AU9643077

(12) PATENT ABRIDGMENT (11) Document No. AU-B-43077/96
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 692981

(54) Title
FLEXIBLE TUBULAR PIPE COMPRISING AN INTERLOCKED ARMOURING WEB

International Patent Classification(s)
(51)[6] **F16L 011/08**

(21) Application No. : **43077/96** (22) Application Date : **05.12.95**

(87) PCT Publication Number : **WO96/18060**

(30) Priority Data

(31) Number **94 14600** (32) Date **05.12.94** (33) Country **FR FRANCE**

(43) Publication Date : **26.06.96**

(44) Publication Date of Accepted Application : **18.06.98**

(71) Applicant(s)
COFLEXIP

(72) Inventor(s)
JOSE MALLEN HERRERO; PASCAL ESTRIER; ANNE VINCENT

(74) Attorney or Agent
DAVIES COLLISON CAVE , 1 Little Collins Street, MELBOURNE VIC 3000

(56) Prior Art Documents
WO 92/00481
AU 59688/90
US 3908703

(57) Claim

1. A flexible hose, in particular for transporting fluids under pressure, the hose comprising an internal leakproof sheath, traction armoring constituted by at least two crossed layers of wires, pressure-withstanding armoring referred to as a "pressure layer" and constituted by helically winding at least one pair of interlockable metal section wires at an angle close to 90° relative to the axis of the flexible tubular hose, one of the section wires having a T-shaped section including a base portion provided with projecting ribs at its lateral extremities and a projecting central rib whose end is further from the base portion than are the ends of the lateral ribs, the other section wire having a U-shaped section comprising a base portion having projecting ribs at its lateral extremities, and an outer protective sheath, the ribs of the T-section wire being directed towards the outside of the flexible hose and the ribs of the U-section wire being directed towards the axis of the flexible

.../2

hose, wherein the area of the right section of the T-section wire is substantially greater than the area of the right section of the U-section wire, and in each lateral interlock zone constituted firstly by a lateral rib of the U-section wire engaged in a lateral groove of the T-section wire, and secondly by a lateral rib of the T-section wire facing the base portion of the U-section wire between the two ribs of said U-section wire, there is both contact between the lateral rib of a first of the two section wires and the second section wire, and radial clearance between the lateral rib of the second section wire and the first section wire.

OPI DATE 26/06/96 APPLN. ID 43077/96
AOJP DATE 15/08/96 PCT NUMBER PCT/FR95/01601

AU9643077

ETS (PCT)

(51) **Classification internationale des brevets 6 :**
F16L 11/08

A1

(11) **Numéro de publication internationale:** **WO 96/18060**

(43) **Date de publication internationale:** 13 juin 1996 (13.06.96)

692981

(21) **Numéro de la demande internationale:** PCT/FR95/01601

(22) **Date de dépôt international:** 5 décembre 1995 (05.12.95)

(30) **Données relatives à la priorité:**
94/14600 5 décembre 1994 (05.12.94) FR

(71) **Déposant** *(pour tous les Etats désignés sauf US)*: COFLEXIP [FR/FR]; 23, avenue de Neuilly, F-75116 Paris (FR).

(72) **Inventeurs; et**
(75) **Inventeurs/Déposants** *(US seulement)*: MALLEN-HERRERO, José [FR/FR]; 29, boulevard des Batignolles, F-75008 Paris (FR). ESTRIER, Pascal [FR/FR]; 6, le Clos-Boquet, F-76490 Saint-Wandrille-Rançon (FR). ~~BAUDIN, Anne [FR/FR]; 15, rue de Fontenay, F-76000 Rouen (FR).~~ VINCENT, Anne 627 Rue Du Parc F-76480 Duclair France

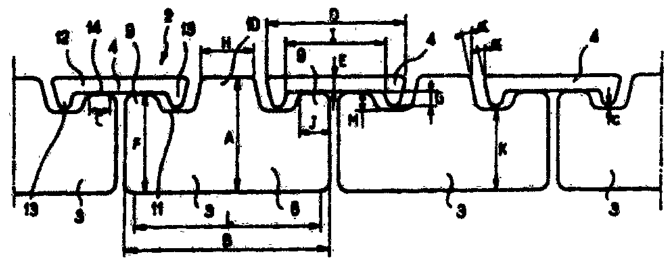
(74) **Mandataire:** LESZCZYNSKI, André; Nony & Associés, 29, rue Cambacérès, F-75008 Paris (FR).

(81) **Etats désignés:** AU, BR, CA, JP, NO, RU, US, brevet européen (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Publiée
Avec rapport de recherche internationale.
Avant l'expiration du délai prévu pour la modification des revendications, sera republiée si de telles modifications sont reçues.

(54) **Title:** FLEXIBLE TUBULAR PIPE COMPRISING AN INTERLOCKED ARMOURING WEB

(54) **Titre:** CONDUITE TUBULAIRE FLEXIBLE COMPORTANT UNE NAPPE D'ARMURE AGRAFEE



(57) **Abstract**

A flexible tubular pipe, in particular for conveying pressurised fluids, comprising pressure-resistant armouring made by winding at least one pair of interlocking metal shaped-section wires of which one has a T-shaped cross-section while the other has a U-shaped cross-section. Ribs on the T-shaped wire extend outwards relative to the flexible tubular pipe, and ribs on the U-shaped wire extend towards the axis of said flexible tubular pipe. The cross-sectional area of the T-shaped wire (3) is substantially larger than the cross-sectional area of the U-shaped wire (4) and, in each side interlocking region consisting of a side rib (13) on the U-shaped wire (4) engaging a side groove in the T-shaped wire (3), and a side groove (9) in the T-shaped wire (3) facing the base portion (12) of the U-shaped wire, as well as between the two ribs (13) of said U-shaped wire, contact is established between the side rib of a first one of the two wires and the second wire, and radial clearance is provided between the side rib of the second wire and the first wire.

(57) Abrégé

Conduite tubulaire flexible, en particulier pour le transport de fluides sous pression, comportant une armure de résistance à la pression constituée par l'enroulement d'au moins une paire de fils profilés métalliques agrafables dont l'un présente une section en T et l'autre une section en U, les nervures du fil profilé en T étant orientées vers l'extérieur de la conduite tubulaire flexible, et les nervures du fil profilé en U étant orientées en direction de l'axe de la conduite tubulaire flexible. L'aire de la section droite du fil profilé en T (3) est sensiblement supérieure à l'aire de la section droite du fil profilé en U (4), et, dans chaque zone d'agrafage latéral constituée, d'une part, par une nervure latérale (13), du fil profilé en U (4) engagée dans une gorge latérale du fil profilé en T (3) et d'autre part par une nervure latérale (9) du fil profilé en T en regard de la partie de base (12) du fil profilé en U et entre les deux nervures (13) de ce fil profilé en U, il y a à la fois contact entre la nervure latérale d'un premier des deux profilés et le second fil profilé et un jeu radial entre la nervure latérale du second fil profilé et le premier fil profilé.

A FLEXIBLE HOSE INCLUDING AN INTERLOCKING ARMORING LAYER

The present invention relates to a flexible hose suitable for use in particular for transporting fluids under pressure, in particular hydrocarbons produced by operating a subsea well.

The Applicant company manufactures and sells great lengths of various types of such hose, having high mechanical qualities, in particular traction strength, and resistance to crushing, to the internal pressure of the fluid being transported, and to the effects of twisting.

Thus, the Applicant company manufactures and sells hoses designed to withstand high pressures, greater than 100 bars and possibly as great as 500 bars to 1000 bars, and comprising an internal leakproof sheath, "traction" armoring constituted by at least two crossed layers of wires of simple shape in section, generally being rectangular or circular in section, and between the internal leakproof layer and the traction armoring, armoring for withstanding pressure, referred to as a "pressure layer", and comprising one or more layers of metal wires that are spiral-wound at an angle that is close to 90° relative to the axis of the flexible hose, the traction armoring being covered by an outer protective sheath.

In practice, the angle at which the pressure layer is spiral-wound is greater than 80° relative to the axis of the flexible hose so as to give the pressure layer maximum strength against the circumferential component of the forces generated by the pressure inside the hose (hoop stress).

Various configurations for such pressure layers have already been described, in particular in document WO-91/00467.

That prior document discloses, in particular, a pressure layer configuration constituted by a helical winding of at least one pair of interlockable metal section wires, one of the section wires having a so-called "T-shaped" section while the other section wire has a so-called "U-shaped" section, with the wires being organized and dimensioned so that on being wound they provide lateral interlocking between turns, i.e. they put a limit on the extent to which the turns can move apart laterally in the direction of the axis of the flexible hose.

A T-section wire can be defined as having a base portion provided at its lateral extremities with ribs projecting from the base portion, and the section also has a central rib projecting from the base portion with the end thereof being located at a greater distance from the base portion than are the ends of the lateral ribs.

The U-section wire comprises a base portion provided at its lateral extremities with ribs that project from the base portion.

In the configurations known from the above-mentioned prior document in which the pressure layer is made by spiral-winding and interlocking section wires where one has a T-shaped section and the other has a U-shaped section, the U-section wire is large in thickness and in section.

According to that prior document, the U-section wire can be disposed either with its ribs facing outwards or else with its ribs facing inwards.

As a result of experimental work, the Applicant company has found firstly that in dynamic applications, i.e. when the flexible hose is subjected to alternating bending deformation, such a flexible hose presents very disappointing performance if it has a pressure layer constituted by an inner layer of U-section wire and an outer layer of T-section wire, so that the U-section wire has ribs that are outwardly directed. It has been observed that, in practice, once the hose is in the assembled state, there always exists contact between the T- and U-section wires constituting the pressure layer and that this continues throughout the time the hose is in use, with the mutual thrust forces between the projecting portions of the section wires being large.

It has been observed that in use, the friction generated by such contact, associated with the large thrust forces, gives rise to a reduction in lifetime due to cracking phenomena that appear in the section wires and due to the reduction of the section thereof.

On deciding to make the inner layer out of T-section wire with the ribs of the U-section wire being inwardly directed, it has been found that, in practice, it is not possible to prevent radial contact taking place between the T-section wire and the U-section wire, and that the U-section wire contributes significantly to the resistance against the circumferential component of the pressure forces. Under such conditions, the thrust forces between the T-section wire and the U-section wire run the risk of remaining excessively great.

A first prototype was made with the ribs of the U-section wire directed inwardly and with modification to the dimensional characteristics of the T- and U-section wires. Fatigue testing on the prototype under dynamic conditions and under pressure, terminated prematurely because the U-section wire broke.

The present invention relies, in particular, on the discovery made when studying the broken U-section wire, that the U-section wire is subjected to bending moments of greater or lesser extent caused by the friction forces which are associated with the radial thrust forces between the T-section wire and the U-section wire.

The present invention proposes to provide a flexible hose that includes a pressure layer with a T-section wire and a U-section wire and that does not present the drawbacks of known structures of the same type.

According to the present invention, there is provided a flexible hose, in particular for transporting fluids under pressure, the hose comprising an internal leakproof sheath, traction armoring constituted by at least two crossed layers of wires, pressure-withstanding armoring referred to as a "pressure layer" and constituted by helically winding at least one pair of interlockable metal section wires at an angle close to 90° relative to the axis of the flexible tubular hose, one of the section wires having a T-shaped section including a base portion provided with projecting ribs at its lateral extremities and a projecting central rib whose end is further from the base portion than are the ends of the lateral ribs, the other section wire having a U-shaped section comprising a base portion having projecting ribs at its lateral extremities, and an outer protective sheath, the ribs of the T-section wire being directed towards the outside of the flexible hose and the ribs of the U-section wire being directed towards the axis of the flexible hose, wherein the area of the right section of the T-section wire is substantially greater than the area of the right section of the U-section wire, and in each lateral interlock zone constituted firstly by a lateral rib of the U-section wire engaged in a lateral groove of the T-section wire, and secondly by a lateral rib of the T-section wire facing the base portion of the U-section wire between the two ribs of said U-section wire, there is both contact between the lateral rib of a first of the two section wires and the second section wire, and radial clearance between the lateral rib of the second section wire and the first section wire.

Preferably, the first section wire is the T-section wire, the two lateral ribs of said section wire being in contact with the facing surface of the base portion of the U-section wire which constitutes the preferably flat wide bottom of the groove situated between the lateral ribs of said U-section wire, and the two lateral ribs of the U-section wire being at a distance from the corresponding grooves of the T-section wire, leaving a certain amount of radial clearance.

The ratio of said areas of the right sections of the T- and U-section wires, respectively, is advantageously greater than or equal to 2 and preferably greater than or equal to 3. In the advantageous case of steel wires, particularly advantageous results have been obtained with a ratio lying in the range 4 to 5 and with a total thickness for the T-section wire lying in the range about 12 mm to about 18 mm corresponding to typical applications.

The thickness of the T-section wire may be smaller, but it is preferably greater than or equal to 5 mm. In which case, the section of the U-section wire is reduced to a minimum, while nevertheless preferably remaining not less than 1 mm.

For greater wire thicknesses, it is advantageous to keep the thickness of the base portion of the U-section wire to a value that is relatively small, e.g. of the order of 1.5 mm to 3 mm, so that the ratio of said areas can exceed the above-mentioned value of 5.

Because of the respective disposition provided by the invention for the T- and U-section wires, this characteristic is advantageous insofar as it is the T-section wire which is called on to withstand the major portion of the circumferential component of the forces generated by the pressure inside the hose.

The geometrical shapes of the T-section wire and of the U-section wire are such, that in right section, they present circumferential outside surfaces facing inwards and outwards that are substantially parallel to the axis of the flexible hose. I.e., in longitudinal section through the pressure layer, the inner base of the T-section wire and the outer edge of its central rib, and also the outer face of the U-section wire and the inner face thereof constituting a wide groove between the ribs are in the form of straight lines parallel to the axis of the flexible hose.

Since the flexible hose is made in such a way that the two lateral ribs of a first wire, preferably the T-section wire, are in contact with the corresponding groove(s) of the second section wire, preferably the internal base of the U-section wire, there exists initial radial clearance that is equal in practice to not less than 0.1 mm between the lateral ribs of the second section wire and the corresponding groove of the first section wire. This initial radial clearance is preferably greater than or equal to 0.2 mm, and in common practice may be about 3% to 5% of the thickness of the T-section wire.

Under such conditions, when the flexible hose is put into service and is filled with fluid under pressure, the resistance of the pressure layer to the circumferential component of forces due to the pressure, taking account of the role played by the traction armoring, is shared between the T-section wire and the U-section wire. When the materials of the section wires have the same Young's modulus, the circumferential component is shared approximately as a function of the respective areas of the right sections of the two section wires. As a result, in the initial situation of the flexible hose being put into service, there exists a radial thrust force between the ribs of the first section wire and the facing grooves of the second section wire. When the flexible hose is used under dynamic conditions, the curvature of the hose varies over time, normally at the period of the swell, and there results relative displacement between the two section wires in the lateral direction of the wires, i.e. in the axial direction of the flexible hose. The radial thrust force thus gives rise to a state of alternating stresses of relatively low level that combine with the static traction stress extending lengthwise in the wire and of relatively high value corresponding to withstanding the circumferential component of the pressure. It is not obvious, a priori, that the fatigue state created in this way is compatible with the lifetime required in the intended applications, e.g. 20 years. Also, the thrust force generates friction and causes progressive wear of the surface of one or both of the wires in contact.

According to the present invention, the section area of the T-section wire is the greater, and it is preferably several times greater than the area of the U-section wire. As a result, the portions of the circumferential force and of the radial thrust force absorbed by the U-section wire are relatively small, as a function of the ratio of the section areas of the two wires.

The progressive wear of the surfaces of the two thrust-together wires causes the winding radius of the

T-section wire to increase slightly and causes the winding radius of the U-section wire to reduce slightly, while simultaneously causing the inertial axes of the two wires to move towards each other.

As the wires wear, it has been found that the portion of the circumferential force taken up by the T-section wire increases progressively, with the contribution of the U-section wire decreasing proportionally more quickly and, in numerous cases, being replaced at the end of a certain length of time by a small compression force. Correspondingly, the radial thrust force between the wires decreases together with the circumferential force in the U-section wire. The discovery of this favorable property has played an essential role in evaluating the advantages provided by the invention.

Another consequence of the wear on contact between the rib of the first section wire and the corresponding groove of the second section wire is that compared with its initial value, the radial clearance between the rib of the second section wire, preferably the U-section wire, and the groove of the second section wire, decreases progressively.

According to the present invention, this radial clearance, i.e. the radial clearance of the second rib, must remain throughout the entire time the flexible hose is in use. It has been found that if, because of initial clearance that is insufficient compared with the possible amount of wear, a second radial thrust appears after a certain length of time between the rib of the second wire and the corresponding groove of the first wire, then this gives rise rapidly to breakage in the U-section wire. This has been attributed to a combination firstly of the situation in which the U-section wire then finds itself in four-point contact against two adjacent turns of the T-section wire, the two ribs of the U-section wire and a lateral rib of each of the two T-section wires being in contact, and secondly of the existence of a bending moment in the U-section wire which has been discovered elsewhere and which is attributed to the alternating transverse compression/traction stresses created in the inside wall and at the end of the rib of the U-section wire by the friction forces at the contact with the facing surfaces of the T-section wire. However, when the initial value of the radial clearance of the second rib is great enough for the radial clearance to remain without contact throughout the lifetime of the flexible hose, it has been found that the U-section wire is not subject to breakage.

In a first embodiment, the characteristics of the T-section wire and of the U-section wire are selected so that the flexible hose has two successive operating stages.

During an initial stage there exists contact with a thrust force acting between the T-section wire and the U-section wire, and a fraction of the circumferential forces is taken up by the U-section wire with contact pressure between the two section wires.

This contact gives rise to friction and to initial wear which continues for as long as a certain amount of thrust force exists between the T- and U-section wires, in spite of the thickness of the two contacting bearing surfaces beginning to be reduced.

Work performed by the Applicant company has shown that given the variation in the stresses and the deformations associated with dynamic effects, essentially the action of swell, the wear reaches a final and maximum amplitude that is small, being of the order of a few tenths of a millimeter. Given the dimensions of the section wires and in particular of the T-section wire which is of large section, the resulting reduction in the area of the section is extremely small and quite negligible in practice.

During a second operating stage, the T-section wire and the U-section wire remain approximately in contact, but the thrust force becomes extremely small, and even practically negligible. More precisely, the thrust force remains equal to the level below which there can be no further wear.

The section wires are thus no longer subject to wear and a considerable increase in lifetime is observed compared with previously known structures, including those in which a T-section wire is associated with a U-section wire.

According to the invention, since the sections of the wires are stabilized at values very close to their initial values, and since the thrust forces between the section wires disappear after a thin surface film has been regularly worn away, it can be observed that the pressure layer shows no beginning of cracking.

In a second embodiment, although the thrust force decreases continuously, it remains sufficient for wear to continue throughout the lifetime of the flexible hose, with the rate of wear decreasing simultaneously with decreasing thrust force, and thus becoming smaller and smaller. It has been found that the final wear is little, as is the first embodiment, and is likewise a few tenths of a millimeter, such that, in particular, the radial clearance of the second rib remains without contact, even when wear in the thick wire reaches about one millimeter.

Outside the pressure layer constituted by the T- and U-section wires, there is the traction armoring, an intermediate layer of polymer material optionally and advantageously being disposed between the pressure layer and the traction armoring. In conventional manner, the traction armoring exerts a compression force on the underlying pressure layer, and that force must be taken into account when evaluating the forces applied to the T-and U-section wires, and also when evaluating the contact forces between the T-section wire and the U-section wire.

The T- and U-section wires are preferably dimensioned in such a manner that, when in the wound state, each section wire has two contact points on the wire of complementary shape, and each turn of the wire is thus in single contact with each of the two adjacent turns, the cylindrical outside surface of the U-section wire having a diameter that is equal to or slightly less than that of the T-section wire.

The pressure layer of the invention can, where appropriate, also include an additional pressure layer placed thereon and constituted by a non-interlocking wire that is spiral-wound at a large angle, with the traction armoring being disposed outside the additional pressure layer. Preferably, the non-interlocking wire is of rectangular section with rounded corners, and is wound in the opposite direction to the section wires of the pressure layer, the outside surface of the U-section wire being slightly offset from the end face of the central rib of the T-section wire. An intermediate plastics sheath may optionally be disposed between the pressure layer and the additional pressure layer of non-interlocking wires.

The present invention is applicable to making smooth bore type flexible hoses, i.e. hoses in which the internal leakproof sheath is the innermost layer of the hose and the fluid to be transported circulates in contact therewith, and also rough bore type hoses which include, inside the leakproof sheath, a flexible metal lining such as a structure of the interlocking metal tape type.

The present invention has remarkable advantages:

1) Mechanical performance that is considerably better than that of prior art flexible hoses, in particular in terms of lifetime. The effects of fatigue

and of wear are extremely small, and cracking phenomena have disappeared.

2) In severe dynamic applications, the mean stress in the section of the section wire can reach a value that is close to, or in the limit equal to, the maximum acceptable stress in a static application, without there being any need to increase the section of the wire and decrease the stress, as can be necessary with prior art wires in order to compensate for the effects of wear, of fatigue, and of stress concentration.

3) The T- and U-section wires are easier to manufacture without any risk of degrading the metal, in particular because of the section wires are formed. In addition, taking account of the manufacturing means available in the industry, it is possible in practice to make section wires of greater thickness and sectional area.

4) The operation of manufacturing the hose by spiral-winding the section wires of the pressure layer is made easy. The T-section wire can be wound in the same manner as the non-interlocking wire of an additional pressure layer. This operation is relatively easy, while the U-section wire forming the interlocking is laid over the T-section wire under tension, rather like a single tape.

In the present description, it is mentioned that the pressure layer is constituted by a T-section wire and a U-section wire in order to simplify the description. Clearly the pressure layer of the invention could, in conventional manner, and like the additional pressure layer, be made up of a plurality of T-section wires disposed in adjacent turns, together with a plurality of U-section wires in number equal to the number of T-section wires. Advantageously, the pressure layer has two T-section wires and two U-section wires, with the winding pitch then being twice that of a layer made up of a single T-section wire and a single U-section wire having the same section dimensions. Such a structure makes it possible to double the speed of winding and to facilitate balance in the winding machine, and also to halve the size of the empty space between two adjacent T-section wires.

Other advantages and characteristics of the invention appear on reading the following description of a non-limiting embodiment given with reference to the accompanying drawings, in which:

• Figure 1 is a diagrammatic view of an embodiment of a flexible hose of the invention;

• Figure 2 shows an embodiment of the pressure layer of the Figure 1 hose;

• Figures 3 and 4 are detail views showing possible configurations for the components of the pressure layer of the flexible hose of the invention; and

• Figures 5A and 5B show variant embodiments with an additional pressure layer, while Figure 6 is a detail view of a variant embodiment.

The flexible hose shown in Figure 1 is of the smooth bore type and comprises, going from the inside towards the outside: a leakproof sheath of plastics material 1, in particular of polyamine, of fluoropolymer, or of cross-linked polyethylene; a pressure layer 2 whose structure is described in greater detail below and which is formed by spiral winding two section wires, a T-section wire 3 and a U-section wire 4; traction armoring constituted by two crossed layers of metal wires 5 and 6; and an outer leakproof sheath of plastics material 7. An intermediate sheath (not shown) may optionally be provided between the pressure layer 2 and the first layer 5 of traction armoring.

In a variant (not shown), the pressure layer 2 may comprise two T-section wires and two U-section wires, with the pitch of the coils formed by the section wires then being twice as great.

The invention is not limited to such a smooth-bore type hose, and it can be implemented with a rough-bore type hose, containing inside the sheath 1 a helically wound interlocking steel tape layer.

Reference is now made to Figure 2 which shows an embodiment of the pressure layer 2 formed by spiral winding T-section and U-section wires 3 and 4 respectively with non-touching turns.

The T-section wire 3 has a base portion 8 of substantially rectangular section including ribs 9 at its lateral extremities and a central rib 10 of substantially symmetrical trapezoidal section.

Between each of the lateral ribs 9 and the central ribs 10 there is formed a groove whose bottom wall is constituted by the surface 11 of the base portion 8.

The section wire 3 is wound in the disposition shown so that the ribs 9 and 10 project outwards from the flexible hose, i.e. radially away from the longitudinal axis of the hose, as shown in Figure 2.

The section wire 4 has a base portion 2 with ribs 13 formed at the lateral extremities thereof. These ribs 13 extend towards the longitudinal axis of the hose.

As can be seen in Figure 2, the lateral flanks of the central ribs 10 of the T-section wire 3 and the outer flanks of the ribs 13 of the U-section wire 4 are inclined at the same angle α relative to a plane perpendicular to the axis of the flexible hose, said angle α lying in practice in the range 0° to 30°.

The lateral flanks at the extremities of the base portion 8 of the T-section wire 3 may advantageously extend perpendicularly to the axis of the flexible hose, as shown in Figure 2, or they may form an angle β therewith, where β is less than 10° in practice, as shown in the variant of Figure 3.

In the right section of the wire, these lateral flanks may be rectilinear as shown, or where appropriate they may be slightly curved, as shown in Figures 5A and 5B.

As shown in particular in Figure 2, and by choosing particular dimensions, it is possible to ensure that while the pressure layer is being made, contact is provided between the lateral ribs 9 of the T-section wire 3 with the U-section wire 4, and more specifically with the surface 14 of the base portion of the U-section wire which constitutes the wide and preferably flat bottom of the groove formed between the lateral ribs 13 thereof.

As explained above, the thrust forces at the location of the surfaces in contact are intended to disappear more or less quickly in use. In some cases, when the thrust forces at the beginning of the hose being put being into operation are particularly small, it can happen that only progressive reduction of the thrust forces, and consequently of the wear rates, takes place without there being any transition to a second stage with extremely low thrust forces that are clearly different from the first stage in which the thrust forces are relatively greater.

In Figure 2, the following references are used:

A: the height of the T-section 3 as determined by the distance between the bottom face of the base portion 8 and the top end face of the central rib 10;

B: the width of the T-section 3;

C: the width at the top of the lateral ribs 9 of the T-section 3, assuming that this bearing surface is cylindrical, given that in the embodiment shown in Figure 4 it could be curved, being characterized by an osculating circle of radius R;

D: the width of the base portion of the U-section 4;

E: the thickness of the U-section 4, in its central portion constituted by the groove 14;

F: the height of the lateral ribs 9 of the T-section 3, measured from the bottom face of its base portion 8;

G: the height of the lateral ribs 13 of the U-section 4, measured from the surfaced at the bottom of the groove 14;

H: the width of the top of the central rib of the T-section 3;

I: the width of the bottom surface of the groove 14 of the U-section 4;

J: the width of the lateral ribs 9 of the T-section wire 3;

K: the height of the base portion 8 of the T-section wire 3, i.e. the distance between the bottom face of the base portion and the surfaces 11 of the bottom portions of the lateral grooves of the T-section wire, and preferably the ratio of K and A is such that K/A is equal to or greater than 0.4, and advantageously equal to or greater than 0.5;

L: the width of the substantially plane central portion of the base surface of the T-section wire 4, facing towards the axis X; and

M: the height of the lateral ribs 9 of the T-section wire 3.

c is the gap between the ribs 13 of the U-section wire 4 and the surfaces 11 at the bottoms of the grooves of the T-section wire 3.

This gap constitutes the radial clearance between the lateral ribs of the first wire, in this case advantageously the T-section wire, and the corresponding groove of the second wire, in this case the U-section wire, with the initial value of this radial clearance being of the order of one or a few tenths of a millimeter.

It is thus possible by calculation and/or by testing a model or a prototype to determine for each application the dimensions of the T- and U-section wires, and in particular the gap c, in such a manner that the radial clearance of the first rib, i.e. of the lateral ribs of the first wire, remains throughout the design lifetime.

The thickness of the pressure layer 2 is preferably determined by the thickness A in the central portion of the T-section wire 3. This value may typically correspond likewise to the sum of the values E and F plus, where appropriate, the distance a in the variant corresponding to Figure 6, with the sum being equal to the value A.

Figure 6 shows the case where the U-section wire is the first wire such that its lateral ribs bear against the corresponding grooves of the T-section wire which constitutes the second wire.

Theoretically, this variant of Figure 6 is less advantageous than the variant of Figure 2, insofar as it implies increasing the alternating bending stresses, thereby generating fatigue effects in the U-section wire.

In the variant embodiment shown in Figure 4, a distance b is provided between the end face of the central rib 10 of the T-section wire 3 and the outside surface of the base portion of the U-section wire 4.

In practice the distance b may be of the order of a few tenths of a millimeter.

The variant shown in Figure 5 is particularly advantageous when the flexible hose includes, around its pressure layer 2, a layer of non-interlocking wires constituting an additional pressure layer.

Such a variant with an additional pressure layer, referred to as "banding" is shown in Figures 5A and 5B. The ferrule wire 15 is spiral-wound in the opposite direction to the T-section wires 3 and the U-section wires 4 of the pressure layer. Lengthwise, the U-section wire 4 may be covered either by two wires 15A and 15B of the banding when two parallel wires are spiral-wound, or else by two adjacent turns 15A and 15B of the banding wire when a single wire is spiral-wound, as shown in Figure 5A, or else by a wire such as 15B, as shown in Figure 5B. In particular, in the situation illustrated in Figure 5B, it has been found that a small value for the radial distance <u>b</u> is sufficient to prevent the banding wire, such as 15B in Figure 5B, from bearing against the U-section wire 4, and to increase the thrust force between the U-section wire and the T-section wire, which would have damaging consequences for the strength and the lifetime of the pressure layer.

The heights G and M are each preferably greater than or equal to 0.5 mm, and in particular greater than 1 mm.

The width C is preferably greater than or equal to 1 mm, and may typically be 2 mm to 3 mm.

In the embodiment of Figure 3, the radius R is preferably greater than or equal to 0.5 mm, and in particular greater than or equal to 1 mm.

The ratio of A to B preferably lies in the range 1.25 to 2, and in particular in the range 1.45 to 1.65.

In the axial direction of the flexible hose, the following preferably apply:

$D + H \leq B$, and

$I -$ [illegible] < 5 mm and preferably less than 2.55,

and preferably $1.2 \text{ mm} \leq B - L \leq 2.5$ mm.

Preferably, since the inside surface 14 of the groove of the U-section wire 4 is plane, the height of the U-section wire 4 in its central portion is greater than or equal to 1 mm, advantageously greater than or equal to 2 mm, with advantageous results being obtained for a height lying in the range 2 mm to 3 mm.

<u>**Examples of prototypes tested**</u>

	Examples of the invention		Comparative example
	Prototype 1	Prototype 2	Prototype 3
<u>**Flexible hose**</u>			
Inside diameter	6" (152.4 mm)	10" (254 mm)	6" (152.4 mm)
Maximum internal pressure	370 bars	425 bars	281 bars

Pressure layer

T-section wire

- Height A	14 mm	14 mm	10 mm
- Weight B	25 mm	25 mm	19.4 mm
- Height of ribs F	11 mm	11 mm	8 mm
- Material	Carbon steel R_m = 722 MPa	Carbon steel R_m = 850 MPa	Carbon steel R_m = 877 MPa HV hardness (20 kg) = 270 to 320

U-section wire

- Central height E	2.9 mm	2.3 mm	1.8 mm
- Width D	17.8 mm	17.6 mm	13.2 mm
- Height of ribs G	1.9 mm	1.9 mm	2.5 mm
- Material	Carbon steel R_m = 860 MPa	Carbon steel R_m = 860 MPa	Carbon steel HV hardness (20 kg) = 90 to 120

Radial clearances

1) Radial thrust between lateral ribs of T-section wire and central bearing surface of U-section wire

2) Radial clearance c between ribs of U-section wire and grooves of T-section wire	0.3 mm to 0.5 mm	0.3 mm to 0.5 mm	0
3) Offset b of the central rib of the T-section wire relative to the outside surface of the U-section wire	nominal = 0.1 mm real = 0.2 mm (tolerances on wire dimensions, U-section wire projecting slightly)	nominal = 0.7 mm real = 0.4 mm	0.2 mm

<u>Additional pressure layer</u>			
Wire thickness	None	7.5 mm	None

<u>Test results</u>

<u>Prototype 1</u>

- Internal pressure maintained at 369 bars.
- Axial traction equal to 793 kN.
- Dynamic conditions (angular offsets imposed on hose, varying cyclically) corresponding to typical conditions for the North Sea (very severe) for 20 years.

  The flexible hose withstood a number of cycles corresponding to a lifetime of 20 years.

  Examination of the wires shows a small amount of wear, that was regular and without cracking.

<u>Prototype 2</u>

- Internal pressure maintained at 425 bars.
- Axial traction equal to 800 kN.
- As for Prototype 1, dynamic conditions corresponding to the North Sea over a period of 20 years.

  Excellent results, confirmed by examination of the wires, as for Prototype 1.

<u>Prototype 3</u>

- Internal pressure = 277 bars.
- Axial traction = 850 kN.
- Dynamic conditions corresponding, as for the other two prototypes, to the North Sea over a duration of 20 years.

  The T-section wire broke shortly before the end of the 20-year design limit, giving rise to a leak and making the flexible hose unusable.

The unsatisfactory result of Prototype 3 can be explained by the fact that contact took place in two locations in each overlap zone, both on the ribs of the U-section wire and on the ribs of the T-section wire, with this being made worse by the fact that the steel of the U-section wire was much too soft relative to the T-section wire.

In general, the T- and U-section wires can be made of any kind of metal, steel or other metals, that are suitable for use as flexible hose reinforcement. In particular, it is possible to use the same metal for both wires, using the same grade, or grades that are similar.

In the typical case of carbon steel wires, the ultimate tensile strength Rm of the U-section wire is preferably greater than a value equal to the ultimate tensile strength Rm of the T-section wire minus 200 MPa:

$$Rm_U \geq Rm_T - 200 \text{ MPa}$$

and advantageously 100 MPa to 200 MPa greater than the value Rm of the T-section wire:

$$Rm_U = Rm_T + (100 \text{ to } 200)\text{MPa}$$

Although the invention is described above with reference to particular embodiments, it is clearly not limited in any way thereto and diverse variants and modifications may be applied thereto without thereby going beyond its ambit as defined by the claims.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or group of integers or steps but not the exclusion of any other integer or group of integers or steps.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A flexible hose, in particular for transporting fluids under pressure, the hose comprising an internal leakproof sheath, traction armoring constituted by at least two crossed layers of wires, pressure-withstanding armoring referred to as a "pressure layer" and constituted by helically winding at least one pair of interlockable metal section wires at an angle close to 90° relative to the axis of the flexible tubular hose, one of the section wires having a T-shaped section including a base portion provided with projecting ribs at its lateral extremities and a projecting central rib whose end is further from the base portion than are the ends of the lateral ribs, the other section wire having a U-shaped section comprising a base portion having projecting ribs at its lateral extremities, and an outer protective sheath, the ribs of the T-section wire being directed towards the outside of the flexible hose and the ribs of the U-section wire being directed towards the axis of the flexible hose, wherein the area of the right section of the T-section wire is substantially greater than the area of the right section of the U-section wire, and in each lateral interlock zone constituted firstly by a lateral rib of the U-section wire engaged in a lateral groove of the T-section wire, and secondly by a lateral rib of the T-section wire facing the base portion of the U-section wire between the two ribs of said U-section wire, there is both contact between the lateral rib of a first of the two section wires and the second section wire, and radial clearance between the lateral rib of the second section wire and the first section wire.

2. A flexible hose according to claim 1, wherein said first section wire is the T-section wire, the two lateral ribs of said wire being in contact with the facing surface of the base portion of the U-section wire which constitutes a wide bottom of the groove situation between the lateral ribs of said U-section wire, and the two lateral ribs of the U-section wire being distant from the corresponding grooves of the T-section wire, with a certain amount of radial clearance.

3. A flexible hose according to claim 2, wherein said wide bottom of the groove of the base portion of the U-section wire is flat.

4. A flexible hose according to claim 1, 2 or 3, wherein the ratio of said areas of the right sections of the section wires is greater than or equal to 2.

5. A flexible hose according to claim 4, wherein the ratio of said areas of the right sections of the section wires is greater than or equal to 3.

6. A flexible hose substantially as hereinbefore described with reference to the drawings and/or Examples, but excluding the comparative Examples.

DATED this TWENTIETH day of APRIL, 1998

COFLEXIP
by DAVIES COLLISON CAVE
Patent Attorneys for the Applicants

A B S T R A C T

A FLEXIBLE HOSE INCLUDING AN INTERLOCKING ARMORING LAYER

A flexible hose, in particular for transporting fluids under pressure, comprising pressure-resisting armoring constituted by winding at least one pair of interlockable metal section wires, one of which has a T-section and the other of which has a U-section, the ribs of the T-section wire being directed towards the outside of the flexible hose and the ribs of the U-section wire being directed towards the axis of the flexible hose. The area of the right section of the T-section wire (3) is substantially greater than the area of the right section of the U-section wire (4), and in each lateral interlock zone constituted firstly by a lateral rib (13) of the U-section wire (4) engaged in a lateral groove of the T-section wire (3), and secondly by a lateral rib (9) of the T-section wire facing the base portion (12) of the U-section wire between the two ribs (13) of said U-section wire, there is both contact between the lateral rib of a first of the two sections and the second section wire, and radial clearance between the lateral rib of the second section wire and the first section wire.

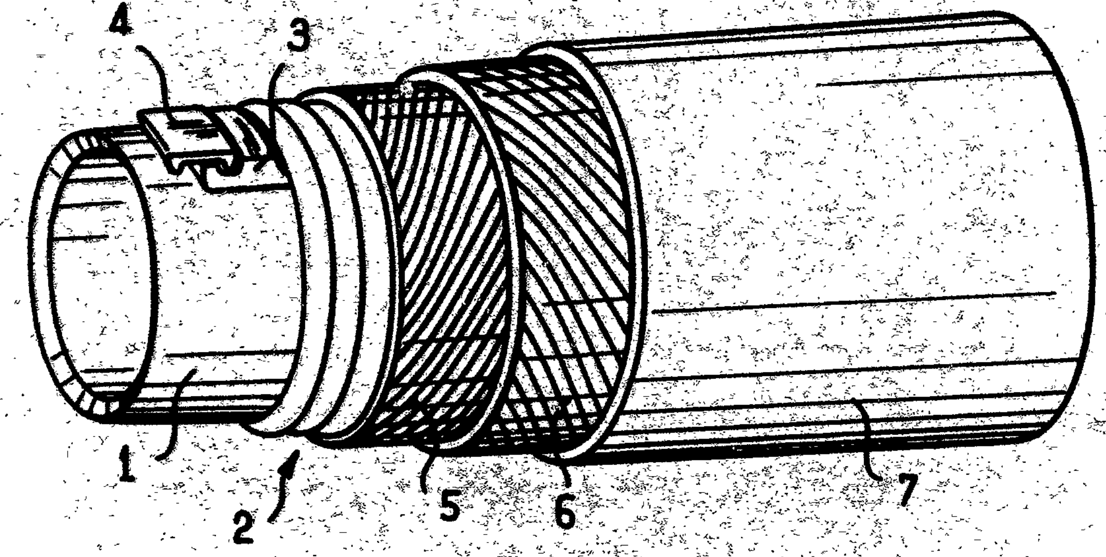


FIG_1

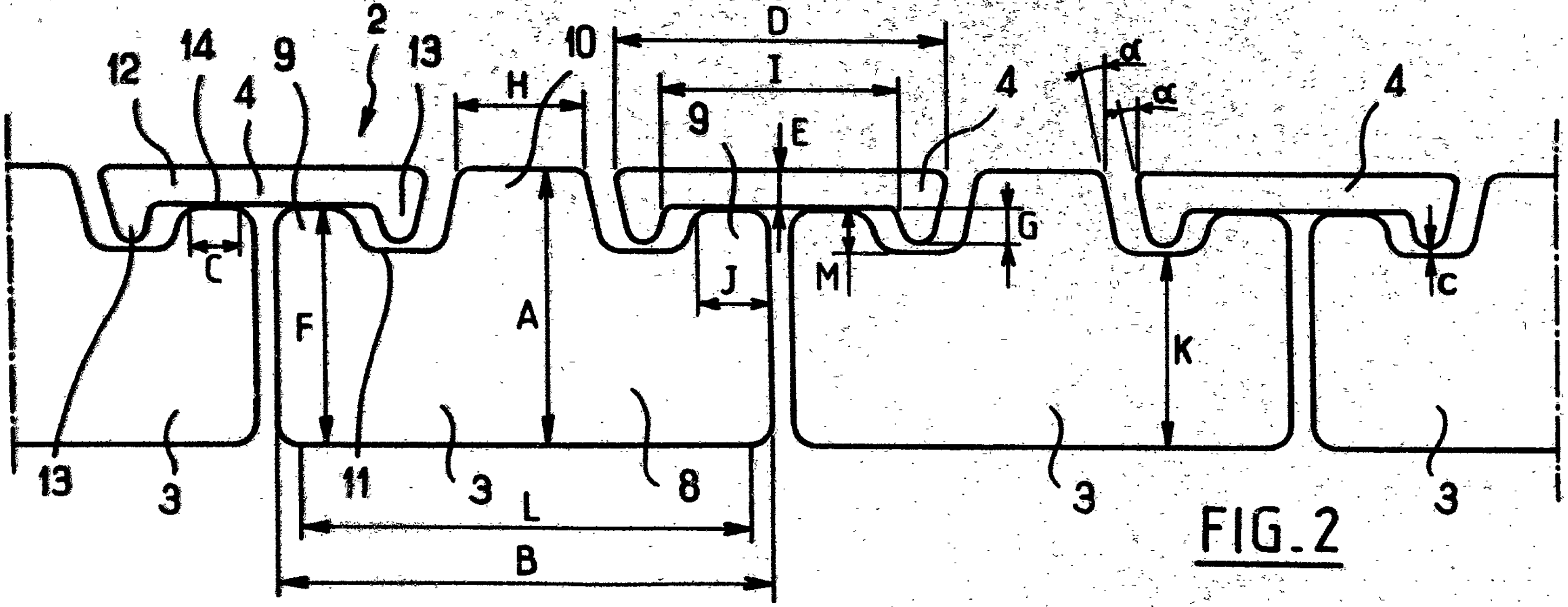


FIG_2

PCT/FR95/01601

4 30 TT |96

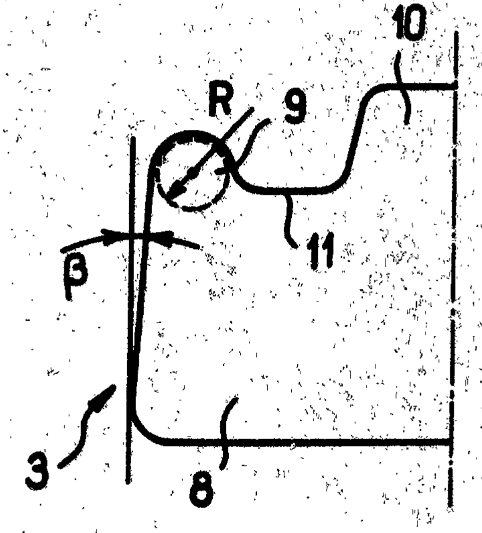


FIG.3

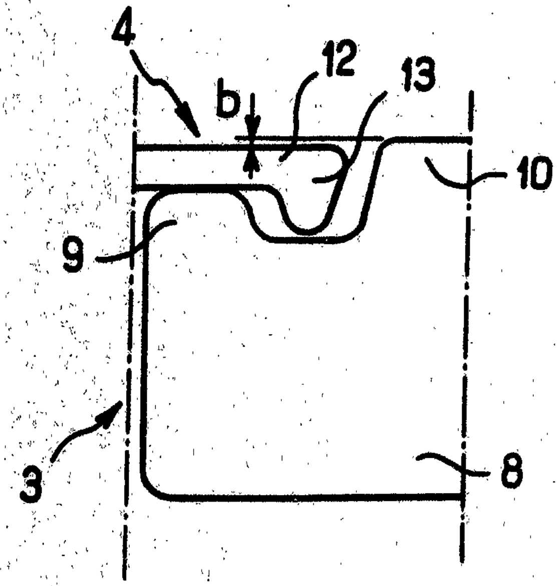


FIG.4

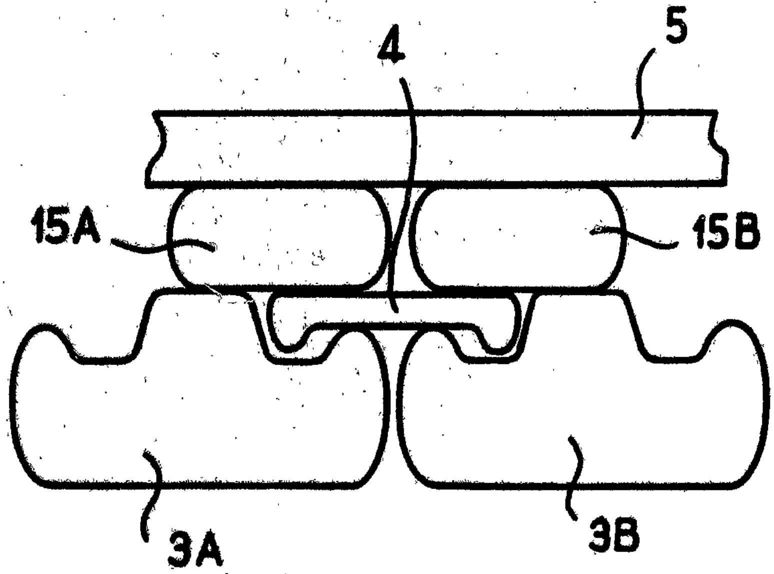


FIG.5A

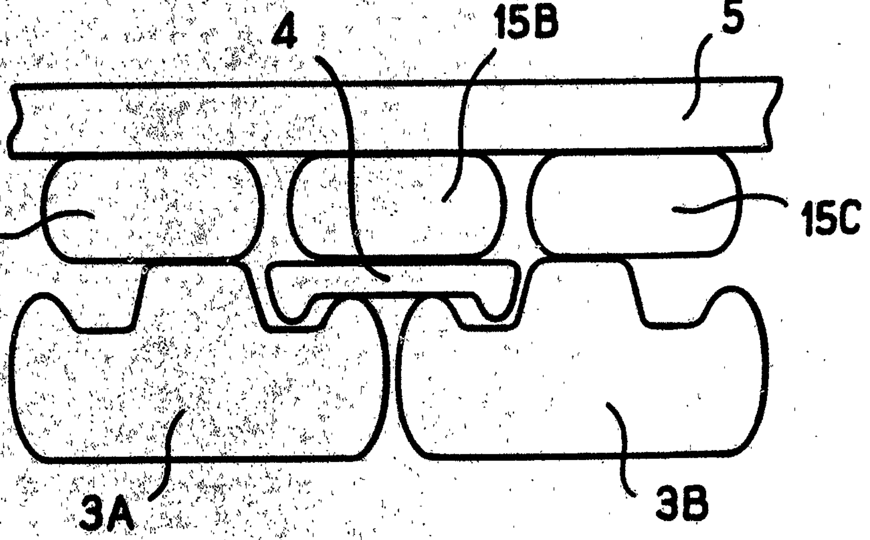


FIG.5B

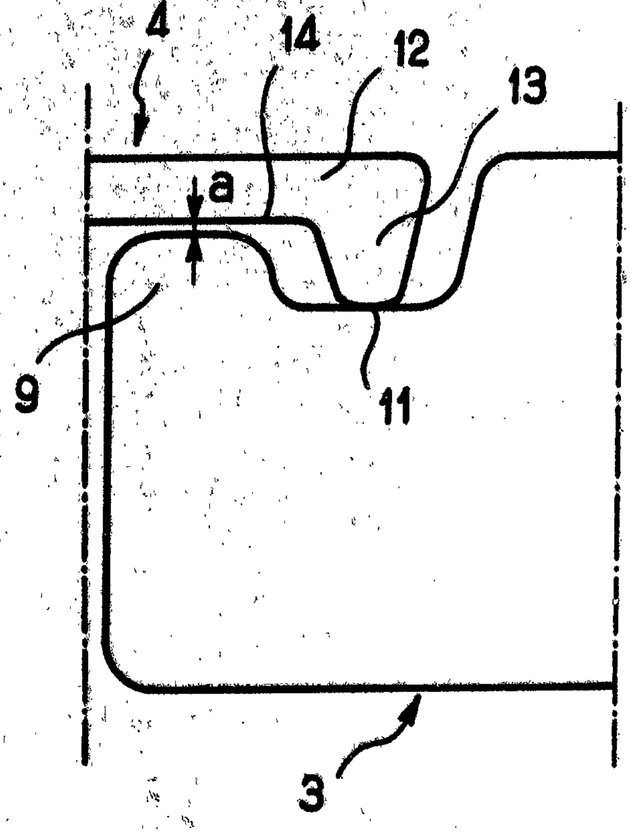


FIG.6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/FR 95/01601

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F16L11/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,91 00467 (INST FRANCAIS DU PETROL ;COFLEXIP (FR)) 10 January 1991 cited in the application see page 10, line 22 - line 24; figure 7 see page 11, line 14 - line 20 ---	1-3
Y	FR,A,2 217 621 (INST FRANCAIS DU PETROL) 6 September 1974 see claim 5; figure 3 ---	1-3
Y	DE,C,43 03 508 (WITZENMANN METALLSCHLAUCHFAB) 24 March 1994 see column 4, line 25 - line 28; figure 5 ---	1-3
A	FR,A,2 561 745 (FURUKAWA ELECTRIC CO LTD) 27 September 1985 see figures --- -/--	1,2

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"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 when the document is taken alone
"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

1

Date of the actual completion of the international search	Date of mailing of the international search report
3 April 1996	18.04.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Cordenier, J

International Application No
PCT/FR 95/01601

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR,A,1 483 914 (GEORGE ANGUS & COMP. LTD.) 9 June 1967 see figure 4 ---	1-3
A	WO,A,92 00481 (COFLEXIP ;INST FRANCAIS DU PETROL (FR)) 9 January 1992 see figures ---	
A	FR,A,1 346 924 (AIR REDUCTION COMP. INC) 20 December 1963 see figure 8 -----	

International Application No
PCT/FR 95/01601

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9100467	10-01-91	FR-A-	2650652	08-02-91
		AU-B-	635292	18-03-93
		AU-B-	5968890	17-01-91
		CA-A-	2027568	31-12-90
		EP-A,B	0431142	12-06-91
		ES-T-	2048497	16-03-94
		JP-T-	5503137	27-05-93
FR-A-2217621	06-09-74	GB-A-	1429104	24-03-76
		NL-A-	7402155	19-08-74
		SE-B-	393849	23-05-77
		US-A-	3908703	30-09-75
DE-C-4303508	24-03-94	NONE		
FR-A-2561745	27-09-85	DE-A-	3409734	26-09-85
		GB-A,B	2156031	02-10-85
		US-A-	4549581	29-10-85
FR-A-1483914	20-09-67	NONE		
WO-A-9200481	09-01-92	FR-A-	2664019	03-01-92
		AU-B-	646477	24-02-94
		AU-B-	8105591	23-01-92
		CA-A-	2064837	30-12-91
		DE-D-	69104331	03-11-94
		DE-T-	69104331	16-03-95
		EP-A-	0489896	17-06-92
		ES-T-	2062803	16-12-94
		JP-T-	5504818	22-07-93
FR-A-1346924	20-03-64	NONE		

RAPPORT DE RECHERCHE INTERNATIONALE

Demande internationale No
PCT/FR 95/01601

A. CLASSEMENT DE L'OBJET DE LA DEMANDE
CIB 6 F16L11/08

Selon la classification internationale des brevets (CIB) ou à la fois selon la classification nationale et la CIB

B. DOMAINES SUR LESQUELS LA RECHERCHE A PORTE

Documentation minimale consultée (système de classification suivi des symboles de classement)
CIB 6 F16L

Documentation consultée autre que la documentation minimale dans la mesure où ces documents relèvent des domaines sur lesquels a porté la recherche

Base de données électronique consultée au cours de la recherche internationale (nom de la base de données, et si cela est réalisable, termes de recherche utilisés)

C. DOCUMENTS CONSIDERES COMME PERTINENTS

Catégorie *	Identification des documents cités, avec, le cas échéant, l'indication des passages pertinents	no. des revendications visées
X	WO,A,91 00467 (INST FRANCAIS DU PETROL ;COFLEXIP (FR)) 10 Janvier 1991 cité dans la demande voir page 10, ligne 22 - ligne 24; figure 7 voir page 11, ligne 14 - ligne 20 ---	1-3
Y	FR,A,2 217 621 (INST FRANCAIS DU PETROL) 6 Septembre 1974 voir revendication 5; figure 3 ---	1-3
Y	DE,C,43 03 508 (WITZENMANN METALLSCHLAUCHFAB) 24 Mars 1994 voir colonne 4, ligne 25 - ligne 28; figure 5 --- -/--	1-3

[X] Voir la suite du cadre C pour la fin de la liste des documents

[X] Les documents de familles de brevets sont indiqués en annexe

* Catégories spéciales de documents cités:

"A" document définissant l'état général de la technique, non considéré comme particulièrement pertinent

"E" document antérieur, mais publié à la date de dépôt international ou après cette date

"L" document pouvant jeter un doute sur une revendication de priorité ou cité pour déterminer la date de publication d'une autre citation ou pour une raison spéciale (telle qu'indiquée)

"O" document se référant à une divulgation orale, à un usage, à une exposition ou tous autres moyens

"P" document publié avant la date de dépôt international, mais postérieurement à la date de priorité revendiquée

"T" document ultérieur publié après la date de dépôt international ou la date de priorité et n'appartenenant pas à l'état de la technique pertinent, mais cité pour comprendre le principe ou la théorie constituant la base de l'invention

"X" document particulièrement pertinent; l'invention revendiquée ne peut être considérée comme nouvelle ou comme impliquant une activité inventive par rapport au document considéré isolément

"Y" document particulièrement pertinent; l'invention revendiquée ne peut être considérée comme impliquant une activité inventive lorsque le document est associé à un ou plusieurs autres documents de même nature, cette combinaison étant évidente pour une personne du métier

"&" document qui fait partie de la même famille de brevets

1

Date à laquelle la recherche internationale a été effectivement achevée	Date d'expédition du présent rapport de recherche internationale
3 Avril 1996	18.04.96

Nom et adresse postale de l'administration chargée de la recherche internationale	Fonctionnaire autorisé
Office Européen des Brevets, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Cordenier, J

Demande internationale No
PCT/FR 95/01601

C.(suite) DOCUMENTS CONSIDERES COMME PERTINENTS

Catégorie °	Identification des documents cités, avec, le cas échéant, l'indication des passages pertinents	no. des revendications visées
A	FR,A,2 561 745 (FURUKAWA ELECTRIC CO LTD) 27 Septembre 1985 voir figures ---	1,2
A	FR,A,1 483 914 (GEORGE ANGUS & COMP. LTD.) 9 Juin 1967 voir figure 4 ---	1-3
A	WO,A,92 00481 (COFLEXIP ;INST FRANCAIS DU PETROL (FR)) 9 Janvier 1992 voir figures ---	
A	FR,A,1 346 924 (AIR REDUCTION COMP. INC) 20 Décembre 1963 voir figure 8 -----	

1

RAPPORT DE RECHERCHE INTERNATIONALE

Renseignements relatifs aux membres de familles de brevets

Demande internationale No
PCT/FR 95/01601

Document brevet cité au rapport de recherche	Date de publication	Membre(s) de la famille de brevet(s)		Date de publication
WO-A-9100467	10-01-91	FR-A-	2650652	08-02-91
		AU-B-	635292	18-03-93
		AU-B-	5968890	17-01-91
		CA-A-	2027568	31-12-90
		EP-A,B	0431142	12-06-91
		ES-T-	2048497	16-03-94
		JP-T-	5503137	27-05-93
FR-A-2217621	06-09-74	GB-A-	1429104	24-03-76
		NL-A-	7402155	19-08-74
		SE-B-	393849	23-05-77
		US-A-	3908703	30-09-75
DE-C-4303508	24-03-94	AUCUN		
FR-A-2561745	27-09-85	DE-A-	3409734	26-09-85
		GB-A,B	2156031	02-10-85
		US-A-	4549581	29-10-85
FR-A-1483914	20-09-67	AUCUN		
WO-A-9200481	09-01-92	FR-A-	2664019	03-01-92
		AU-B-	646477	24-02-94
		AU-B-	8105591	23-01-92
		CA-A-	2064837	30-12-91
		DE-D-	69104331	03-11-94
		DE-T-	69104331	16-03-95
		EP-A-	0489896	17-06-92
		ES-T-	2062803	16-12-94
		JP-T-	5504818	22-07-93
FR-A-1346924	20-03-64	AUCUN		