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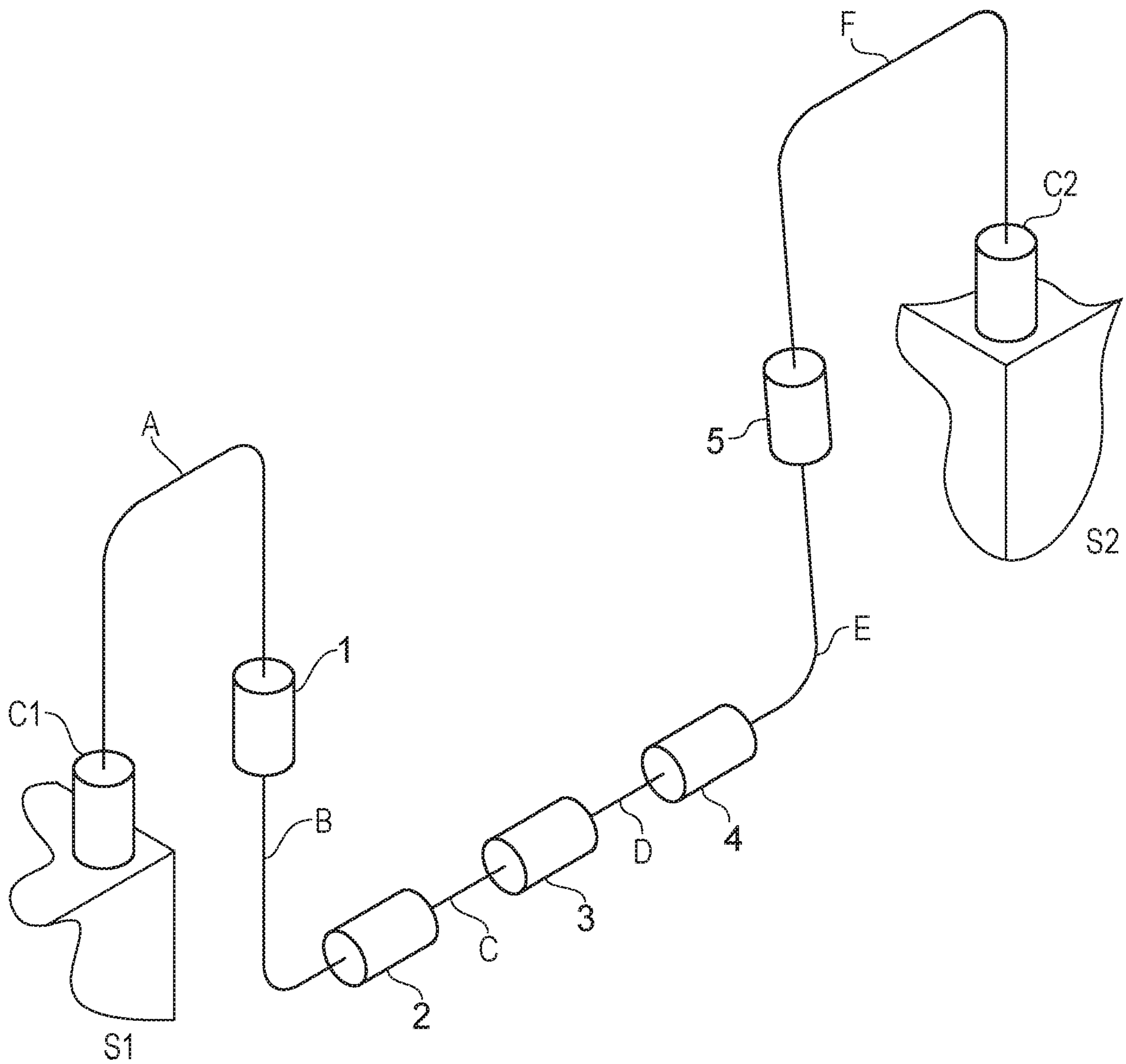

FIG. 1

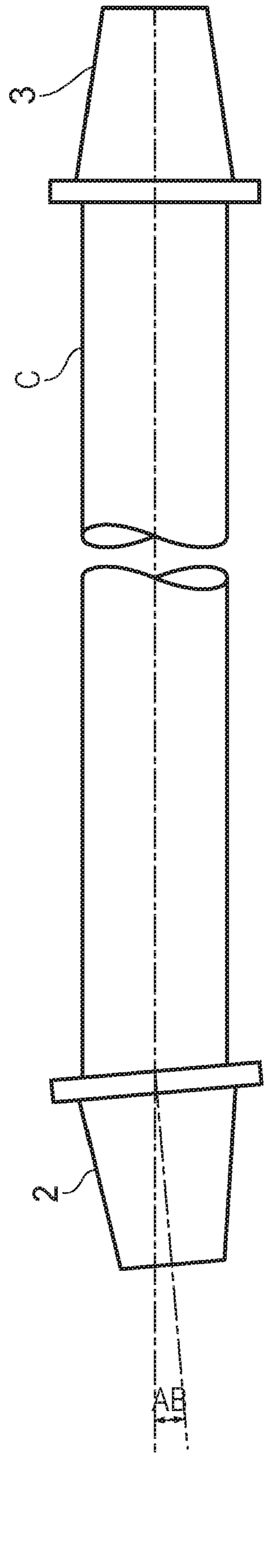

FIG. 2

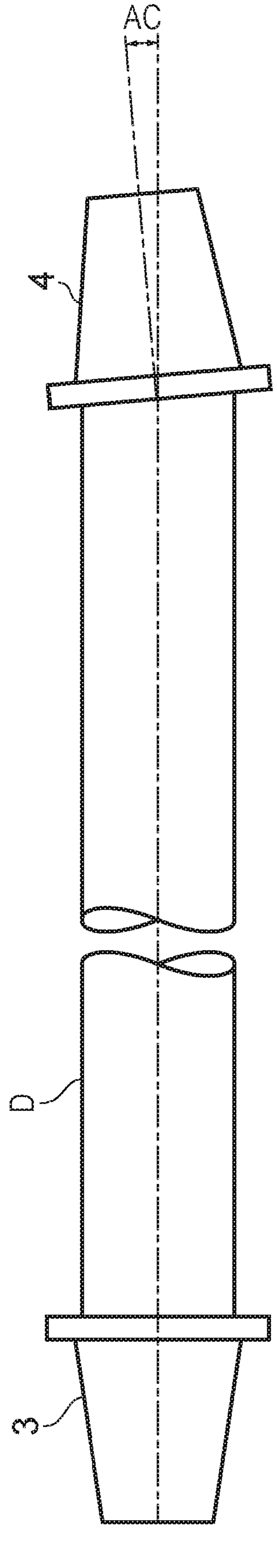

FIG. 3

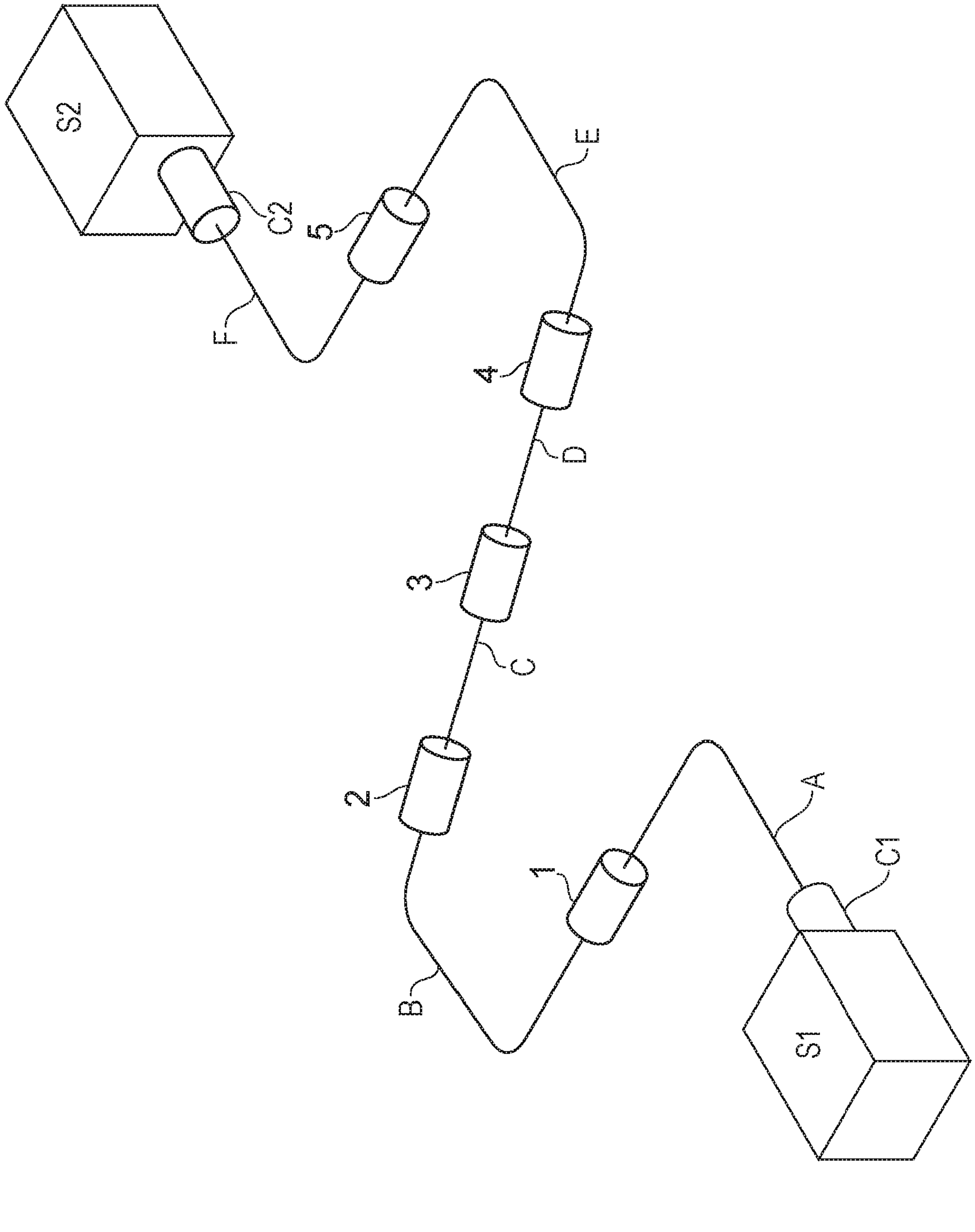

FIG. 4

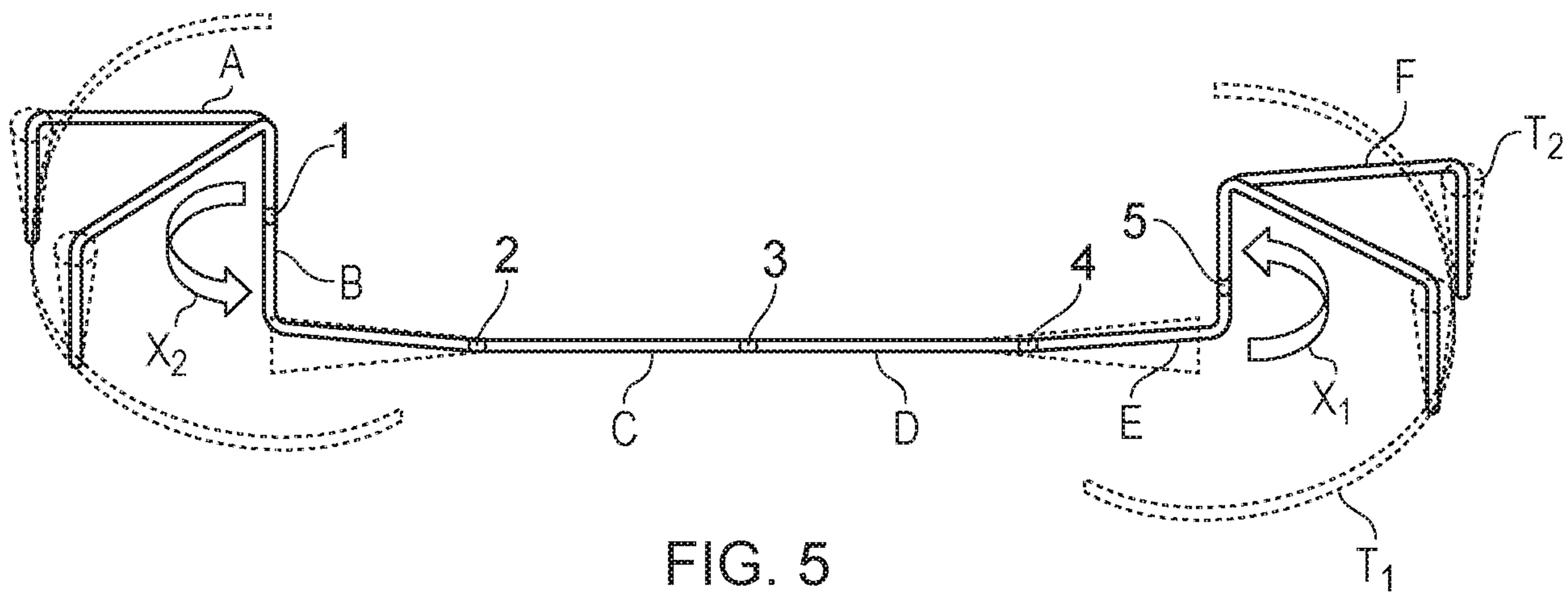

FIG. 5

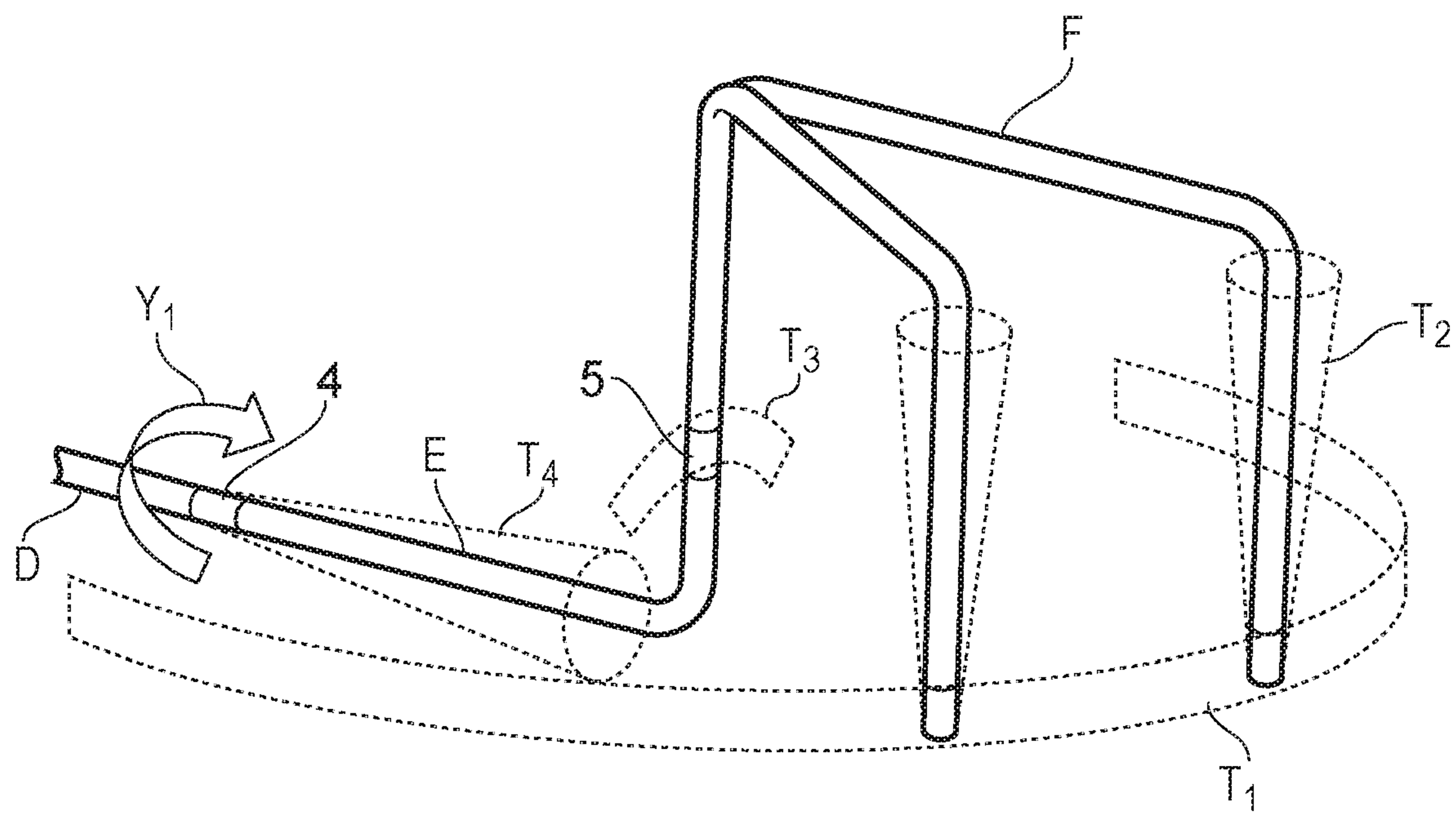

FIG. 6

JUMPER ASSEMBLY

FIELD OF THE INVENTION

The invention relates to jumper assemblies, particularly those used in the hydrocarbon exploration and production industries. The invention may find utility in both on shore and subsea environments.

BACKGROUND TO THE INVENTION

Subsea oil and gas production systems require complex interconnections between subsea hydrocarbon equipment such as wellheads, manifolds, and further processing facilities. Generally, a series of wellheads will each be connected back to a single manifold by a jumper (also known as a spool), which is essentially a relatively short flow-line which provides a fluid connection between two pieces of hydrocarbon equipment. The manifold can then be connected to a pipeline via a Pipeline End Termination (PLET). The sea bed is often not a flat planar surface, and wellheads and manifolds may lie at different orientations and angles with respect to one another and with respect to the horizontal. Connection points, usually called hubs, on each piece of equipment may therefore be oriented at a variety of relative and absolute angles and orientations. Each jumper is therefore required to conform to an exact set of measurements and, under usual practice, will be manufactured bespoke for each fluid connection that is required.

Once a field of subsea hydrocarbon extraction and processing equipment has been established with equipment installed located in its final positions for production, the locations of the trees, manifolds and wellheads will be known with a certain degree of accuracy. However, prior to the fabrication of a jumper assembly, offshore metrology must be carried out to ascertain the exact distances and angles which exist for the relevant connection points which the jumper assembly will be required to connect. Once obtained, this information is relayed back to the shore. A jumper assembly is then manufactured to the correct dimensions, with the pipe segments to be connected cut and ground to the correct angles, to ensure that the lengths of the jumper and the connections at each end will be suitable for installation and match the metrology carried out after installation. The bespoke jumper is then delivered to site, and installed at the necessary offshore or on-shore location. The bespoke manufacture, as well as the delivery time for each jumper, after the metrology stage, can be a time consuming and costly process.

Presently the process of fabricating a jumper, including carrying out the necessary subsea metrology can take in the order of 10 to 20 days. In addition, the engineering equipment and labour requirements to fabricate a bespoke jumper assembly can be onerous and costly. There is clearly a need to improve both the apparatus which is to be installed and also the method of manufacture and installation of such apparatus.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided a jumper assembly for providing a fluid connection path between hydrocarbon production or processing equipment, the assembly comprising a plurality of fluid conduit sections joined by mechanical connectors and having a net flow axis extending between fixing points for the first and second ends of the assembly, wherein at least one mechanical connector is oriented such that rotation of adjacent conduit sections about the connector induces a change in an overall length of the assembly and at least one angular offset connector is mounted to a conduit section at an offset angle such that rotation of the angular offset connector relative to a longitudinal axis of the conduit section induces a change of angle of an end of the assembly relative to the net flow axis.

Such a jumper assembly has the advantage that immediate assembly and any necessary adjustments can be made in response to detailed metrology data by rotating the relevant mechanical connectors to achieve the desired overall length and angle of approach of the end of the conduit sections. No remote manufacturing and delivery of bespoke parts to site is necessary between the metrology stage and the assembly and installation stage. This in turn means that the overall deployment time for the jumper assembly may be reduced. Therefore, fewer resources are required after collection of the metrology data and installation of the jumper can be a more cost effective activity. Further, the overall manufacturing and engineering costs are lowered, since the adjustments can be made simply and cheaply either on site, or remotely, depending on the installation site location.

Further, the advantage of combining the mechanical offset connector with the rotatable connector which is angularly offset with respect to the longitudinal axis of, or net flow direction provided by, the jumper assembly itself, is that it allows for very straightforward adjustments in the length of the overall jumper assembly. This means that the length can be quickly adjusted again, on site either on land or offshore, depending on the installation site location. Combined with the ability to adjust the angle of approach of the end of the jumper assembly provided by the angular offset connector of the invention, this provides the jumper assembly with means to exactly match the dimensions required by the specific dimensions of the items of hydro-carbon production and processing equipment which are to be connected. This means that the assembly of the entire jumper assembly can take place offshore, if necessary.

The function of the offset connector could be reproduced by mounting a connector to a pipe or conduit section in which the desired angular offset has been formed.

As illustrated herein, a further means of providing the angular offset connector is to mount the connector to a pipe of conduit section such that the longitudinal axis of the connector is at an offset angle with respect to the a flow axis of the pipe section at the relevant end or connection point of the connector to the pipe or conduit.

The jumper assembly may comprise at least a hub connection at a first end of the jumper assembly, connected to a first end of a first conduit section, the second end of the first conduit section being connected to the mechanical connector; the mechanical connector further connected to a first end of a second conduit section, and the second end of the second conduit section being connected to a first angular offset connector.

The jumper assembly may further comprise a third conduit section connected at a first end to the first angular offset connector, and preferably connected at a second end to a second mechanical connector.

The first conduit section may have a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet.

The net change in the flow direction at the inlet and the outlet of the first conduit section may be substantially 180°. The first conduit section may be a U-shaped conduit section.

The second conduit section may provide a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°. The second conduit section may be an L-shaped conduit section.

Rotation of the first conduit section about an axis of a first end of the conduit section connected to the first mechanical connector may induce the change in an overall length of the assembly.

In a first example the jumper assembly may further comprise a fourth conduit section connected at a first end to the second mechanical connector, and preferably connected at a second end to a second angular offset connector. The jumper assembly may further comprise a fifth conduit section, connected at a first end to the second angular offset connector, and preferably connected at a second end to a third mechanical connector. The jumper assembly may further comprise a sixth conduit section, connected at a first end to the third mechanical connector, and preferably connected at a second end to a second hub connection.

The fifth conduit section may have a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°. The fifth conduit section may be an L-shaped conduit section.

The sixth conduit section may a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet. The net change in flow direction between the inlet and the outlet of the sixth conduit section may be substantially 180°. The sixth conduit section may be a U-shaped conduit section.

Rotation of the sixth conduit section about an axis of a first end of the sixth conduit section connected to the first mechanical connector may induce a change in an overall length of the assembly.

In a second example, the jumper assembly further comprises a third conduit section connected at a first end to the first angular offset connector, and preferably connected at a second end to a second angular offset connector. The jumper assembly may further comprise a fourth conduit section, connected at a first end to the second angular offset connector, and connected at a second end to a second mechanical connector. The jumper assembly may further comprise a fifth conduit section, connected at a first end to the second mechanical connector, and connected at a second end to a second hub connection.

The fourth conduit section may have a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°. The fourth conduit section may be an L-shaped conduit section. The fifth conduit section may have a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet. The net change in flow direction between the inlet and the outlet of the fifth conduit section is substantially 180°. The fifth conduit section may be a U-shaped conduit section.

In a third example, the jumper assembly may further comprise a third conduit section connected at a first end to the first angular offset connector, and connected at a second end to a second mechanical connector. The jumper assembly may further comprise a fourth conduit section connected at a first end to the second mechanical connector, and connected at a second end to a second hub connection.

The third conduit section may have a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°. The third conduit section may be an L-shaped conduit section. The fourth conduit section may have a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet. The net change in flow direction between the inlet and the outlet of the fourth conduit section may be substantially 180°. The fourth conduit section may be a U-shaped conduit section.

It will be appreciated from the below description of the embodiments and further examples, that the examples provided above may be combined while still falling within the main embodiment of the invention. In all examples of the invention, rotation of a fluid conduit section to which the angular offset connector has been applied can adjust the desired angle of approach to a connection point at one or both of first and second ends of the assembly.

The jumper assembly may be of the vertical tie-in type. The jumper assembly may be of the horizontal tie-in type.

The jumper assembly may comprise a first conduit section having a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet towards a first end of the jumper assembly, and a second conduit section having a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet towards a second end of the jumper assembly.

The jumper assembly may further comprise a first conduit section having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90° towards a first end of the jumper assembly, and a second conduit section having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90° towards a second end of the jumper assembly,

The jumper assembly may further comprise a first conduit section having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90° towards a first end of the jumper assembly, and a second conduit section having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90° towards a second end of the jumper assembly,

The one or more of the conduit sections having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90° may be located between the first and second conduit sections each having a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet.

One or more of the conduit sections having a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet may be between the conduit sections each having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°.

At least one angular offset connector may be located between the first and second respective conduit sections. The offset angle of the angular offset connector may be between 0° and 3°. The offset angle may be between 0° and 5°. The mechanical connectors may be provided with indexing markings.

According to a second aspect of the invention, there is provided a kit of parts for a jumper assembly of the invention.

The provision of a kit of parts which can be assembled into the jumper assembly of the present invention means that the jumper can either be assembled on land, once the detailed metrology data has been gathered including the exact length and hub angle requirements, but also that the jumper assembly can be assembled offshore, possibly on board the same boat which carries out the metrology, or at an on-shore installation site. Since no complex bespoke production or joining, welding, of components or grinding of angles is required using the present invention, construction and installation costs can be greatly reduced.

According to a third aspect of the invention, there is provided a method comprising: prefabricating the components of a jumper assembly to within a predefined tolerance based on the physical locations of two pieces hydrocarbon equipment, wherein the jumper assembly components comprise a plurality of fluid conduit sections and a plurality of mechanical connectors; assembling the jumper assembly components, wherein assembling includes: connecting the components together, thereby defining a net flow axis which extends between the two ends of the jumper assembly; orienting at least one of the mechanical connectors such that rotation of adjacent pipe sections about the connector induces a change in an overall length of the assembly, and mounting at least one angular offset connector to a pipe section at an offset angle such that rotation of the second connector relative to the longitudinal axis induces a change of angle of an end of the assembly relative to the net flow axis.

The method can be applied in combination with any aspect of the jumper assembly of the invention.

A conduit section adjoining the at least one mechanical connector may have a flow direction at its inlet which is axially offset and substantially inverted relative to the flow direction at its outlet. The offset angle may be between 0° and 3°. The offset angle may be between 0° and 5°.

At least one of the mechanical connectors may be provided with indexing markings, and setting the relative angle of rotation of the at least one second mechanical connector includes referencing the position of the indexing markings. Indexing markings may be physical, magnetic, visually identifiable or invisible and may be machine identifiable.

The rotation of any or all of the connectors may induce both a change in length and a change in angle of an end of the assembly. The advantages of this method of installation are a reduced installation time, and a reduction in the amount of complex engineering required either onshore or on site (which may be offshore).

Further features and advantages of embodiments of the invention will be apparent from the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by non-limiting example only, with reference to the accompanying drawings, in which:

Figure 1 is a view of a jumper assembly according to an embodiment of the present invention when applied to a vertical tie-in jumper assembly;

Figure 2 is a drawing of a portion of the jumper assembly, showing the offset angle created by mechanical offset connector (2);

Figure 3 is a drawing of a portion of the jumper assembly, showing the offset angle created by mechanical offset connector (3);

Figure 4 is a view of a jumper assembly according to an embodiment of the present invention when applied to a horizontal tie-in jumper assembly;

Figure 5 is a drawing showing the range of motion which can be achieved by using mechanical connectors on the portions of pipe lying off axis in accordance with an embodiment of the present invention; and

Figure 6 is an isometric drawing showing the range of motion achieved using the mechanical offset connector of the present invention.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

A jumper assembly is essentially a connecting flow-line or pipeline which connects an item of hydrocarbon production or processing equipment, such as a wellhead, with a manifold, tree assembly, or other piece of production or processing equipment. It can comprise a series of mechanical connectors in the form of large pipe or conduit sections, which allow for a fluid connection to be made between the outlet of the first piece of hydrocarbon production or processing equipment, such as a wellhead, and the inlet of the second piece of hydrocarbon production or processing equipment, such as a manifold. A jumper has a net flow axis which may be defined as a straight line between the outlet of the first piece of hydrocarbon production or processing equipment and the inlet of the second piece of hydrocarbon production or processing equipment. Even if many changes in direction are present along the length of the jumper assembly, the net flow direction will always be along a straight line between these two points. In an idealised jumper assembly of the vertical tie-in type, discussed below, all parts of the jumper assembly could lie in a vertical plane on which this axis lies, substantially perpendicular to the seabed.

The jumper assembly of the present invention is provided with one or more mechanical connectors between the sections of pipe which, when rotated, allow the angle of one of the pipes to be altered with respect to the net flow axis of the jumper assembly. Due to the shape of the remainder of the jumper assembly, the angle of approach of the end portion of the jumper assembly can be changed in this manner. The end portion of the jumper assembly is the point at which the jumper assembly connects to the 1st and/or 2nd piece of hydrocarbon processing or production equipment mentioned above. The absolute angular orientation of the connector portion of the subsea equipment may be at substantially any angle, due to inconsistencies in the seabed or problems with installation which result in the equipment not being installed perfectly vertically or horizontally. The angle of approach of the jumper assembly is the angle at which the end portion must lie with respect to the ideal connection position, due to the orientation of the connection point on the subsea equipment. This may be defined differently for vertical tie-in and horizontal tie-in systems. For instance, in a vertical tie-in system, the ideal vertical tie-in angle of approach is coincident with a vertical axis lying in the plane on which the net flow axis lies. Similarly, for a horizontal tie-in system, the ideal angle of approach is coincident with a horizontal axis lying in the plane on which the net flow axis lies.

The present invention provides a jumper assembly which is manufactured from standard parts, yet is adaptable to a large range of lengths and angles of approach in different installation conditions. It is simple, quick and effective to assemble, so that it satisfies the dimensional requirements of the specific location to which it is be installed.

The jumper assembly is provided with rotationally adjustable connectors on sections of pipe which lie at an offset angle relative to the main longitudinal axis of the jumper assembly. Again, due to the shape of jumper assemblies, incorporating, as they often do, sections of piping carry bends which may be of substantially 90° or more, these connectors can be used to simply and quickly alter the overall length of the jumper assembly, as will be explained further below. It is noted that in the case of a vertical tie-in jumper assembly, the use of a U-shaped conduit section will mean that the "legs" of the U portion will be substantially vertical. Therefore if one of these legs were to be rotated on its axis then the other leg will sweep out an arc with the axis of the other leg at its centre. Preferred embodiments include a conduit section having a net change in flow angle between first and second ends of the conduit section of substantially 180 degrees. A simple example is a U-shaped section, although any series of bends may be present between the first and second ends so long as the first end receives flow in a first direction and the second end delivers a flow in a second direction which is substantially the reverse of the first direction. Other net changes in flow direction can be envisaged, anywhere between a little over zero degrees to around 180 degrees.

In this description, the terms "pipe", and "conduit" will be used interchangeably, without restricting the scope of the described invention.

A jumper assembly 10 can be seen in Fig. 1. The jumper assembly 10 comprises six conduit sections A, B, C, D, E and F, which together provide a fluid connection between the two ends of the assembly, which ends are to be connected to hydrocarbon equipment as described above. The two ends of the assembly 10 are connected to two pieces of hydrocarbon processing equipment S1, S2 at connectors C1, C2. The assembly shown in Fig. 1 relates to a vertical tie-in jumper assembly, in which the ends of the endmost conduit sections A and F connect to C1 and C2 in a vertical orientation. This is achieved in the vertical tie-in assemblies in the embodiment shown in Fig. 1 through the use of two U-shaped sections A and F, and two L-shaped conduit sections B and E. These provide the necessary three substantially right-angled sections to connect the flow in a direction of the BC and DE connections 2 and 4, which in this case lie substantially in the net-flow axis of the jumper assembly, to C1 and C2 at a substantially perpendicular angle relative to the net flow axis.

In the illustrated case, the hydrocarbon equipment is a subsea structure, but the invention is not limited to use in a subsea environment.

The embodiment shown in Fig. 1 has six conduit sections, but could comprise more or fewer, depending on the specific implementation. The assembly could function with four or five sections, in which case C and/or D may be omitted. Connectors 4 or 2 may also be omitted.

The conduit sections A, B, C, D, E, and F are connected by mechanical connectors 1, 2, 3, 4 and 5. The pipe or conduit sections are said to be connected to one another. The pipe sections may be mounted, joined, welded or coupled to the mechanical connectors or angular offset connectors in any way which is known in the art.

The conduit sections are steel pipe sections, which may be of a length of the order of 30m, and they must be tightly sealed together to prevent leakage. One implementation of the mechanical connectors is to threadably connect the pipe sections via a helical thread, or via axially spaced (with respect to the conduit section axis) circular threads that lie on an imaginary cone. A sealed pipe joint of this type can be seen in US patent application US2011/0227338 A1. In order to provide the angular offset required by the present invention, the threaded portions on one or more ends of one or more of the pipe sections may be provided at an offset angle. This, combined with a chosen rotation of a pipe section carrying the offset connector can set a desired angle of approach, relating to the connector hubs on the subsea equipment. It will be appreciated that other connectors and methods of joining the pipe sections are possible.

For example the connectors can be pinned together as is known in the oil & gas industry. In these methods, two parts making up the connector are aligned, a pin part of the connector is inserted into a box part of the connector until the connectors are partially mated. Hydraulic pressure can be induced into the radial space between the pin and box sections to elastically expand the space between the pin and box. This allows complementary circumferential grooves provided on the pin and box to pass over one another as the pin is introduced further into the box by a longitudinally acting force. Once the pin is fully inserted into the box, the hydraulic pressure is removed. This causes the elastic forces in the pin and box to bring the complementary grooves radially together to lock the connectors together. These types of connectors are an example of one which allows the pipe sections to be connected together at substantially any relative rotational angle, since the circumferential grooves can engage one another at any relative rotational angle. Any such connector which allows the relative rotational angle of the connectors to be selected on assembly can be used in embodiments of the invention.

The connector portions may be welded onto pipe sections or formed integrally on the pipe sections. Any method of construction which achieves the desired resulting angular offset may be used.

It can be seen that the conduit sections A, B, C, D, E and F in the idealised scenario shown in Fig. 1 all lie substantially in the same plane, which extends vertically and between the two subsea structures S1, S2, along the net flow axis. In reality, due to the exact positions of S1, S2, which may be one of a wellhead, a manifold, a tree or similar, the connectors C1 and C2 may not be vertical as shown in Fig. 1, but may rather be at a non-zero orientation with respect to a vertical line through C1 or C2 and/or with respect to the plane on which the components shown in Fig. 1 substantially lie. If this is the case, the angle of approach of the ends of the jumper assembly will have to be modified from the ideal case mentioned above.

For this reason, one or more of the mechanical connectors 1, 2, 3, 4 and 5 that are installed in the jumper assembly 10 can be provided as a mechanical angular-offset connector. Shown in Figs. 2 and 3 are angular-offset connectors 2 and 4, and their angular offset in relation to conduit sections C and D, respectively, can be seen in the figure. Angular offset connector 2 defines a non-zero connector offset angle AB with respect to the net flow direction along conduit section C. Mechanical offset connector 4 defines a non-zero connector offset angle AC with respect to the net flow direction along conduit section D. Offset angles AB and AC therefore relate to the offset between the net flow axis of conduit sections C and D with the conduit sections connected to the other end of mechanical offset connectors 2 and 4, respectively.

It will be appreciated that when an angular offset connector is connected to a conduit section C or D and a further conduit section is attached to the opposite end of the angular offset connector, if the angular offset connector of conduit section C or D is rotated, then the direction of the conduit section attached to the second end of the connector will be rotated also, and the net flow path of the rotating further conduit section will sweep out a cone around the angle AB or AC. In the context of the jumper assembly 10 shown in Fig.1 the rotation of mechanical offset connector 2 or conduit section C about its longitudinal axis leads to a change in the angle of approach of the end of conduit section A, through the coupled movement of conduit sections A and B.

Described another way, mechanical offset connectors 2 and 4 are arranged to receive a fluid conduit section at each end. When the two conduit sections are connected via the offset connector 2, 4, a non-zero offset angle AB, AC exists between the ends of the attached two fluid conduits. The purpose of the offset connector is to provide the end of the jumper assembly the correct offset angle from the ideal angle of approach required by the particular location into which it is to be installed, in order that that the jumper assembly may be installed in its location correctly.

A horizontal tie-in spool assembly is shown in Fig. 4. In this embodiment, the flow-line is connected to the subsea equipment via a horizontal, rather than vertical, connection. The jumper assembly 10 is formed of conduit sections A, B, C D, E and F as before, and these conduit sections are joined by mechanical connectors 1, 2, 3, 4, 5 In the assembly shown in Fig. 4, the conduit sections A, F which are attached to the subsea equipment S1, S2 lie in a substantially horizontal plane. Conduit sections A and F contain a right angle bend and can be said to be L sections. It will be apparent that any conduit section providing a net flow direction change of 90° can fulfil the function of sections A and F in this respect. Conduit sections B and E are U-shaped, and in this example contain two right angle bends. Equally possible is a U conduit comprising one right angle bend and a further bend having an angle of less than 90°, and an L section in which the angle of the bend is not 90°.

The embodiment shown in Fig. 4 shows all conduit sections lying on the sea bed in a substantially horizontal configuration.

As in the vertical tie-in embodiment, mechanical connectors 1 and 5, that is, the connectors closest to the ends of the jumper assembly, are rotationally adjustable and lie substantially offset to the net flow axis of the jumper assembly. Mechanical connectors 2 and 4 are angular offset connectors of the type shown in Figs. 2 and 3. In this system, the rotation of mechanical connectors 1 and 5 is carried out to lift or lower the ends of B and E that are distal from connectors 1 and 5 respectively, and in this way alter the overall length of the jumper assembly. It will be appreciated that to achieve a viable length adjustment, mechanical connectors 1 and 5 must be rotated, thereby lifting sections C and D from the sea bed. It is envisioned that connectors 1 and 5 would preferably be rotated by the same amount, because rotating one of these connectors without the other would introduce a twisting and torsion to the string of conduit sections which may be undesirable. This is not a requirement of the invention, however, and various combinations of same or differing amounts of rotation of the connectors are possible.

To compensate for the angle change which could result from the rotation of mechanical connectors 1 and 5, angular offset connectors 2 and 4 are provided. Mechanical offset connectors may be provided so that the angle of incidence of the end of conduit section B with respect to connector 2 is angularly offset from the longitudinal axis of conduit section C, likewise for conduit sections E and D with respect to mechanical offset connector 4. Put another way, the flow direction at one side of the mechanical offset connector 2, 4 is angularly offset from the flow direction at the other side of the connector.

In both the vertical and horizontal tie-in embodiments shown in Figs. 1 and 4, mechanical connector 3 is a standard connector, and does not provide an angular offset to the conduit sections connected to it. This can be removed, if necessary, where the jumper assembly comprises only four or five conduit sections.

Fig. 5 shows the length of the jumper assembly, and the range of motion which can be achieved with the placing of rotationally adjustable connectors in the sections of pipe which lie at an angle which is at a non-zero relative to the net flow path of the jumper assembly. In the case of the jumper assembly shown in Fig. 5, the mechanical connectors are located between the vertically extending portions of conduit sections B and E and conduit sections A and F, respectively.

Conduit sections A and F are U-shaped conduit sections, meaning that they having a net change in flow angle between first and second ends of the conduit section of substantially 180 degrees. Specific examples can contain two right angled bends. More broadly, it can be said that the flow direction at the inlet of conduit sections A and F is spatially offset and substantially the inverse of the flow direction at the outlet of conduit sections A and F. Due to the use of L-Shaped and U-shaped conduit sections, it is possible to place connectors into the pipe-string at points where the axis of the connector, that is to say the flow direction through the connector, is substantially offset from that of the net flow axis of the jumper assembly. Therefore, rotation of these connectors, or of the conduit sections which extend from the connector towards the end of the assembly will cause a change in the length of the assembly.

As can be seen, if the mechanical connectors 1 or 5 are rotated, this in turn causes the free ends of conduit sections A and F to sweep out the arc T1, shown. This is due to the form of the U-shaped conduit sections, or more broadly to the fact that the axes of the flow directions at the inlet and outlets are spatially offset. When one of the "legs" of the U-shaped conduit is rotated on its axis, the other leg sweeps out a circular arc with this axis at its centre. While sections A and F are U-shaped in this embodiment, it will be appreciated that many other forms of conduit section are possible which would achieve the same result, notably a conduit section wherein the U-shape comprises one smooth arc between the legs. There is no requirement that the flow directions be exactly axially inverted; a range of possible angles exists and may be beneficial in particular installation conditions.

This means that, given the fact that the length between the two subsea structures to be connected is known, the length can be easily adjusted to the exact length required based on the received metrology data, without the need for the conduit sections to have precisely manufactured lengths.

The jumper assembly of the present invention can accommodate and be adjusted for a large range of horizontal length variation, depending on the jumper design. It will be apparent that the lateral distance between the first and second end of conduit sections A and F, for example, can set by how much the length of the overall assembly can be adjusted by rotation of the relevant connectors, 1 and 5.

As can be seen in Fig. 6, the use of angular offset connectors allows for a change in the angle of approach of the end of the jumper assembly, so that it may be adjusted prior to installation. The angle of offset provided by the angular offset connectors shown is such that the axis of the connecting portion of conduit section E is offset from the axis of the connecting end of conduit section D by a pre-set angle of up to 3°. The range of possible angles can be seen outlined in the conical section labelled T_4. A range of pre-set angles may be chosen. Rotation of the adjacent pipe sections then sets the direction in which this angular offset is applied. T_3 indicates a section of the range of possible angles which might be used in the vertical tie-in embodiment. The exact angle of offset provided by the mechanical offset connector is determined during manufacture of the conduit sections. The angle of rotation is then set following receipt of the metrology data to apply the right combination of angular offsets in each angular offset connector to achieve the appropriate angle of approach at each end of the assembly. An offset angle of 3° or less means that the pipe sections can be treated as a straight pipe in accordance with the ASME B31.8 mitre specification. The range of overall angles that can be accommodated by the present system, when provided with multiple angular offset connectors has a range of angles spanning from zero, up to the sum of the angles provided in all of the angular offset connectors in the assembly. In an example where two connectors each with an offset of 3° can therefore result in a maximum difference in angle of approach between each end of the assembly of 6°. Angles between 0° and 6° can be provided by appropriate rotation of the two connectors to complement or cancel one another's angular offset. Partial rotation of the connectors can provide a 3° offset in a first direction from a first angular offset connector, while a second connector can be rotated to provide a 3° angular offset in a different direction. This gives rise to a large range of different permutations which can accommodate a large range of different angles of approach, as illustrated by the cone-shaped envelopes shown in figures 5 and 6. It will be appreciated that angular offset connectors can be provided with angles greater than 3°, and it is envisaged that connectors with offset angles of 5° or up to 10° or more are possible.

It will be appreciated that the angles of rotation and offset provided for in figures 5 and 6 may be applied to the horizontal tie-in embodiment, applied to the appropriate conduit sections.

Both the angular offset connectors and the rotationally adjustable connectors which lie offset from the net flow axis can be provided with indexing markings. These can, for example, take the form of visible angular markings, or physical mating portions on the outer body of the connector and conduit sections which may be appropriately aligned by the installation engineer.

Once a wellhead and a tree assembly, manifold or other piece of subsea equipment have been installed on the seabed and identified as requiring a fluid connection via a jumper assembly, the field layout can be assessed to determine the length and shape of a jumper assembly to within a fixed tolerance. The field layout may be known to an accuracy of +/- 5m at the time of field layout design but prior to field installation and the in-situ advanced metrology being carried out.

The field layout can be used to pre-select the components of the jumper assembly, having appropriate numbers of conduit sections, with the appropriate offset angled connectors. These can then be taken on the installation vessel or on any transport vehicle to the site. The pre-fabricated jumper assembly can be pre-assembled if necessary, to within the tolerances of the known field layout, such that it can later be adjusted following receipt of more accurate metrology data as appropriate. The metrology of the hubs on the subsea equipment is carried out and relayed to the vessel.

The jumper can then be configured by the various rotations of the conduit sections. The length of the jumper set by appropriate selection of the relative angle of rotation of mechanical connector 1 or 5, at the first end of the jumper assembly, and which lies offset from the longitudinal axis of the jumper assembly. In the figures it can be seen that this sweeps the ends of conduit sections A or F through a circular arc. The point on the arc in alignment with the plane of the jumper assembly provides the greatest length. The length of the jumper assembly can be adjusted, in some example, by up to 10m through this method of alignment, depending on the dimensions of the conduit sections connected to connectors 1 and 5 as discussed above. The overall length adjustment is only limited by the overall field layout and possible jumper configurations.

The alignment of the hub connection at the end of the jumper assembly is set by selecting an appropriate relative rotational alignment of one or both of the angular offset connectors.

The same process of length adjustment and hub alignment is then carried out at the other, second end of the jumper assembly. The length can be adjusted by rotational adjustment of the mechanical connector which is offset from the longitudinal axis of the jumper assembly, and the hub alignment of the end of the jumper assembly is adjusted by rotation of the mechanical offset connector. This can be carried out concurrently or following the adjustment of the first end. After metrology is complete, it may be determined that a compound overall length and relative rotational position of each of the angular offset connectors is required. Selecting a certain angle in one angular offset connector may affect overall jumper length as well as angle of approach at one or both ends. Therefore the key aim is to achieve a set length and a set change in angle of approach between opposing ends of the jumper assembly, by appropriate selection of angular positions of any or all of the connectors in the assembly.

CLAIMS

1. A jumper assembly for providing a fluid connection path between hydrocarbon production or processing equipment, the assembly comprising a plurality of fluid conduit sections joined by mechanical connectors and having a net flow axis extending between fixing points for the first and second ends of the assembly,

   wherein at least one mechanical connector is oriented such that rotation of adjacent conduit sections about the mechanical connector induces a change in an overall length of the assembly and at least one angular offset connector is mounted to a conduit section at an offset angle such that rotation of the angular offset connector relative to a longitudinal axis of the conduit section induces a change of angle of an end of the assembly relative to the net flow axis.

2. The jumper assembly of claim 1, wherein the jumper assembly comprises at least a hub connection at a first end of the jumper assembly, connected to a first end of a first conduit section, the second end of the first conduit section being connected to the mechanical connector; the mechanical connector further connected to a first end of a second conduit section, and the second end of the second conduit section being connected to a first angular offset connector.

3. The jumper assembly of claim 2, wherein the jumper assembly further comprises a third conduit section connected at a first end to the first angular offset connector, and preferably connected at a second end to a second mechanical connector.

4. The jumper assembly of claim 3, further comprising a fourth conduit section connected at a first end to the second mechanical connector, and preferably connected at a second end to a second angular offset connector.

5. The jumper assembly of claim 4, wherein further comprising a fifth conduit section, connected at a first end to the second angular offset connector, and preferably connected at a second end to a third mechanical connector.

6. The jumper assembly of claim 5, further comprising a sixth conduit section, connected at a first end to the third mechanical connector, and preferably connected at a second end to a second hub connection.

7. The jumper assembly of claim 2, wherein the jumper assembly further comprises a third conduit section connected at a first end to the first angular offset connector, and preferably connected at a second end to a second angular offset connector.

8. The jumper assembly of claim 7, further comprising a fourth conduit section, connected at a first end to the second angular offset connector, and connected at a second end to a second mechanical connector.

9. The jumper assembly of claim 8, further comprising a fifth conduit section, connected at a first end to the second mechanical connector, and connected at a second end to a second hub connection.

10. The jumper assembly of claim 2, wherein the jumper assembly further comprises a third conduit section connected at a first end to the first angular offset connector, and connected at a second end to a second mechanical connector.

11. The jumper assembly of claim 10, further comprising a fourth conduit section connected at a first end to the second mechanical connector, and connected at a second end to a second hub connection.

12. The jumper assembly of any of claim 2 to 11, wherein the first conduit section has a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet.

13. The jumper assembly of claim 12 wherein net change in the flow direction at the inlet and the outlet of the first conduit section is substantially 180°.

14. The jumper assembly of claim 12 or claim 13, wherein the first conduit section is a U-shaped conduit section.

15. The jumper assembly of any of claims 2 to 14 wherein the second conduit section has a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°.

16. The jumper assembly of claim 15 wherein the second conduit section is an L-shaped conduit section.

17. The Jumper assembly of any of claims 2 to 16, wherein rotation of the first conduit section about an axis of a first end of the conduit section connected to the first mechanical connector induces the change in an overall length of the assembly.

18. The jumper assembly of any of claim 2 to claim 6 wherein the fifth conduit section has a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°.

19. The jumper assembly of claim 18 wherein the fifth conduit section is an L-shaped conduit section.

20. The jumper assembly of claim 18 or claim 19, wherein the sixth conduit section has a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet.

21. The jumper assembly of claim 20 wherein net change in flow direction between the inlet and the outlet of the sixth conduit section is substantially 180°.

22. The jumper assembly of claim 20 or claim 21, wherein the sixth conduit section is a U-shaped conduit section.

23. The jumper assembly of any of claim 20 to claim 22, wherein rotation of the sixth conduit section about an axis of a first end of the sixth conduit section connected to the first mechanical connector induces a change in an overall length of the assembly.

23. The jumper assembly of any of claim 7 to claim 9 wherein the fourth conduit section has a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°.

24. The jumper assembly of claim 23 wherein the fourth conduit section is an L-shaped conduit section.

25. The jumper assembly of claim 23 or claim 24, wherein the fifth conduit section has a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet.

26. The jumper assembly of claim 25 wherein the net change in flow direction between the inlet and the outlet of the fifth conduit section is substantially 180°.

27. The jumper assembly of claim 25 or claim 26, wherein the fifth conduit section is a U-shaped conduit section.

28. The jumper assembly of claim 10 or claim 11, wherein the third conduit section has a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90°.

29. The jumper assembly of claim 28 wherein the third conduit section is an L-shaped conduit section.

30. The jumper assembly of claim 28 or claim 29, wherein the fourth conduit section has a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet.

31. The jumper assembly of claim 30 wherein the net change in flow direction between the inlet and the outlet of the fourth conduit section is substantially 180°.

32. The jumper assembly of claim 30 or claim 31, wherein the fourth conduit section is a U-shaped conduit section.

33. The jumper assembly of any preceding claim, wherein the jumper assembly is of the vertical tie-in type.

34. The jumper assembly of any of claim 1 to claim 32, wherein the jumper assembly is of the horizontal tie-in type.

35. The jumper assembly of claim 1, further comprising a first conduit section having a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet towards a first end of the jumper assembly, and a second conduit section having a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet towards a second end of the jumper assembly.

36. The jumper assembly of claim 1, further comprising a first conduit section having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to substantially 90° towards a first end of the jumper assembly, and a second conduit section having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to 90° towards a second end of the jumper assembly,

37. The jumper assembly of claim 35, comprising a first conduit section having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to substantially 90° towards a first end of the jumper assembly, and a second conduit section having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to substantially 90° towards a second end of the jumper assembly,

38. The jumper assembly of claim 37, wherein the one or more of the conduit sections having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to substantially 90° is located between the first and second conduit sections each having a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet.

39. The jumper assembly of claim 37, wherein one or more of the conduit sections having a flow direction at its inlet which is axially offset from and substantially inverted relative to the flow direction at its outlet is between the conduit sections each having a net change in flow direction between its inlet and its outlet of a non-zero angle of up to substantially 90°.

40. The jumper assembly of any claim 35 to claim 39, wherein at least one angular offset connector is located between the first and second respective conduit sections.

41. The jumper assembly of any preceding claim, wherein the offset angle is between 0° and 3°.

42. The jumper assembly of any of claims 1 to 40, wherein the offset angle is between 0° and 5°.

43. The jumper assembly of any preceding claim, wherein one or more of the mechanical connectors is/are provided with rotational indexing means for identifying a relative rotational orientation of connected conduit sections.

44. A kit of parts comprising a plurality of jumper assembly components comprising a plurality of fluid conduit sections and a plurality of mechanical connectors, the conduit sections and mechanical connectors configured for providing the assembly of any of the preceding claims.

45. A method of manufacturing a jumper assembly, comprising:

providing a plurality of jumper assembly components comprising a plurality of fluid conduit sections and at least one mechanical connector and at least one angular offset connector;

assembling the jumper assembly components, wherein assembling includes: connecting the components together, thereby defining a net flow axis which extends between the two ends of the jumper assembly;

orienting at least one mechanical connector such that rotation of adjacent conduit sections about the connector induces a change in an overall length of the assembly, and

providing at least one angular offset connector, mounted to a conduit section at an offset angle, such that rotation of the angular offset connector relative to a longitudinal axis of the conduit section induces a change of angle of an end of the assembly relative to the net flow axis; and

setting a relative angle of rotation of the at least one mechanical connector to set a desired length of the jumper assembly; and

setting a relative angle of rotation of the at least one angular offset connector to set a desired angle of an end of the assembly relative to the net flow axis.

46. The method of claim 45, wherein the jumper assembly is of the vertical tie-in type.

47. The method of claim 45, wherein the jumper assembly is of the horizontal tie-in type.

48. The method of any of claims 45 to 47, wherein a conduit section adjoining the at least one mechanical connector has a flow direction at its inlet which is axially offset and substantially inverted relative to the flow direction at its outlet.

49. The method of any of claims 45 to 48, wherein the offset angle is between 0° and 3°.

50. The method of any of claims 45 to 49, wherein the offset angle is between 0° and 5°.

51. The method of any of claims 45 to 50, wherein at least one of the mechanical connectors is provided with indexing markings, and setting the relative angle of rotation of the at least one second mechanical connector includes referencing the position of the indexing markings.

52. A jumper assembly according to any of claims 1 to 44, wherein the angular offset connector is provided by mounting a connector to a conduit section such that the longitudinal axis of the connector is at an offset angle with respect to a flow axis of the conduit section at the relevant end.

53. A jumper assembly according to any of claims 1 to 44, wherein the angular offset connector is mounted to a conduit section in which the desired angular offset has been formed.