An assembly of underwater buoyant elements 2A, 2B connected to a submarine article such as a pipeline 1 allows it to float with appropriate reserve of floatability but significantly below the surface away from the zone A disturbed by waves, surface currents and weather. The apparatus consists in splitting the required amount of buoyant elements 2A, 2B between different water depth levels. Such a split limits stress and fatigue damage induced to the submarine article 1 to a minimum, hence allowing for long distance and less weather sensitive towing operations in open seas. It is possible to further enhance the apparatus by introducing dampening devices 6 within the surface buoys connecting links.
Main Pipe Lay Vessel
Conventional J-Lay / Reel Lay

Addition of an offshore Reeling Capability

Heard Surface Floating String

Assisting Tug
Improved buoyancy apparatus and method of use

Field of the invention

The present invention relates to an improved buoyancy apparatus and method of use, and in particular an improved apparatus and method for support and transport of a subsea article. In one of its aspects, the invention relates to a pipeline transportation method and apparatus, and to a method for transporting pipelines to an offshore pipeline installation site.

In an embodiment, the invention provides a safe and efficient method to transport pipeline sections from construction to installation site and pipeline sections may be towed over large distances across seas and oceans.

Background to the invention

In the field of transportation of pipelines it is desirable for offshore contractors to tow pipelines that are buoyant, quasi buoyant or non-buoyant to a pipeline installation site. This helps to reduce transportation and installation costs as the overall requirements on marine effort are reduced by making significant lengths of preassembled pipe sections available at the site.

Various towing methods have been used and may be classified in two categories:

a) Buoyant tows

These consist of towing an over buoyant assembly (including the pipeline) that naturally floats towards the water surface as depicted in Figures 1-A and 1-B. Figure 1-A represents a pipeline (1) being supported by two continuous sections of polymer pipelines (HDPE) (2). Figure 1-B represents a pipeline (1) being supported by conventional buoys (2).

In these cases, the connection between the floating system and the pipeline is made with soft slings or similar rigging.

b) Non Buoyant tows
These consist of towing an under buoyant assembly (including the pipeline under transport) that naturally sinks towards the seabed as depicted in Figures 2-A to 2-C.

Figure 2-A represents a bottom tow where the pipeline (1) is connected to a towing skid (4) which is being pulled by a vessel. Figure 2-C represents a different kind of bottom tow where chains (5) are fitted onto the pipeline (1) and help to regulate the pipeline altitude above the seabed. The overall assembly comprising pipeline and floats is over buoyant. Figure 2-B shows a mid-depth tow, where the pipeline (1) is suspended at both extremities from surface vessels (6).

The prior art tow types (a) and (b) described above have a number of limitations and drawbacks: which are being highlighted below.

In the case of towing an over-buoyant assembly, the pipeline (1) is close to the surface. The presence of surface waves acting on the assembly causes pipeline fatigue and damage. Fatigue is directly generated through the accelerations of the surrounding liquid impacting on the pipeline walls and indirectly through the attachment points of the buoyancy assembly (2).

The amount of fatigue generated within the pipeline while under tow is a critical parameter affecting operational performance of the pipeline. Fatigue damage incurred over surface tows using currently available towing arrangements is such that it impacts on the life expectancy of the pipeline. This transportation method is not viable if lengthy operations are expected on open seas with weather forecast availability not exceeding the expected duration of the operation itself. These tows are limited to favourable weather conditions.

In the case of towing an under-buoyant assembly, there are problems associated with towing in regions anomalous seafloor topography. In particular, boulders, debris or other hazards on the seafloor can cause pipeline to be damaged if the assembly is towed over these features.

Accordingly, to avoid damage the seafloor where the tow is to take place needs to be fully surveyed and mapped. This is costly and time-consuming if seafloor data is not available. In particular, if the pipeline needs to be towed long distances data is typically not available. In general therefore, it is not suitable to tow the assembly long distances.
It is an aim of the invention to obviate or at least mitigate the drawbacks and disadvantages associated with prior art apparatus and methods.

Other aims and objects of the invention will become apparent from the description below.

**Summary of the invention**

According to a first aspect of the invention there is provided apparatus for supporting a subsea article, the apparatus comprising a buoyancy assembly having at least one surface buoy and at least one submerged buoy spatially separated from but coupled to the surface buoy.

Preferably, the submerged buoy is arranged to be located at a depth beneath a disturbed region of water. Preferably, the submerged buoy is arranged to be located at a depth greater than 20m. More preferably, the submerged buoy is arranged to be located at a depth in the range of 20m to 100m. The submerged buoy may be arranged to be located at a depth in the range 30m to 50m.

Preferably, the apparatus comprises a plurality of surface buoys.

Preferably, the submerged buoy is adapted to be coupled to an article to be supported in use.

Preferably, the submerged buoy is coupled to the article. More preferably, the surface buoys are coupled to the submerged buoy by a buoy tether.

Preferably, the surface buoys are connected to the submerged buoy via a damped coupling.

Preferably, the shape of the surface buoy is selected to minimise tension transmitted through the buoy coupling during vertical movement of the buoy. Preferably, the surface buoy is elongate, having a longitudinal axis arranged substantially vertically in use.

Optionally, the shape of the submerged buoy is selected to minimise drag forces during lateral movement of the assembly. Preferably, the submerged buoy is elongate, having a longitudinal axis arranged substantially vertically in use.

Preferably, the submerged buoy provides the majority of the total buoyancy of the buoyancy apparatus, but not enough to float the subsea article. The addition of surface buoys makes the system fully over-buoyant.
Preferably, the submerged buoy provides 50% to 98% of the total buoyancy of the buoyancy apparatus. In this case, the one or more surface buoys will provide 50% to 10% of the total buoyancy.

In one embodiment, the submerged buoy provides 60% to 80% of the total buoyancy of the buoyancy apparatus. In this case, the one or more surface buoys will provide 40% to 20% of the total buoyancy.

In a further embodiment, the submerged buoy provides approximately 70% of the total buoyancy of the buoyancy apparatus.

Preferably, the article is a subsea pipeline.

According to a second aspect of the invention there is provided an assembly comprising buoyancy apparatus and a subsea article supported by the buoyancy apparatus, wherein the buoyancy apparatus includes at least one surface buoy and at least submerged buoy.

Preferably, the net buoyancy of the buoyancy assembly is greater than that required to support the article.

Preferably, the buoyancy of the submerged buoy is less than that required to support the article. Preferably, the buoyancy of the at least one surface buoy is less than that required to support the article. Thus the buoyancy apparatus provides an over buoyant system comprising two under buoyant subsystems.

Preferably, the submerged buoy is coupled to the article. More preferably, the surface buoys are coupled to the submerged buoy by a buoy tether.

Preferably, the surface buoys are connected to the submerged buoy via a damped coupling.

Preferably, the shape of the surface buoy is selected to minimise tension transmitted through the buoy coupling during vertical movement of the buoy. Preferably, the surface buoy is elongate, having a longitudinal axis arranged substantially vertically in use.

Optionally, the shape of the submerged buoy is selected to minimise drag forces during lateral movement of the assembly. Preferably, the submerged buoy is elongate, having a longitudinal axis arranged substantially vertically in use.
 Preferably, the submerged buoy provides 50% to 90% of the total buoyancy of the buoyancy apparatus. In this case, the one or more surface buoys will provide 50% to 10% of the total buoyancy.

In one embodiment, the submerged buoy provides 60% to 80% of the total buoyancy of the buoyancy apparatus. In this case, the one or more surface buoys will provide 40% to 20% of the total buoyancy.

In a further embodiment, the submerged buoy provides approximately 70% of the total buoyancy of the buoyancy apparatus.

Preferably, the submerged buoy is arranged to be located at a depth beneath a disturbed region of water. Preferably, the submerged buoy is arranged to be located at a depth greater than 20m. More preferably, the submerged buoy is arranged to be located at a depth in the range of 20m to 100m. The submerged buoy may be arranged to be located at a depth in the range 30m to 50m.

Preferably, the article is a subsea pipeline.

According to a third aspect of the invention there is provided a method of transporting a subsea article, the method comprising the steps of:

- providing a buoyancy apparatus to support a subsea article, the buoyancy apparatus comprising an arrangement of surface buoys and at least one submerged buoy;
- Supporting the subsea article beneath a disturbed region at the sea surface, and;
- Transporting the subsea article.

Preferably, the buoyancy apparatus is as defined by the first aspect of the invention.

According to a fourth aspect of the invention there is provided a method of transporting a subsea pipeline, the method comprising the steps of:

- providing a buoyancy apparatus to support a subsea pipeline, the buoyancy apparatus comprising an arrangement of surface buoys and at least one submerged buoy;
- Supporting the subsea pipeline beneath a disturbed region at the sea surface, and;
- Transporting the subsea pipeline.
Preferably, the buoyancy apparatus is as defined by the first aspect of the invention.

According to a fifth aspect of the invention there is provided a vessel for laying subsea pipelines, the vessel comprising means for receiving a length of pipeline at an offshore location.

Preferably, the vessel is adapted to receive a pipeline supported by the apparatus of the first aspect of the invention.

Preferably, the vessel is provided with a reel for storing the pipeline received from the buoyancy apparatus.

According to a sixth aspect of the invention there is provided a method of installing a pipeline, the method comprising the steps of:

- Supporting a pipeline by a buoyancy apparatus at an offshore location;
- receiving onto a pipe laying vessel;
- apparatus at an offshore location, and;
- installing the pipeline from the pipe laying vessel.

Preferably, the pipeline is supported by the pipeline apparatus of the first aspect of the invention.

The method may include the additional step of transporting the pipeline to the offshore location using the method of the fourth aspect of the invention.

The method may include the steps of receiving the pipeline onto a storage reel while a second pipeline is installed from the pipe laying vessel.

**Brief description of the drawings**

There will now be described, by way of example only, embodiments of the invention with reference to the following drawings, in which:

Figure 1-A is a schematic representation of a prior art surface-buoyant pipeline towing assembly;

Figure 1-B is a schematic representation of a further prior art surface-buoyant pipeline towing assembly;
Figure 2-A is a schematic representation of a prior art under-buoyant pipeline towing assembly;

Figure 2-B is a schematic representation of an alternative prior art under-buoyant pipeline towing assembly;

Figure 2-C is a schematic representation of further alternative prior art under-buoyant pipeline towing assembly;

Figure 3 is a schematic representation of a pipeline towing assembly in accordance with an embodiment of the invention;

Figure 4 is a schematic representation of behaviour of different buoys for the pipeline towing assembly of Figure 3;

Figure 5 is a schematic representation of an alternative buoy according to an embodiment of the invention; and

Figure 6 is a schematic representation of a pipeline towing assembly in use together with a pipe laying vessel according to an embodiment of the invention.

**Detailed description of the invention**

With reference firstly to Figure 3, there is shown a method of towing a pipeline (1). The pipeline (1) is towed below the zone A typically affected by surface disturbances, i.e. about 40 meters below the surface.

Buoyant material (2B) is attached to the pipeline (1) also within the disturbed zone. The shape of those submerged buoyant material 2B is optimised to reduce the drag forces.

A number of buoys (2A) are attached in turn to the buoyant material 2B to provide further buoyancy to the pipeline and turns the entire assembly into a fully over buoyant assembly. Surface floats directly connected to the mid depth buoyant material 2B limits the stress transmitted to the pipeline.

The buoys 2A are linked (via the intermediate buoyant material 2B) to the pipeline through damping tethers (6). The buoys 2A have shapes that are optimised to minimise both the accelerations transmitted through the float attachments and the drag forces while under tow.
This arrangement allows the pipeline to be towed at depth, while transmission of surface effects on the floats or buoys at the surface to the pipeline at depth is minimised through the damping tethers (6). Damping may be achieved through elastic properties or could be for example a shock absorber.

The buoyancy of the tow assembly, which is shared between surface buoys 2A and mid-water buoyant material 2B is determined as follows:

\[ X \] is the net buoyancy required to zero the pipeline gravity. A Safety Factor SF1 is required to be greater than 1 and is chosen this way to guarantee that the pipeline will always remain buoyant regardless of expected sea water densities and allows for accidental loss of some floats. For example, SF1 could be chosen as equal to 1.3.

On this basis, the total net buoyancy to be installed is \( X \times SF1 \) tons.

Note: submerged pipeline own buoyancy is taken into consideration in all calculations.

Further, the pipeline is set below the disturbed area of the ocean and to avoid it coming accidentally to the surface, the pipeline 1 and 2B floats must be slightly heavy. Accordingly, the amount of net buoyancy provided by 2B must be below \( X \), say \((SF2-1)^*X\).

In order to prevent the pipeline breaking through the surface, SF2 is to be chosen between 1 and 2 providing a safety margin.

The amount of buoyancy is split as follows:

\[ 2A \text{ net buoyancy} = (SF1-SF2+1)^*X. \]
\[ 2B \text{ net buoyancy} = (SF2-1) ^*X. \]

Various safety factors shall take into account buoyancy compressibility when subject to increasing external pressure.

In Figure 4, the effect of buoy shape on the tension transmitted to the pipeline via the tether (6) is illustrated. Buoy 1 (B1) is a classical spherical buoy. Buoy 2 (B2) is a cylindrical buoy providing same uplift as B1 but with a high height to radius ratio.

The graph F(force) vs t(time) illustrates tension profiles through time and illustrates the amount of tension transmitted through the buoy tether when the buoy is hit by a wave.
Due to the shape of the buoy itself, the tension profile is smoothened and as a consequence the transmitted fatigue minimised.

In order to reduce further the drag forces, in the embodiment of Figure 5, assembling together the vertical cylinders to generate a long vertically orientated parallelogram with profiled extremities (refer to figure 5) may also be an option for buoy design.

The buoyant material 2B may be a continuous horizontal foam cylinder or an HDPE pipeline resisting to the crushing pressure.

An underwater shock absorber is inserted in each of 2A type buoyancy tethers. In other embodiments, this device might not be required depending upon the pipeline specification.

In Figure 6, there is shown a method of using the pipe towing apparatus as described above together with a conventional pipe laying ship fitted with a reel and clamp. In this arrangement the towed floating pipeline is fed onto the pipe laying ship which undertakes S-Lay or J-Lay pipe laying. In this case, the ship would be modified to welcome the near surface floating string. Using this method, the pipe laying vessel would not to have to travel back and forth to a spoolbase as pipeline sections would be brought to the vessel by the assisting tug.

The ship would first reel the floating string onto its reel and then lay it. On a ship equipped with 2 reels, it would be possible to feed a reel at the same time the other one is being laid. In this way, pipe sections can be stored to then lay it at a later time.

Various modifications and improvements may be made to the invention herein described without departing from the scope of the invention.
Claims

Improved Buoyancy Apparatus & Method of Use:

What is claimed is:

1. An apparatus to provide buoyancy to a submarine article in order to make it float with appropriate reserve of floatability but significantly below the surface away from the zone disturbed by waves, currents and weather. The apparatus consists in splitting the required amount of buoyant elements attached to the submarine article at different water depth levels;
   - some buoyant element(s) would be totally submerged close to the submarine article itself below the disturbed zone; and,
   - others would be at the surface within the disturbed zone.

2. The apparatus of claim 1 wherein the majority of the required buoyancy is provided by the submerged buoys whereas the remaining required buoyancy (including contingency guaranteeing the entire assembly will remain over buoyant despite some buoyancy loss or environmental changes or potential incidents) is provided through the surface buoys.

3. The apparatus of claim 1 wherein the surface buoys are optimised in shape – such as a vertically elongated volume – to provide as progressive as possible vertical forces variations when subject to waves.

4. The apparatus of claim 1 wherein the submerged buoys are optimised in shape – such as horizontally elongated volume – to minimise generated drag forces when under tow or subject to sub surface currents.

5. The apparatus of claim 1 wherein the link between surface buoys and submarine structure or submerged buoys includes a dampening mechanism such as a shock absorber or an elastic link.

6. A towing method allowing to move a submarine article and consisting in connecting tow means including one or more towing vessels to the subsea article and apparatus as described in claim 1 and possibly including any of the features described in any of the claims 2 to 5.

7. The towing method of claim 6 wherein the subsea article is a pipeline or section of pipeline.

8. A wet storage method consisting in connecting anchor means to the subsea article and apparatus as described in claim 1 and possibly including any of the features described in any of the claims 2 to 5. The anchor would be connected to the seabed or to any fix point.

9. The storage method of claim 8 wherein the subsea article is a pipeline to be kept in storage for an indefinite duration without suffering from swell, tidal currents or contact with the seabed.

10. A pipelay method wherein a pipelay vessel equipped with the appropriate equipment known in the industry – i.e. allowing a controlled lowering of a section of pipeline to the seabed – would be suitably equipped to recover a pipeline or a pipeline section having been previously brought to said vessel using the method of claim 7 and subsequently lay it to the seabed.

11. A pipeline loading method wherein a vessel would be suitably equipped to receive and load a pipeline or a pipeline section having been previously stored using the method of claim 9.
**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

<table>
<thead>
<tr>
<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>X,E</td>
<td>1, 2, 4, 6, 7, 10 &amp; 11</td>
<td>WO 2006/117249 A2 (ACERGY) see whole document, especially figures 1, 3, 5 and 7</td>
</tr>
<tr>
<td>X</td>
<td>1, 2 &amp; 6-11</td>
<td>GB 2114700 A (MOBIL) see whole document, especially figure 1</td>
</tr>
<tr>
<td>X</td>
<td>1, 2 &amp; 6-11</td>
<td>NL 8701849 A (BLUEWATER) see the figure in particular, and also WPI Abstract Accession No. 1989-098148 [13]</td>
</tr>
<tr>
<td>X</td>
<td>1, 2 &amp; 6-11</td>
<td>US 4075862 A (FMC) see whole document, especially figures 5 and 6</td>
</tr>
<tr>
<td>X</td>
<td>1, 2 &amp; 4</td>
<td>EP 0931965 A2 (URSPRUNG) see especially figure 2, and also WPI Abstract Accession No. 1999-155100 [14]</td>
</tr>
</tbody>
</table>

**Categories:**

<table>
<thead>
<tr>
<th>X</th>
<th>Document indicating lack of novelty or inventive step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Document indicating lack of inventive step if combined with one or more other documents of same category. &amp;</td>
</tr>
<tr>
<td>A</td>
<td>Document indicating technological background and/or state of the art.</td>
</tr>
<tr>
<td>P</td>
<td>Document published on or after the declared priority date but before the filing date of this invention.</td>
</tr>
<tr>
<td>E</td>
<td>Patent document published on or after, but with priority date earlier than, the filing date of this application.</td>
</tr>
</tbody>
</table>

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X:

- Worldwide search of patent documents classified in the following areas of the IPC
  - F16L

The following online and other databases have been used in the preparation of this search report:

- WPI, EPODOC
### International Classification:

<table>
<thead>
<tr>
<th>Subclass</th>
<th>Subgroup</th>
<th>Valid From</th>
</tr>
</thead>
<tbody>
<tr>
<td>F16L</td>
<td>0001/16</td>
<td>01/01/2006</td>
</tr>
<tr>
<td>F16L</td>
<td>0001/24</td>
<td>01/01/2006</td>
</tr>
</tbody>
</table>