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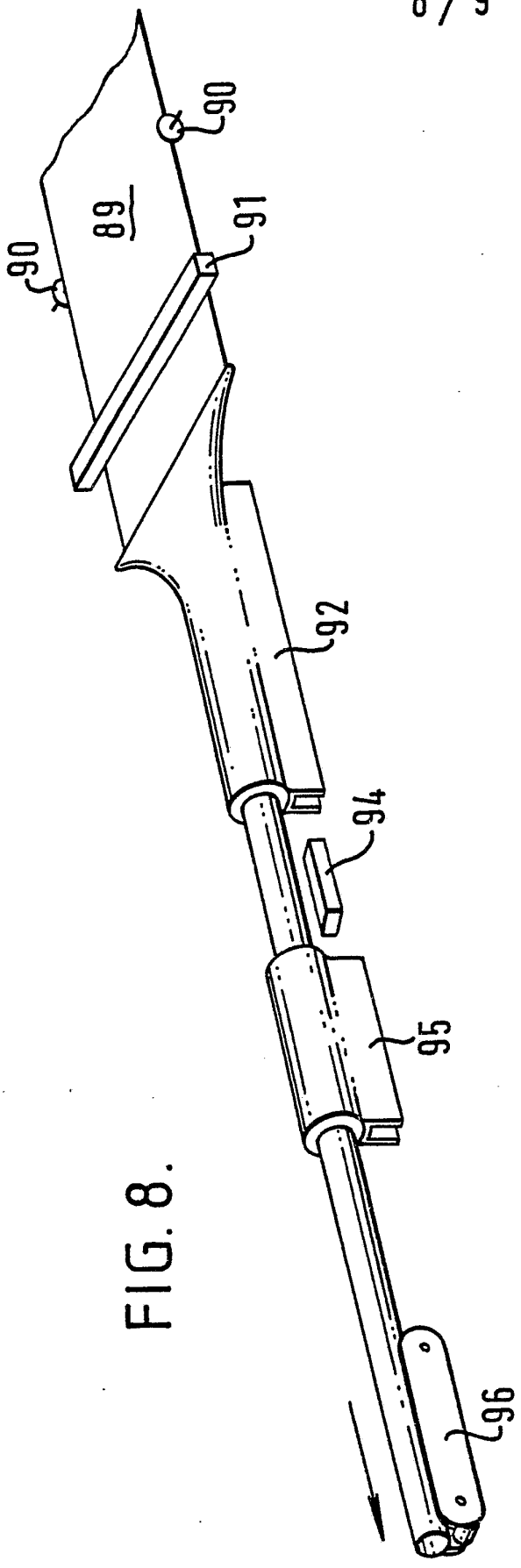



FIG. 8.

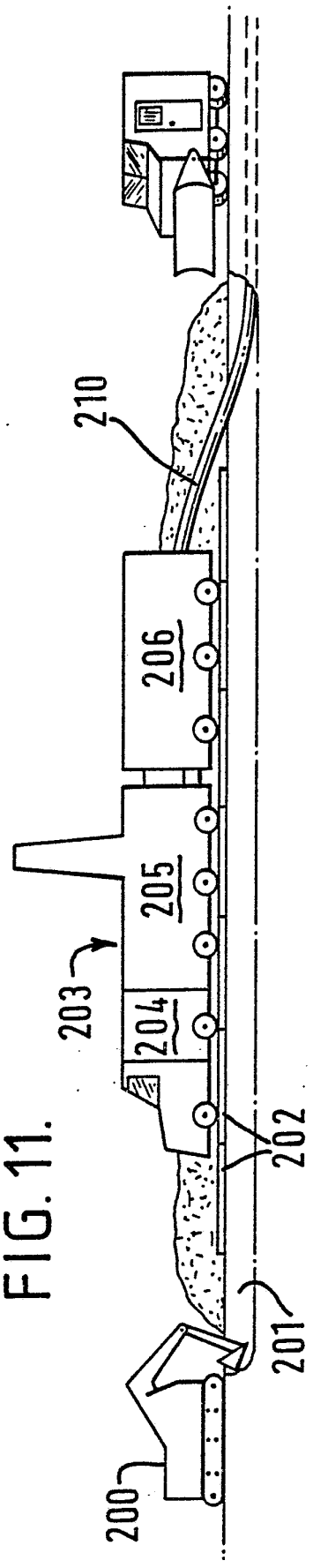



FIG. 11.

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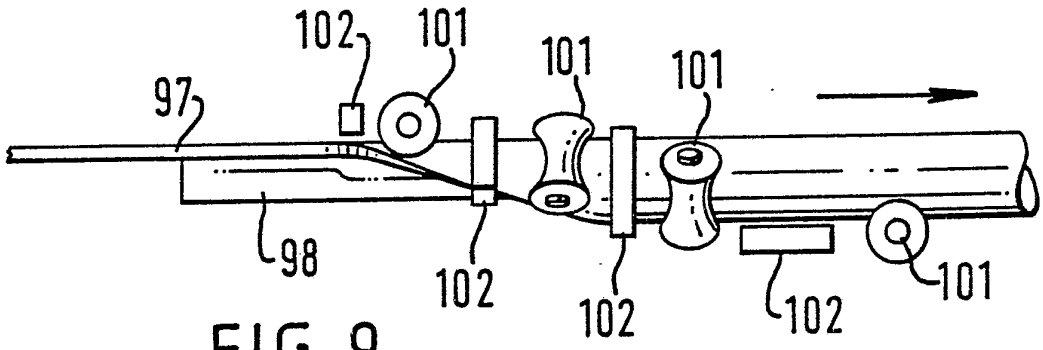



FIG. 9.

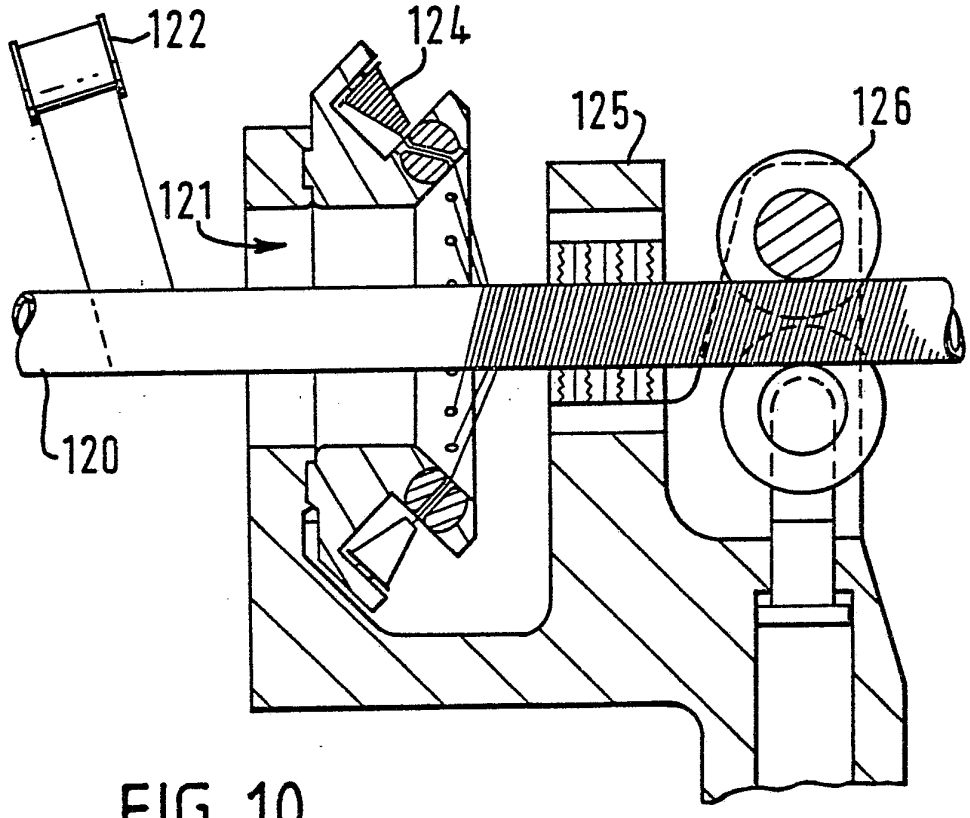



FIG. 10.

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# INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 82/00350

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

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

IPC[3]: B 29 D 3/02; B 32 B 27/04

## II. FIELDS SEARCHED

Minimum Documentation Searched [4]

| Classification System | Classification Symbols |
|---|---|
| IPC[3] | B 29 C; B 29 D; B 32 B |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

## III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No. [18] |
|---|---|---|
| X | DE, A, 1629830 (VOHRER) 28 January 1971 see claims 1,2; figure | 1,3 |
| A | BE, A, 834458 (CENTRE DE COOPERATION TECH- 2 February 1976 -NIQUE ET PEDAGOGIQUE) see abstract | 1,3,7,8,14 |
| A | EP, A, 0024895 (FORD) 11 March 1981 see page 7, line 18 - page 8, line 4; claims; figures 2,3 | 2,6 |
| A | DE, A, 1504302 (GLUCK) 3 April 1969 see page 7, line 11 - page 8, line 2; figure 2 | 1,3,7,8 |
| A | DE, A, 2165470 (MAN) 12 July 1973 see claims 3,4; figure 7 | 11,12 |
| A | GB, A, 1157239 (KABEL) 2 July 1969 see column 2, lines 5-80; figures | 11,13 |
| A | DE, A, 2647821 (DORNIER) 27 April 1978 | |

* Special categories of cited documents: [15]

"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 [2] | Date of Mailing of this International Search Report [2] |
|---|---|
| 15th April 1983 | 29 AVR. 1983 |
| **International Searching Authority [1]** | **Signature of Authorized Officer [20]** |
| EUROPEAN PATENT OFFICE | G.L.M. Kruydenberg |