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(71) Applicant(s)
FMC Corporation

(Incorporated in USA - Delaware)

200 East Randolph Drive, Chicago, Illinois 60601, United States of America

(72) Inventor(s)
Harold Brian Skeels
Christopher Edward Cunningham

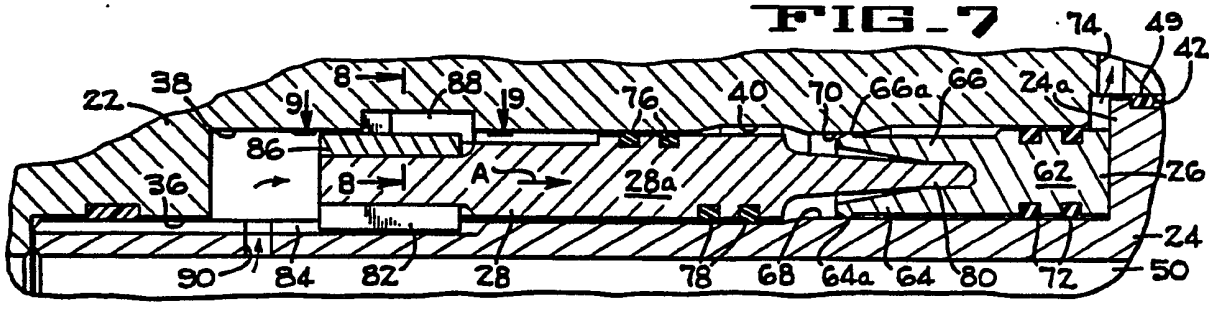
(72)cont
Edmund Marcus Mouret
Donald Michael Underwood
Michael John Krenek

(74) Agent and/or Address for Service
Phillips & Leigh
7 Staple Inn, Holborn, LONDON, WC1V 7QF, United Kingdom

(54) Lockable pipe swivel joint with metal to metal and dynamic seals

(57) The joint, useful with a subsea well completion system to interconnect a subsea wellhead to a lay-away flowline, has a seal element 26 with metallic sealing surfaces 64a, 66a and inner and outer tubular elements 22, 24 also with metallic sealing surfaces 68, 70 that can be moved into or withdrawn from sealing engagement with sealing surfaces 64a, 66a. The tubular elements 22, 24 are locked against relative rotation prior to energisation of seal element 26, by a sleeve 28 axially movable upon element 24 and secured against rotational movement thereon by key 82 and keyway 84. During energisation of seal element 26 by fluid pressure applied to sleeve 28, keys 86 on sleeve 28 engage keys 88 on tubular element 22 to cause said locking. Dynamic seal means 72 are provided between seal element 26 and tubular elements 22, 24 to maintain a fluid seal during axial movement of seal element 26. Alternatively locking may be achieved by external spring-biased pins (112, 114 Fig. 16) engageable in receptacles (126, 128) on one of the joint elements.

FIG_7



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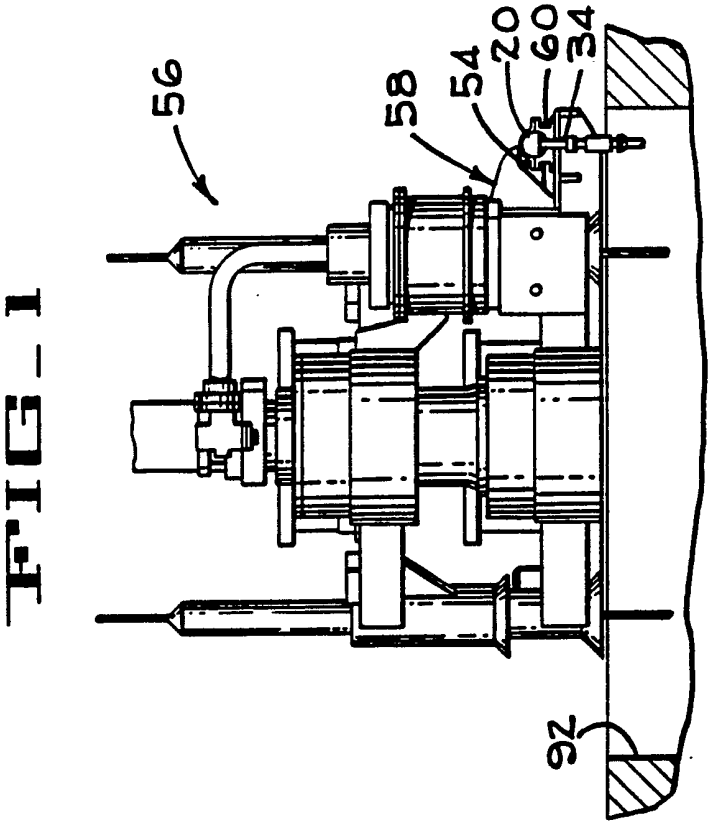

FIG_1

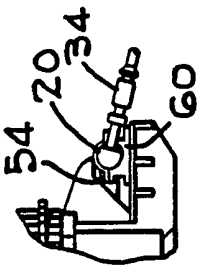

FIG_2

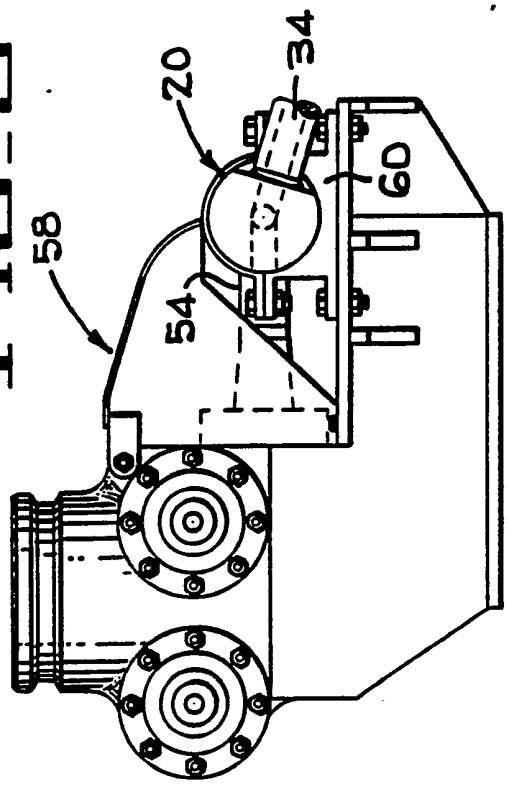

FIG_3

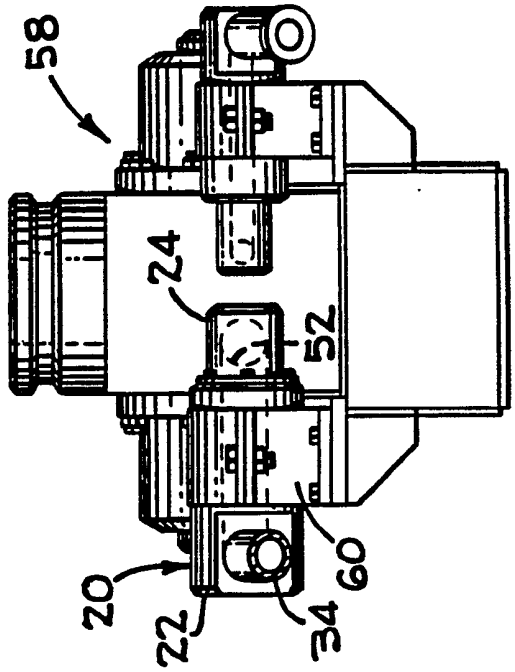

FIG_4

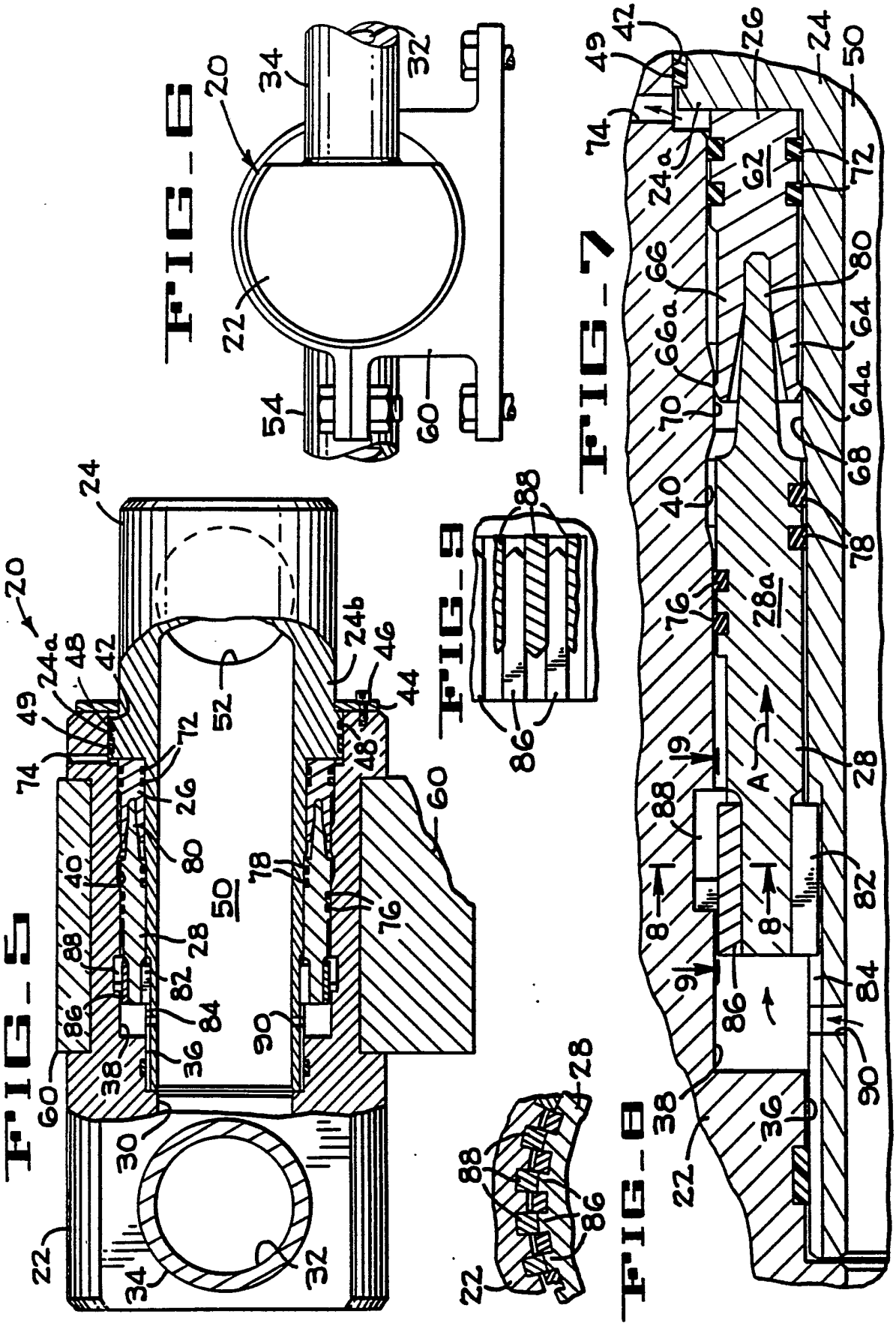
FIG-5
FIG-6
FIG-7
FIG-8
FIG-9

FIG_10

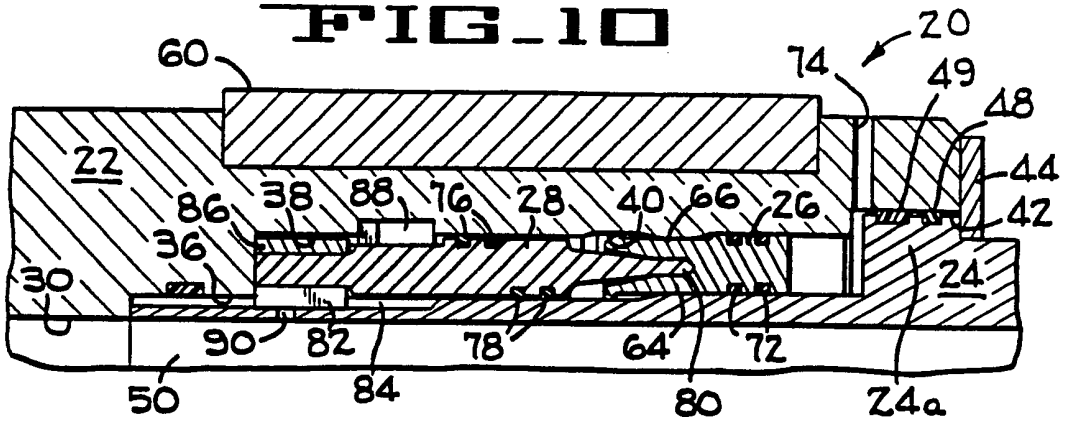

FIG_11

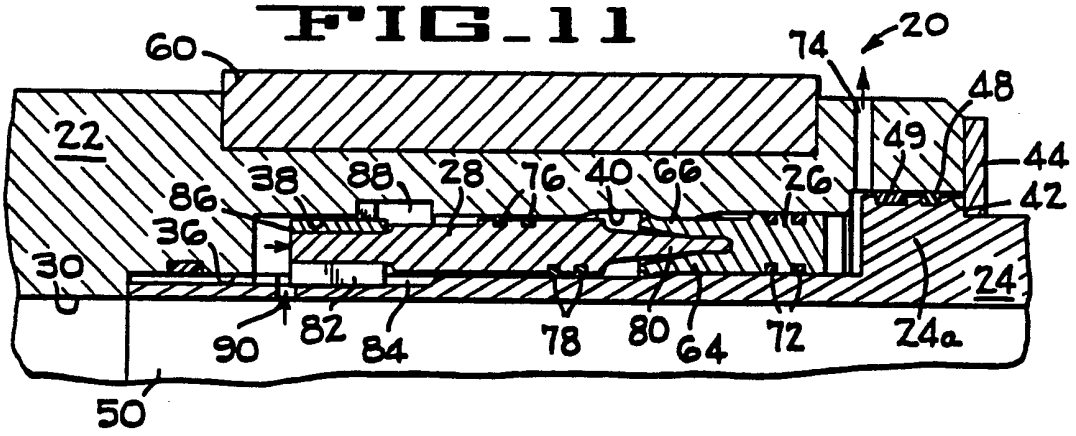

FIG_12

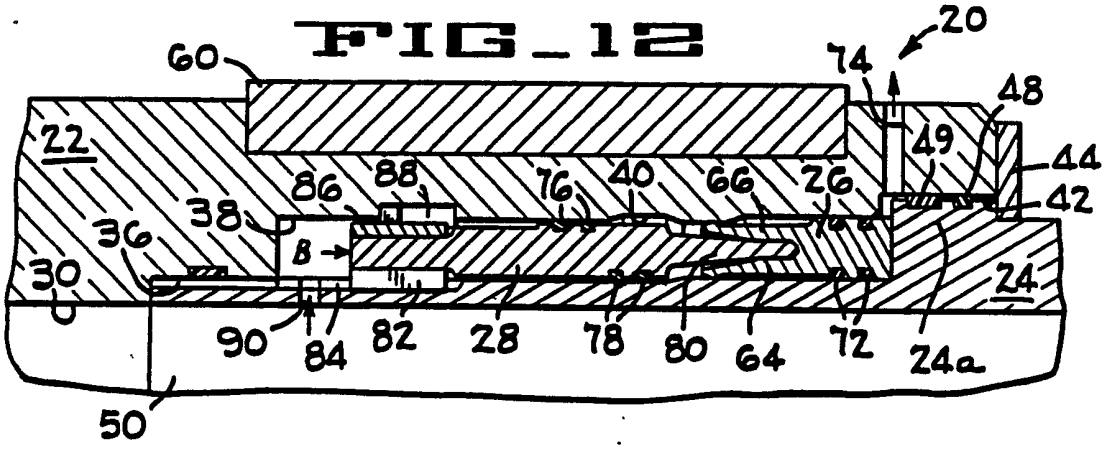

FIG_13

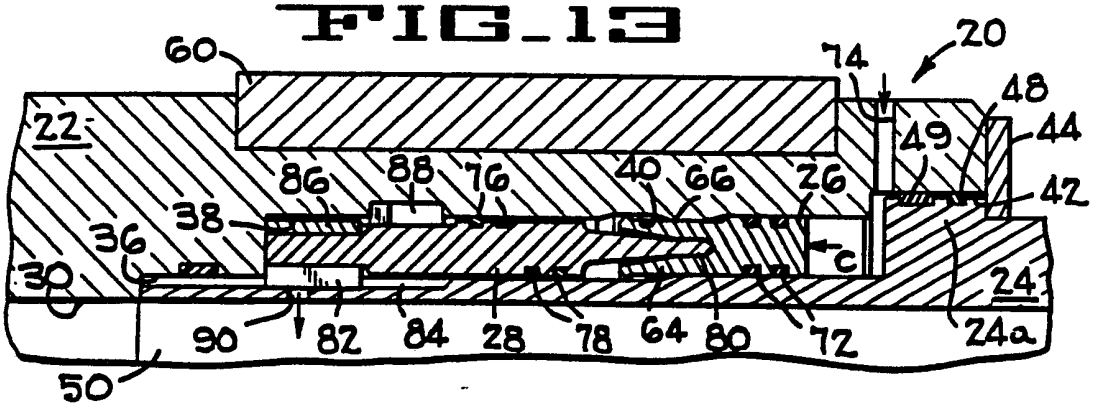

FIG_14

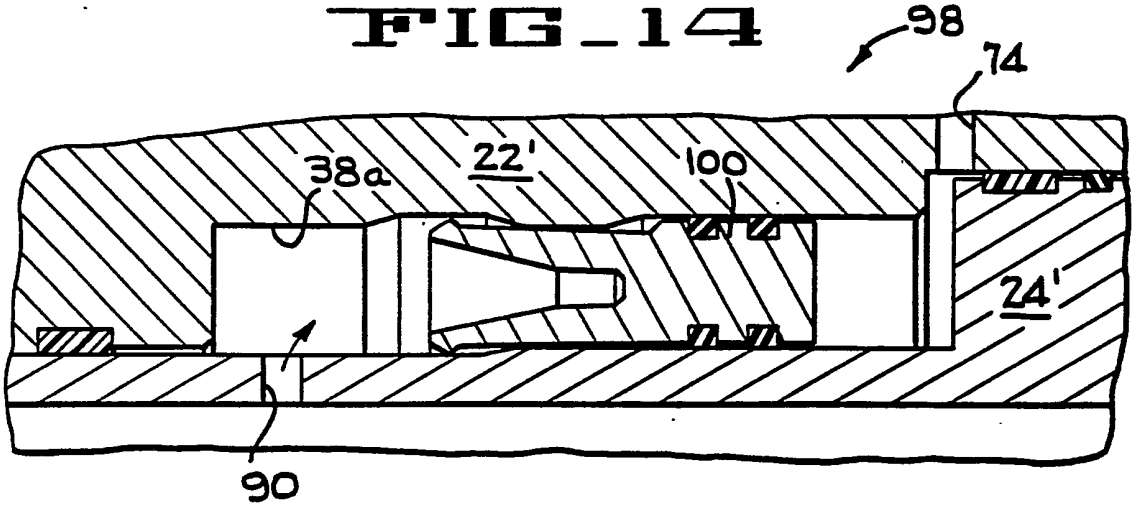

FIG_15

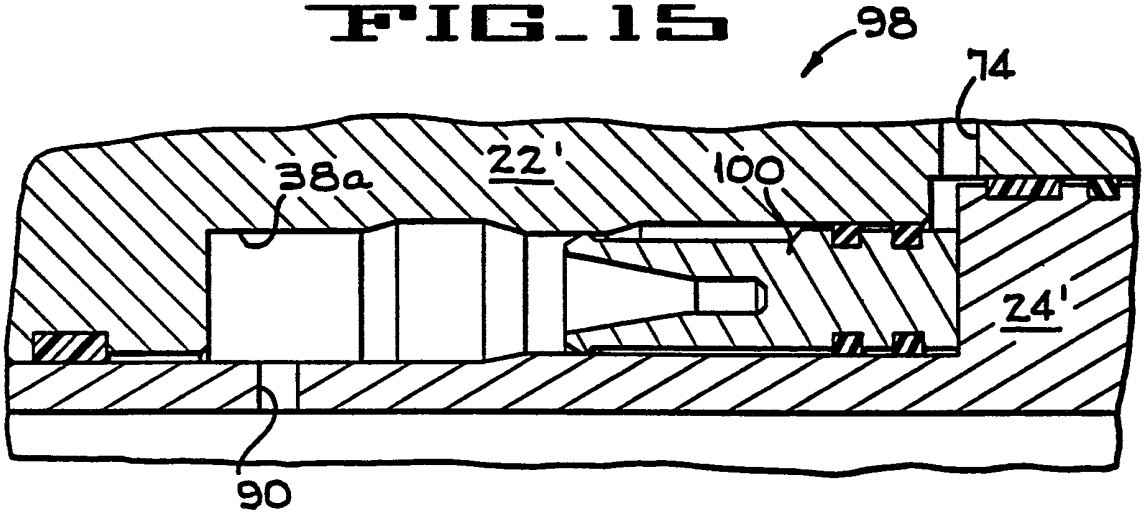

FIG_16

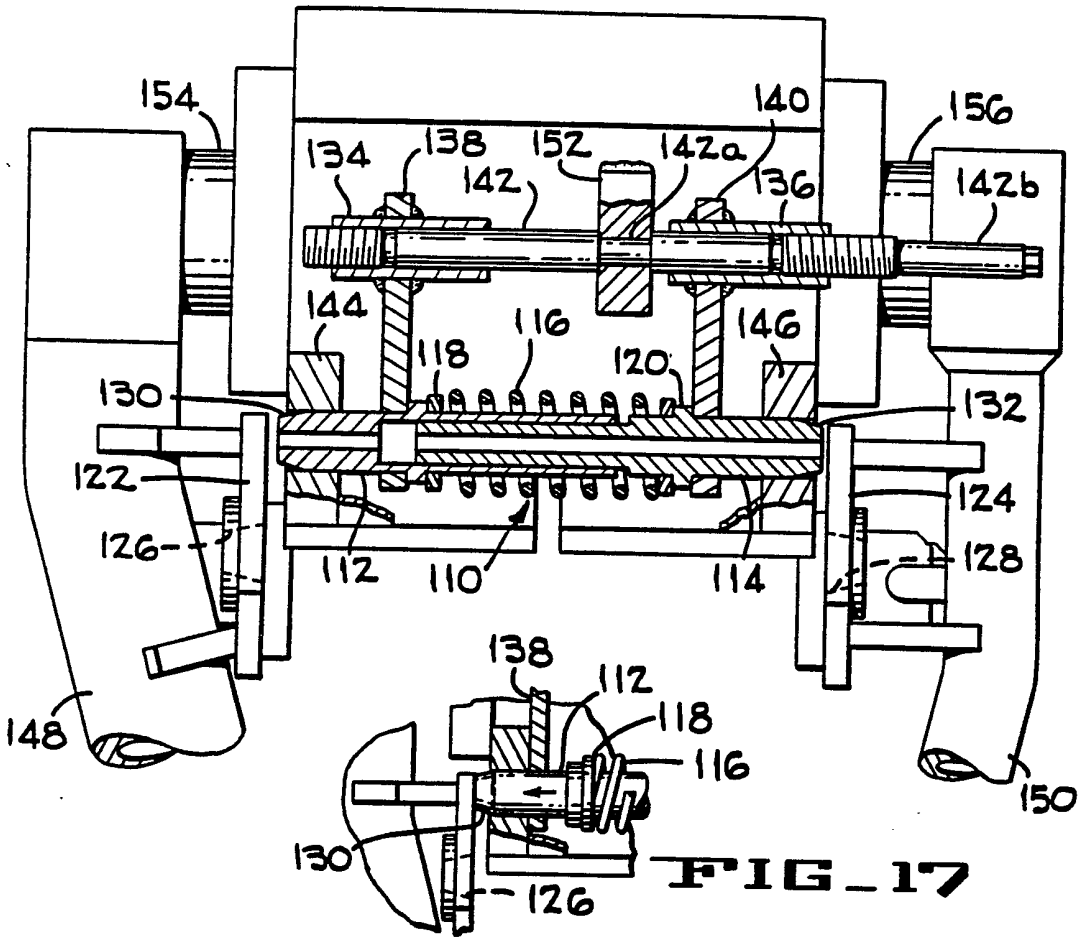

FIG_17

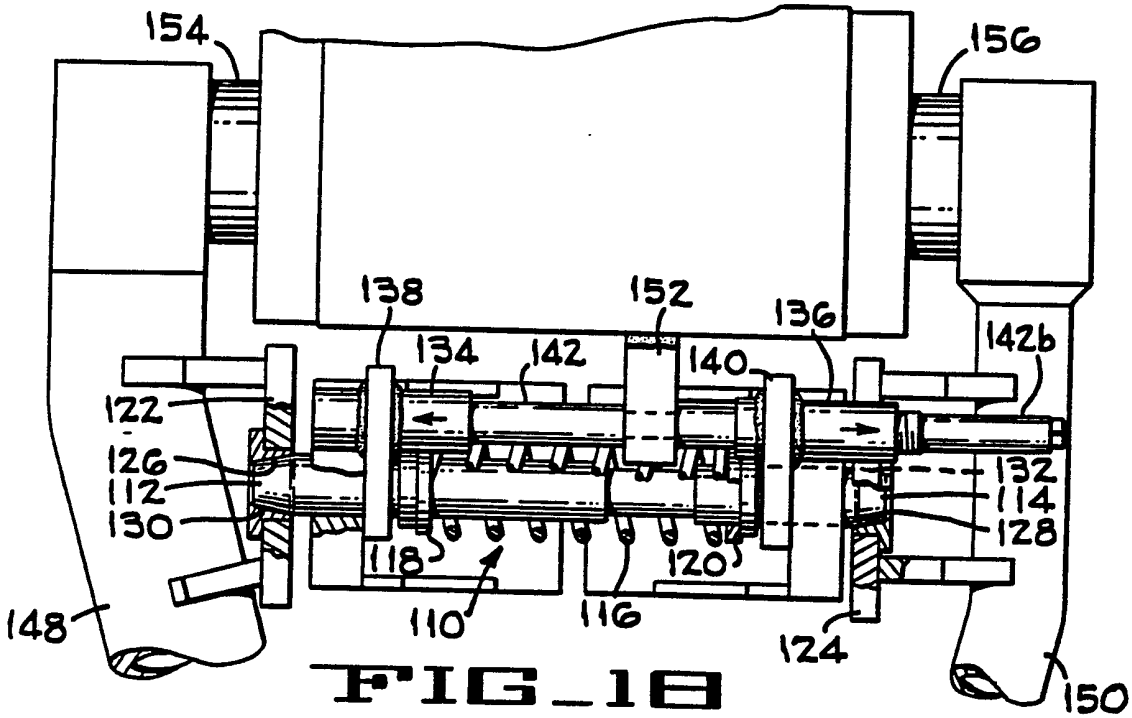

FIG_18

PIPE JOINT

BACKGROUND OF THE INVENTION

This invention relates to pipe swivel joints, and more particularly to such swivel joints that are designed to withstand large external loads such as are encountered when used in the oil and gas industry.

A major advance in the completion of offshore wells in water depth at which diver assistance is uneconomical or otherwise impractical has been the design and development of diverless lay-away flowline type subsea Christmas trees for installation on subsea wellheads. These trees utilize flexibility of the flowline to make the flowline-to-tree connection at the surface prior to lowering the tree to the subsea wellhead, thereby eliminating the need to make that connection at a subsea location and also permitting pressure testing the connection in the drillship moonpool. Prior to the present invention the flowlines of a lay away system were connected to the tree in a fixed manner and extended from the tree at an angle, usually about twenty degrees from the vertical, which required more space in the moonpool than was always available, especially on drillships designed for guidelineless drilling and subsea completion systems.

One proposed solution to the problem involved connecting the lay-away flowlines to the universal guidebase by swivel joints, allowing the flowlines to hang vertically in the moonpool and then seek their final angle when they and the tree are landed on the sea floor. However, in this arrangement the flowlines cannot be run with the tree, whereby the highly desirable advantage of making up the flowline-to-tree connection at the surface is not available. Furthermore, this arrangement does not include the advantage of a flowline jettison feature, and the swivel joints employed at the guide do not have metal-to-metal seals, a feature both highly desirable and frequently required by oil and gas industry specifications where elastomer or other non-metallic

seals are inadequate.

SUMMARY OF THE INVENTION

The present invention comprises a pipe joint formed between a pair of relatively rotatable joint elements and including a seal element axially movable into and out of metal-to-metal sealing engagement between the joint elements, dynamic seal means being provided between the seal element and each respective joint element to maintain a fluid seal therebetween during said axial movement, the joint further comprising locking means selectively operable to prevent relative rotation between the joint elements.

In a below described preferred embodiment, an annular metal seal element is energized by an internal sleeve that responds to fluid pressure in the joint flow passage to move the seal element axially into a position between the relatively rotatable joint elements where inner and outer annular lips of the seal element bear against opposed annular surfaces of those joint elements in a pressure-tight interference-fit manner. In this embodiment, the metal-to-metal seal is released (de-energized) by application of external hydraulic pressure to overcome the flow passage pressure and return the seal element and sleeve to their initial positions.

A metal-to-metal sealing pipe swivel joint is described herein and claimed in our co-pending application no. 91 04187.1 (Serial No. GB 2242246) entitled "Metal-to-Metal Sealing Pipe Swivel Joint", the joint comprising:

a) an outer tubular joint element with an inner annular metallic sealing surface;

b) an inner tubular joint element with an outer annular metallic sealing surface, said inner element extending at least partially within said outer element;

c) means securing together said inner and outer elements in a relatively rotatable but non-axially separable manner; and

d) an annular seal element disposed between said inner and

outer joint elements, said seal element having inner and outer annular metallic sealing surfaces moveable in direct response to fluid pressure axially between an active position wherein said seal element sealing surfaces bear against said inner and outer joint element sealing surfaces to establish a metal-to-metal fluid pressure seal therebetween and an inactive position wherein said seal element sealing surfaces are not in contact with said inner and outer joint elements.

A feature of the present invention is a means for locking the relatively rotatable joint elements against rotation for example when the seal element is in its metal-to-metal sealing position, thereby preventing movement at the interface of the seal element and the joint elements and thus assuring that a leak will not develop in the established metal-to-metal seal. This locking means may comprise a first plurality of insert keys spaced circumferentially about the outer surface of the locking sleeve, a second plurality of keys on the inner surface of the outer swivel joint element that cooperate with the first set of keys in a spline-like manner when the locking sleeve is in the advanced or seal-establishing position, and a key and slot connection between the locking sleeve and the inner swivel joint element that prevents relative rotation between the sleeve and this element at all axial positions of the sleeve.

Alternatively, as described herein and claimed in our co-pending Application No. (Serial No.) entitled "Locking Swivel Joint", in a well completion system comprising a subsea Christmas tree and a pair of lay-away flowlines individually interconnected to the subsea tree by pipe swivel joints, an apparatus usable as such locking means comprises:

a) a pair of lock pins, one pin at least partially telescoped within the other pin;

b) means for biasing said pins axially away from each other;

c) pin operating means for moving said pins axially towards each other;

d) support means for said swivel joints, lock pins and pin

operating means, said support means adapted for rigid yet releasable connection to said Christmas tree; and

e) receptacle means on said flowlines for receiving and holding said pins when said flowlines are in a predetermined angular attitude with respect to said Christmas tree.

The present invention also provides assurance that the inner and outer swivel joint elements are locked against relative rotation preferably before the seal element moves into its functional position between the opposed sealing surfaces of those joint elements, and corresponding assurance that the seal element can move out of that functional position preferably before the joint elements are released from their locked condition.

The swivel joint described below is ideally suited for use in situations where very high lateral loads and bending moments are experienced, such as the catenary load imposed by flowlines extending from a subsea Christmas tree while the tree is in a drillship moonpool during pressure tests.

Further preferred features of the present invention are in the dependent claims. Embodiments of the present invention are described below by way of example and with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a side elevation of a subsea Christmas tree suspended just above a drillship moonpool and a lay-away flowline connected to the tree by a swivel joint according to an embodiment of the present invention and depending vertically therefrom.

Figure 2 is a fragmentary view of the tree and flowline of Figure 1, showing how the flowline extends laterally from the tree after the tree has been installed on its subsea wellhead.

Figure 3 is a side elevation, on an enlarged scale, of the flowline hub, swivel joint and flowline of Figures 1 and 2, with the flowline shown in the Figure 2 attitude.

Figure 4 is a front elevation of the apparatus shown in Figure 3, and including a second flowline connected to the hub by a second swivel joint.

Figure 5 is an enlarged plan view, partially broken away to a horizontal section, of a swivel joint for interconnecting a tree and flowline as shown in Figures 1-4.

Figure 6 is a side elevation of the swivel joint of Figure 5.

Figure 7 is an enlarged fragmentary view of the swivel joint of Figure 5.

Figure 8 is a fragmentary view taken along the line 8-8 of Figure 7.

Figure 9 is a fragmentary view taken along the line 9-9 of Figure 7.

Figures 10-13 are fragmentary views, similar to Figure 7 but on a reduced scale, showing the swivel joint seal element and locking sleeve in their various positions during metal-to-metal seal make-up and release operations.

Figure 14 is an enlarged fragmentary view like Figure 7, showing a modified version of the swivel joint and seal elements of the preceding Figures, which is used in conjunction with external locking means.

Figure 15 is a view like Figure 14, but showing the seal element in its functional position.

Figure 16 is a front elevation, with some parts shown in vertical section of an embodiment of the locking means, for high flowline load applications to releasably lock a pair of flowlines in a desired attitude with respect to a subsea tree to which they are pivotally connected by swivel joints , for example as shown in Figures 14 and 15.

Figure 17 is a fragmentary view, on a slightly reduced scale, of a portion of the locking means of Figure 16, showing a locking pin released for spring-biased extension into its receptacle port upon upward pivotal movement of the flowlines from their dependent running position as seen in Figure 16.

Figure 18 is a plan view, with some parts broken away, of the flowline locking means of Figure 16, showing the flowlines

locked against pivotal movement through their swivel joints.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of a pipe swivel joint according to the present invention is illustrated at 20 in Figures 5-13, and in Figures 1-4 this embodiment is shown as interconnecting a lay-away flowline to a subsea Christmas tree.

Referring first to Figures 5-9, the swivel joint 20 generally comprises an outer tubular element 22, an inner tubular element 24 partially extending within the element 22, an annular metallic seal element 26 between the outer and inner joint elements 22, 24, and a sleeve 28 between the outer and inner elements 22, 24.

The outer element 22 has an axial bore 30 that communicates with a lateral port 32 which facilitates connecting the outer element to a pipe such as the illustrated subsea flowline 34, and the bore 30 is counterbored at 36, 38, 40 and 42 to provide annular spaces for the inner element 24, the sleeve 28, the seal element 26, and a radially enlarged portion 24a of the inner element 24, respectively. As seen in Figure 5, a washer-like annular retainer 44 surrounds the outer portion 24b of the inner element 24 and is releasably secured to the end face of the outer element 22, such as by a plurality of circumferentially spaced cap screws 46, to retain the inner and outer elements in axial position while permitting relative rotation between them. An annular seal element 48, such as an elastomeric O-ring, functions to provide a pressure-tight dynamic seal between the inner and outer elements 24, 22, and an annular wear ring 49 of Teflon or other suitable plastic functions as a dynamic bearing between the two elements.

The inner joint element 24 has an axial bore 50 communicating with a lateral port 52, and as seen in Figure 6 a pipe 54 extends from the port 52 to connect the joint element 24 into a fluid control system such as a subsea Christmas tree of the type illustrated at 56 in Figure 1. In such use, the swivel joint 20 can be firmly secured to a

suitable structure, such as a flowline hub assembly 58 which is removably connectable to the tree 56, by means of a pillow block 60 (Figures 5 and 6) that fits around the joint's outer element 22 in a manner that facilitates rotation of that element with respect to the block.

As seen best in Figure 7, the seal element 26 includes an annular base portion 62 from which extend axially an inner annular lip 64 and an outer annular lip 66. Each lip 64, 66 has an annular sealing surface 64a, 66a, respectively, with a radiused cross-section configuration, and in the seal's functional position (Figure 7) these sealing surfaces 64a, 66a bear against opposed cylindrical sealing surfaces 68, 70, respectively, of the inner and outer joint elements 24, 22, respectively, in an interference manner to establish a metal-to-metal seal between the elements 24, 22. The seal element base 62 includes inner and outer pairs of annular grooves in which are annular elastomeric dynamic seals 72 that enable the seal element to be returned axially into its non-functional position (Figures 10 and 13), that is moved to the left from the Figure 7 position, by hydraulic pressure inletted through a lateral port 74 in the outer element 22.

Again referring primarily to Figure 7, the sleeve 28 includes a body portion 28a surrounding which are a pair of outer annular elastomeric seals 76, and within which are a pair of inner annular elastomeric seals 78, these seals functioning to provide a dynamic seal system between the sleeve and the joint elements 22, 24. An annular axial extension 80 of the sleeve body 28a protrudes into the annular space between the seal element lips 64, 66 to bear against the seal element base 62, so that when the sleeve 28 moves axially in the direction of the arrow A it forces the seal element 26 to move in a corresponding manner. At its other end the sleeve 28 includes a plurality of circumferentially spaced inner keys 82 that extend into axial slots 84 in the outer surface of the adjacent portion of the joint inner element 24, these keys and slots cooperating to prevent relative rotation of the sleeve 28 and element 24, but facilitate axial movement

of the sleeve with respect to that element. On the outer surface of that same end of the sleeve 28 are a plurality of circumferentially spaced keys 86 that cooperate with a plurality of circumferentially spaced keys 88 on the inner surface of the joint outer element 22 in a spline-like manner to prevent relative rotation between the outer element and the sleeve when these keys 86, 88 are engaged as shown in figures 7-9. As seen best in Figure 9, the forward end portion of each key 86, 88 is tapered to ease axial movement of the sleeve keys 86 into meshed engagement with the keys 88.

Accordingly, when the keys 86, 88 are engaged the outer element 22 is rotationally locked to the inner element 24 through the keys 88, 86, the sleeve 28, and the keys 82 and slots 84, whereas when the keys 86, 88 are disengaged (Figures 10 and 13) the outer element 22 is free to rotate with respect to the sleeve 28 and the inner element 24. The sleeve 28 thereby functions to lock the swivel joint elements when rotation therebetween is not desired, such as when the metal-to-metal seal between the elements has been established, and to release this locked status when the seal element 26 has been moved out of its functional position and freedom for such rotation is desirable.

In reference to Figures 10-13, movement of the seal element 26 into and out of its functional position is as follows. From a starting position where the seal element 26 and the locking sleeve 28 are in their respective locations relative to the inner and outer joint elements 24, 22 as shown in Figure 10, the element bores 30, 50, which together comprise a flow passage for fluid to be conveyed through the joint, are subjected to fluid pressure as represented in Figure 11. As this pressure is conducted from the flow passage through one or more ports 90 in the inner element 24 into the annular space between the inner and outer elements, the locking sleeve 28 is moved axially in the direction of the arrow B until it arrives at its final or locking position shown in Figure 12. During this movement the seal element 26 is likewise moved axially from its Figure 10 position into its

functional metal-to-metal sealing position shown in Figure 12. In this position the seal can be tested, as at the drillship when this swivel joint comprises the connection between a subsea tree and a flowline as depicted in Figure 1.

When a satisfactory test is achieved, the seal element 26 is returned to its initial non-functional position shown in Figures 10 and 13 by venting the joint flow passage and admitting pressure through the port 74, as indicated by arrow C in Figure 13, thereby also returning the locking sleeve 28 to its starting position and, accordingly, unlocking the joint outer element 22 for rotation about the sleeve, seal element and joint inner element 24, thereby allowing the flowline 34 to depend vertically from the subsea tree 56 to facilitate clear passage through the drillship moonpool 92. When the tree 56 has been landed and connected to its subsea wellhead, and the flowline has come to rest in its final position on the sea floor, the metal-to-metal seal can then be re-established by repressurizing the swivel joint flow passage as above.

Figures 14 and 15

These figures illustrate a modified version 98 of the foregoing preferred embodiment for use where the means to lock the swivel joint out element is exterior thereto. In this version the metallic seal element 100 is identical to the seal element 26 of the preferred embodiment, there is no locking sleeve such as 28 and no keys such as 82, 86, 88 or slots 84, and the counterbore 38a is substantially less in axial dimension than its foregoing counterpart 38. In essentially all other design respects, this version is equivalent to the swivel joint 20, and movement of the seal element 100 between its non-functional position of Figure 14 and its functional position of Figure 15 is achieved by fluid pressure as in the preferred embodiment, except that said pressure acts directly on the seal element 100 in moving it in either direction without aid of a locking sleeve.

Figures 16-18

One type of external locking means that can be employed with the modified swivel joint 98 of Figures 14 and 15 is identified as 110 in Figures 16-18. The locking means 110 comprises a pair of elongated lock pins 112, 114, the pin 114 telescoped into the pin 112, a helical spring 116 surrounding the telescoped pins 112, 114 and extending between radial flanges 118, 120 on the pins 112, 114, respectively, a pair of lock plates 122, 124 each with a tapered receptacle 126, 128, respectively, for receiving the tapered outer ends 130, 132 of the pins 112, 114, respectively, a pair of interiorly threaded sleeves 134, 136 to each of which is fixed a lateral strut 138, 140, respectively, and an operating shaft 142 threaded into the sleeves 134, 136.

The telescoped lock pins 112, 114 extend freely through supports 144, 146 that are mounted on a suitable portion of a structure to which pipe swivel joints are attached, such as the flowline hub assembly 58 of Figure 3, and the plates 122, 124 are mounted in facing relationship on a pair of flowlines such as 148, 150, respectively.

The operating shaft 142 has a reduced diameter portion 142a that rotatably resides in a support strut 152 that is also mounted on the flowline hub assembly 58. The threads interconnecting the operating shaft 142 with the sleeve 134 are of opposite hand with respect to their counterparts that interconnect the shaft with the sleeve 136, so that as the shaft is rotated by, for instance, a wrench or other means temporarily engaged with a suitably configured shaft extension 142b, the sleeves will move axially toward or away from each other while the shaft is maintained in axial position by the strut 152. The helical spring 116 exerts a constant expanding bias against the pin flanges 118, 120 so that rotation of the shaft 142 to cause the aforesaid movement of the sleeves 134, 136 also results in telescopic axial movement of the pins 112, 114.

Figure 16 illustrates the contracted position of the pins 112, 114 wherein the flowlines 148, 150 are free to pivot by

means of their swivel joints 154, 156, through their full range of movement without becoming locked in any attitude by the locking means 110. When it is desired to lock the flowlines and their swivel joints against pivotal movement, the operating shaft 142 is rotated to move the sleeves 134, 136 apart until the struts 138, 140 come to rest against the pin supports 144, 146, whereby the pins 112, 114 will be biased by the spring 116 into contact with their lock plates 122, 124 as illustrated in Figure 17. As the flowlines are pivoted the lock plates are carried along until their receptacles 126, 128 come into alignment with the pins, whereupon the pins are biased further apart until their tapered ends are fully inserted into locking engagement with the receptacles as shown in Figure 18. As will be understood, reverse rotation of the operating shaft 142 will cause withdrawal of the pins 112, 114 from their locking receptacles, freeing the flowlines for pivotal movement about their swivel joint axes.

Although the best mode contemplated for carrying out the present invention has been herein shown and described, it will be apparent that modification and variation may be made without departing from what is regarded to be the subject matter of the invention, as defined in the claims.

CLAIMS

1. A pipe joint formed between a pair of relatively rotatable joint elements and including a seal element axially movable into and out of metal-to-metal sealing engagement between the joint elements, dynamic seal means being provided between the seal element and each respective joint element to maintain a fluid seal therebetween during said axial movement, the joint further comprising locking means selectively operable to prevent relative rotation between the joint elements.

2. A joint as claimed in claim 1 wherein operation of the locking means is arranged to cause the seal element to be moved into such sealing engagement.

3. A joint as claimed in claim 2 wherein, upon operation of the locking means, relative rotation between the joint elements is prevented prior to such sealing engagement, and upon release of the locking means, the seal element is moved out of such sealing engagement prior to release of the joint elements for relative rotation.

4. A joint as claimed in any of claims 1-3 including a sleeve which is axially movable to cause the seal element to be moved into such sealing engagement and which forms a keyed connection with each of said joint elements to prevent relative rotation therebetween when the seal is so engaged, at least one of said keyed connections being disengageable when the seal element is not so engaged.

5. A joint as claimed in claim 1 including a locking pin mounted for co-axial movement along an axis fixed with respect to one of the joint elements and a receptacle on the other joint element arranged to be alignable with the fixed axis by relative rotation of the joint elements, for receiving an end of the pin.

6. A joint as claimed in claim 5 wherein the pin is biassed against a lock plate containing the receptacle, the lock plate acting as a stop against axial movement of the pin until the pin and receptacle are aligned.

7. A joint as claimed in claim 6 including pin retaining means operable against said bias to hold the pin away from the lock plate.

8. A joint as claimed in any of claims 5-7 including a pair of said pins and corresponding said receptacles.

9. A metal-to-metal sealing pipe swivel joint substantially as described with reference to or as shown in figures 1-15 or figures 16-18 of the drawings.

10. A subsea well completion system substantially as described with reference to or as shown in the drawings.

Patents Act 1977

Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

GB 9317386.2

Relevant Technical fields

(i) UK Cl (Edition L) F2G (G6C1 G6C2 G6Z)

(ii) Int Cl (Edition 5) F16L 27/08 39/04

Search Examiner

R J DOWNING

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

29 SEPTEMBER 1993

Documents considered relevant following a search in respect of claims 1-10

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

		to claim(s)

Categories of documents

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Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

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