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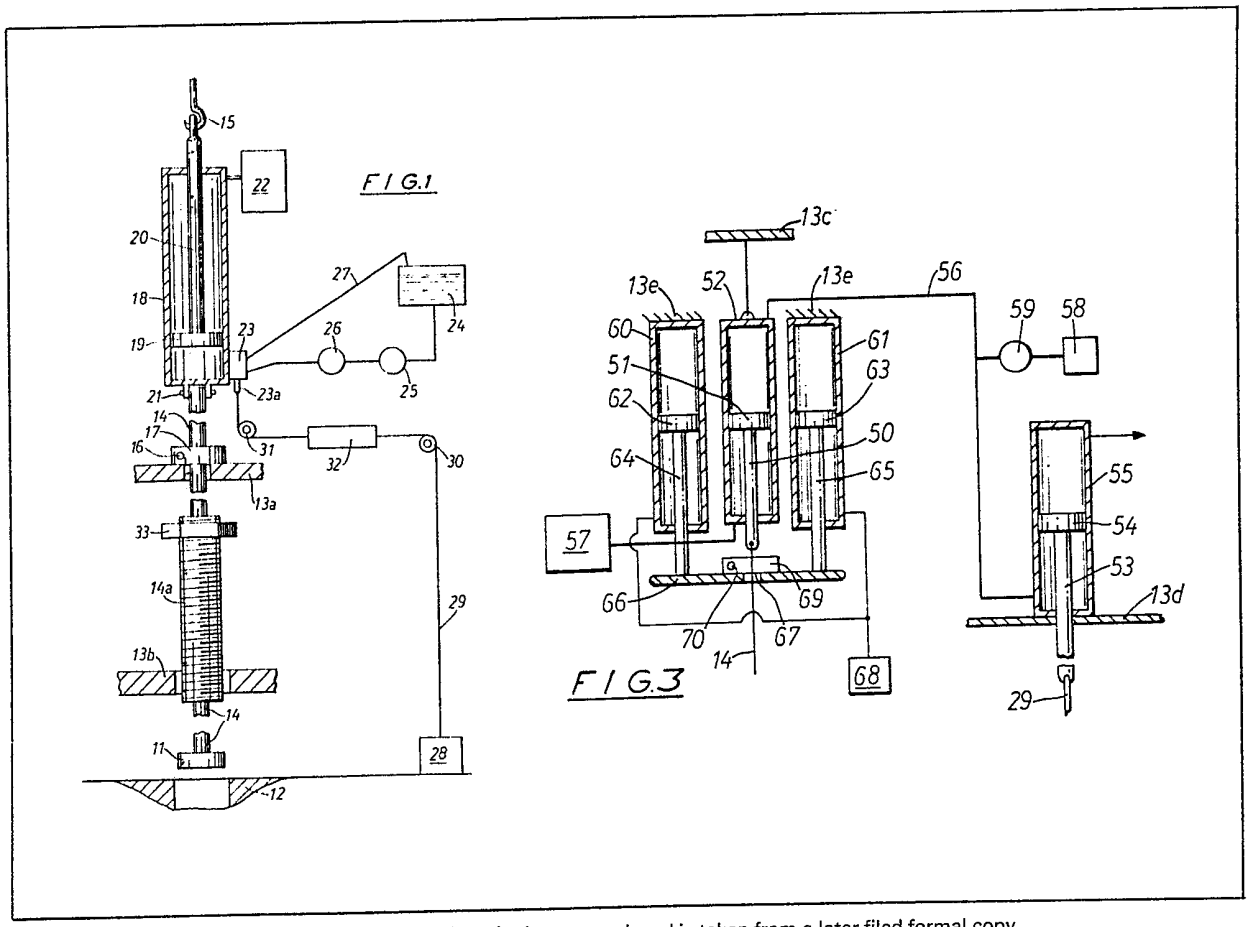
(71) Applicant **Robert Colin Pearson, 105, Welton Road, Brough. N. Humberside**
(72) Inventor **Robert Colin Pearson**
(74) Agents **H. L. Cottrell & Co., 22 Whitefriargate, Hull, North Humberside HU1 2EX**

(54) Anchoring arrangements for a floating structure

(57) The floating structure is to be anchored to the sea-bed by tension members (14) held in templates (12) fixed to the sea-bed. The invention provides a length adjusting device, effective between the floating structure and the tension member, and a control mechanism, mounted on the floating structure and connected by a physical link (29) to the sea-bed to continuously monitor the height of the structure above the template so as to adjust the effective length of said device, in dependence upon variations of said height, to eliminate vertical oscillations of the tension member when the latter is positioned near the template ready for engagement therewith.

In one embodiment said mechanism and said device comprise piston and cylinder arrangements (50, 51, 52 and 53, 54, 55 respectively) connected together without valves.



F I G.1

F I G.3

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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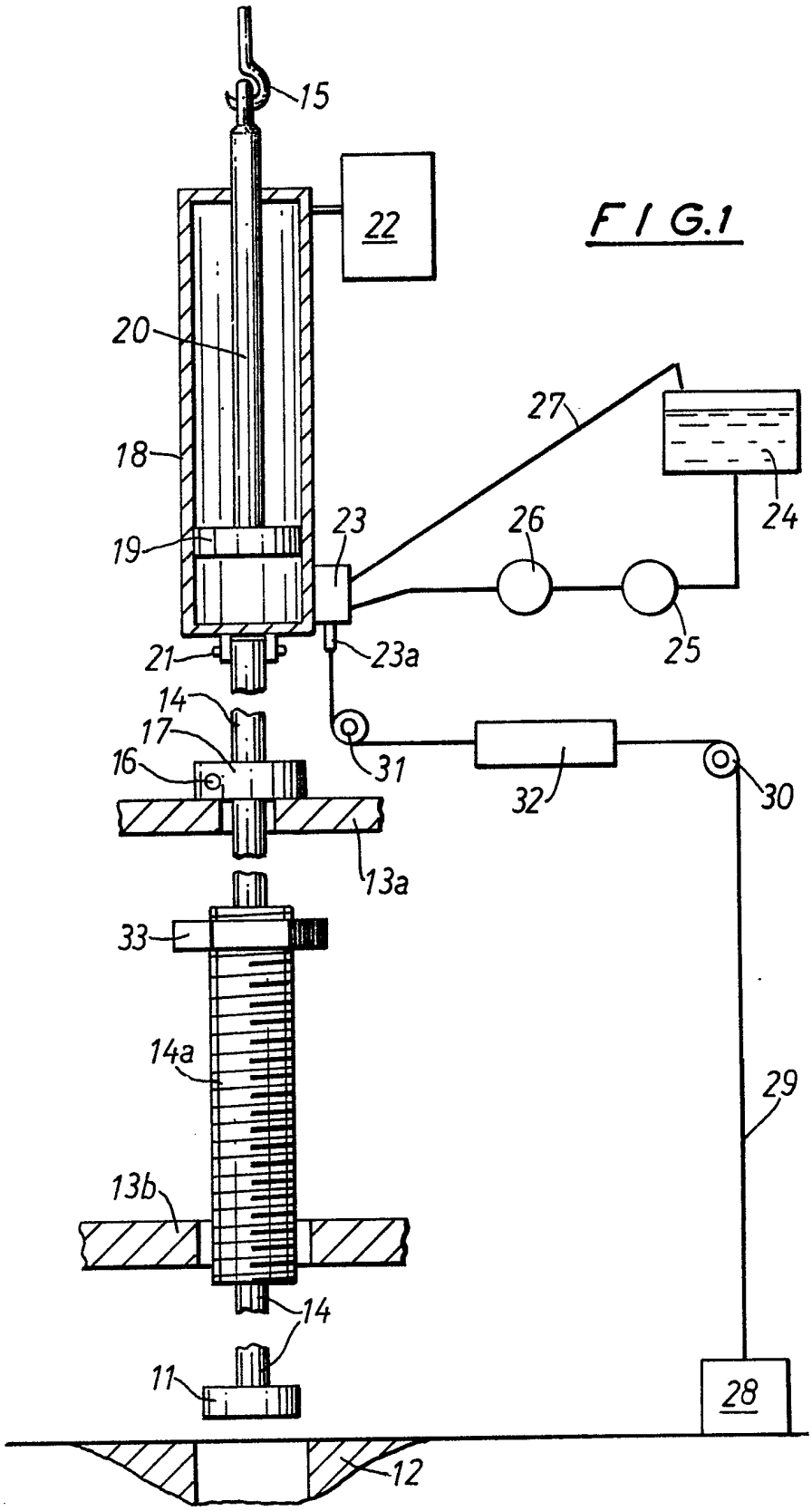

FIG.1

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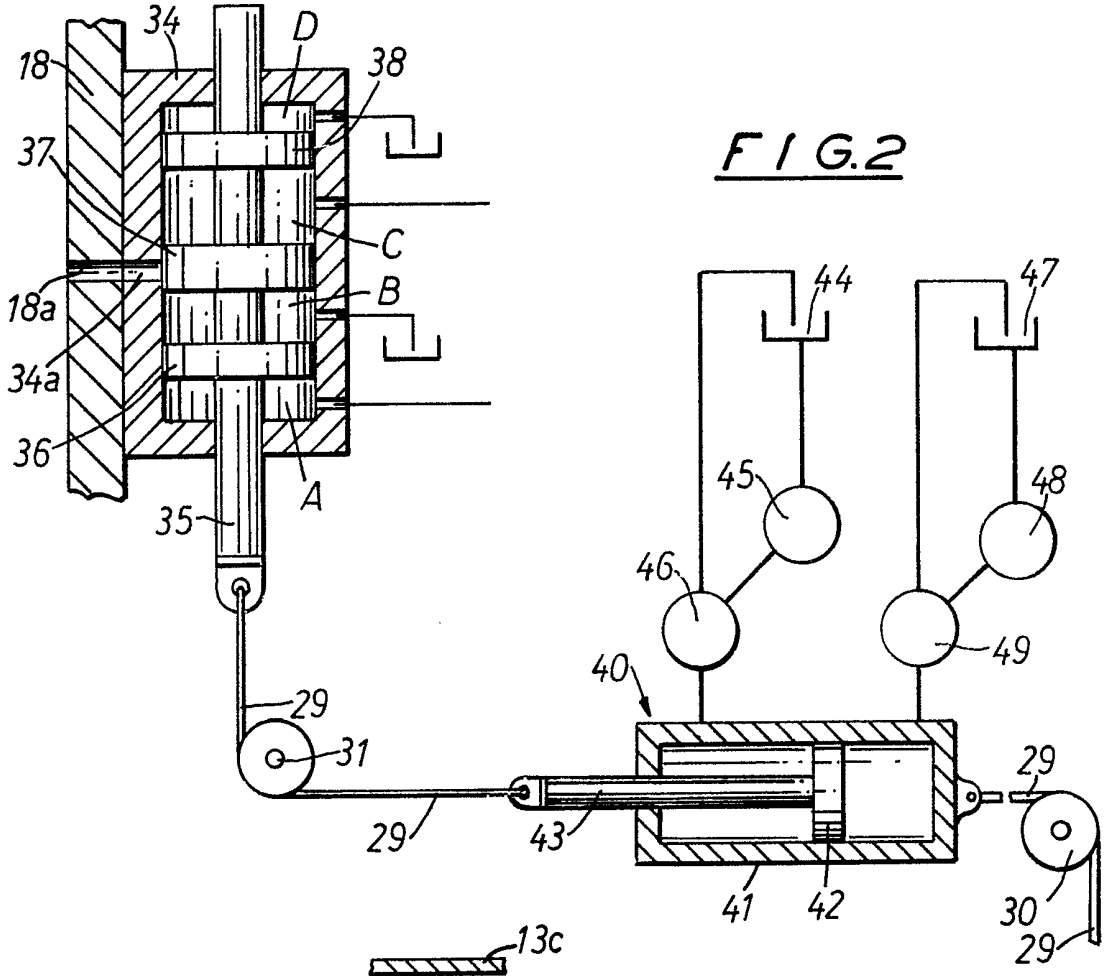

FIG.2

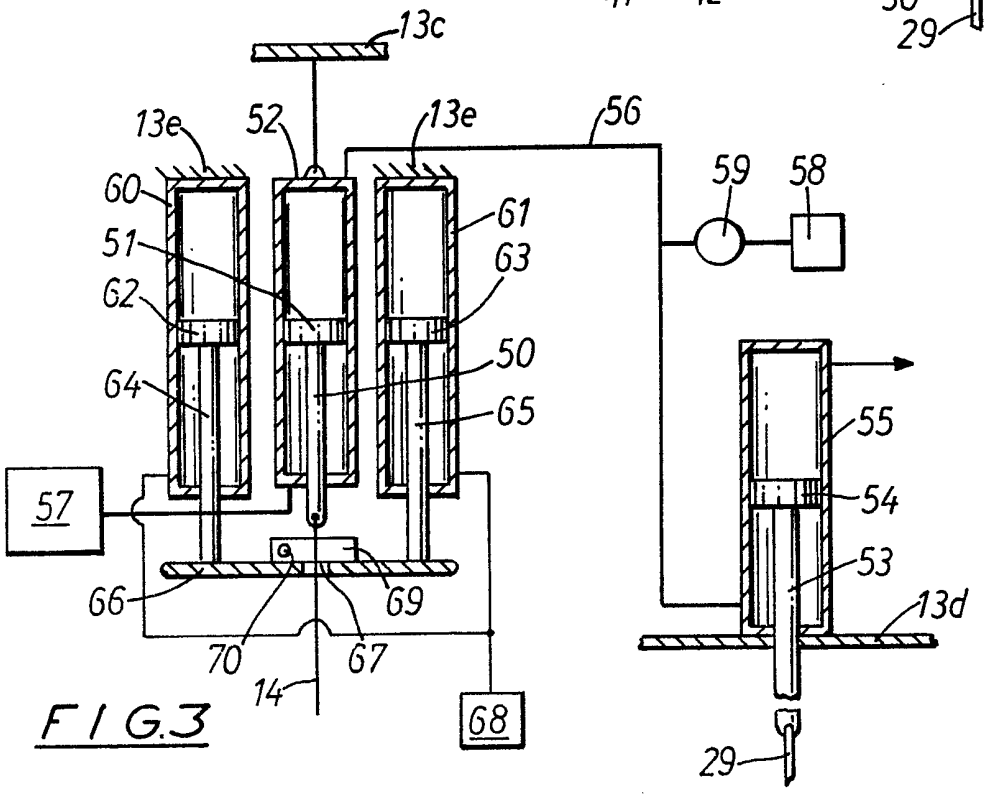

FIG.3

SPECIFICATION

Anchoring arrangements for a floating structure

Description

This invention relates to an anchoring arrangement for a floating structure and has particular application to a floating structure such as an off-shore platform.

So-called "off-shore platforms", generally gas or oil drilling or well servicing platforms, are well known in the art and are usually floated to the desired site and accurately anchored thereat. When operational the rig must be stable against sea and wind actions and when the rig it to be sited in shallow water it is usually supported from the sea bed on rigid legs but in deeper water a more sophisticated anchoring arrangement is required. It has already been proposed that a floating strucutre be anchored to fixed locations on the sea bed by tension members, the tension members when fully loaded drawing the floating structure downwardly from its normal bouyancy position to such depth as to render the structure vertically and horizontally stable. With such an arrangement each tension member must be lowered from the structure and anchored to a predetermined location on the sea bed, conveniently defined by a fixed anchorage member, hereinafter referred to as a "template", and each and every one of the tension members must be located with and anchored to its respective template before the predetermined tension necessary to hold the floating structure at the desired depth can be applied to said members.

One known form of template is secured to the sea bed by piles and presents an upwardly opening recess for receiving therein an anchor member secured on the lower end of the respective tension member. To effect anchorage, the anchor member on the tensile member is lowered into the upwardly opening recess in the template until said anchoring member applies a predetermined load to a trigger mechanism in the lower regions of the recess when a mechanism in the template is activated and elements in the template displace to positively engage and retain the anchor member in said recess. The configuration of such an anchor member and the configuration and mechanism of such a template are well known in the art and form no part of the present invention.

The tension member, frequently a tubular member and which may be made up of a plurality of sections connected together in each to end relationship, is lowered from the structure by a crane or the like lifting and lowering arrangement mounted on the floating structure. Such an anchoring arrangement is, hereinafter, referred to as "an anchoring arrangement of the type defined".

A serious difficulty with the known achoring arrangement of the type defined arises because the structure, in its normal bouyancy condition, can pitch and roll due to wave movements and vertical reciprocating displacement of the platform at a tension member location, which may be as much as one and a half metres, is transmitted to the anchor member of the tension member at that location as the anchor member is lowering towards the respective template so that there is always the danger that the reciprocating anchor member will enter the recess in its respective template, activate the anchorage mechanism, and displace upwardly out of the desired position for engagement by the template mechanism before the anchorage mechanism closes to engage said anchor member. If the anchor member triggers the template mechanism and is not correctly located and anchored thereby the template mechanism must be released, the anchor member withdrawn, the template mechanism reset, and the anchoring process repeated, a timetaking and dangerous operation and one which can adversely delay the anchorage of the platform.

The present invention seeks to provide an anchoring arrangement of the type defined and which overcomes the above described disadvantages.

According to the present invention there is provided an anchoring arrangement of the type defined including a length adjusting device effective between the floating structure and an anchor member to be anchored and a control mechanism mounted on the structure and connected by a physical link to the sea bed to continuously monitor the depth between the structure, at the anchor member suspension location, and the sea bed template for the anchor member, said control mechanism serving to adjust the effective length of the length adjusting device in dependance upon variations in the depth between the structure, at the anchor member supporting location, and the template.

Thus, by the arrangement proposed by the present invention, the length adjusting device extends and contracts in dependance upon the vertical oscillations of the structure at the anchor member supporting location to compensate for the vertical oscillations of the platform and, thereby, substantially reduce or eliminate vertical oscillation of the anchor member relative to the template.

In a preferred method of operation a lowering arrangement on the structure lowers the anchor member, supported by its tension member, to a location adjacent the template, preferably to within two or three feet of the template when that part of the structure supporting the anchor member is at its lowest point of oscillation so that, with the structure oscillating, the anchor member is oscillated with the structure just above and without contacting the template. The length adjusting device is then rendered effective in the suspension system for the tension member, the control mechanism for the length adjusting device is rendered effective and the length adjusting device then extends and contracts in timed relationship with the structure, in effect to counter the vertical component of the structure

oscillations and, thereby, to support the anchor member in a non-oscillating relationship with respect to the template. With the vertical oscillations of the anchor member eliminated the anchor member can be lowered into the template and the anchoring of the structure can proceed.

Preferably the length adjusting device comprises an hydraulic piston and cylinder arrangement arranged in the suspension system for the tension member supporting the anchor member.

In one embodiment in accordance with the invention one part of the piston and cylinder arrangement is suspended from the lowering arrangement for the anchor member assembly and the other part of the piston and cylinder arrangement is attached to the tension member supporting the anchor member. With this arrangement the stroke of the piston and cylinder arrangement need be little more than that necessary to effect a change of effective length equal to the maximum vertical oscillation of the structure at the anchor supporting location.

In operating the above described embodiment the piston and cylinder arrangement is controlled by the control mechanism to reduce or eliminate vertical oscillation of the anchor member and the lowering arrangement is then actuated to lower the anchor member into the template.

In another embodiment in accordance with the invention one part of the said piston and cylinder arrangement is secured to the structure and the other part of said device is attached to the tension member for the anchor member. With such an assembly the stroke of the piston in the piston and cylinder arrangement must be greater than the amplitude of the oscillation of the structure, at the point to which the piston and cylinder arrangement is supported, plus the displacement of the anchor member and tension member necessary to lower the anchor member into the template for effective securement.

Thus, in operating this embodiment, the whole of the support for the tension member and the anchor member is transferred from the lowering arrangement to the displaceable part of the piston and cylinder arrangement, the piston displaces within the cylinder in dependence upon the vertical oscillations of the structure to reduce or eliminate vertical oscillation of the anchor member and, thereafter, with the piston and cylinder arrangement oscillating to maintain a non-oscillating condition of the anchor member relative to the template, the mid-point of the oscillations of the piston within the cylinder is lowered, relative to the cylinder, to lower the anchor member into the template.

Preferably the control mechanism comprises a piston and cylinder arrangement, conveniently an hydraulic piston and cylinder arrangement.

In one embodiment in accordance with the invention one part of the piston and cylinder arrangement is fixed relative to the structure and the other part is attached to the physical link to the sea bed whereby, the piston reciprocates within the cylinder in direct response to the oscillations of the structure at the control mechanism location. With this arrangement the displacement of fluid to and from the cylinder, at one side or the other side of the piston, controls the length adjusting device and, in a preferred embodiment, one end of the cylinder defining the control mechanism is open to one end of the cylinder defining the length adjusting mechanism, thus permitting free flow of fluid between said cylinders.

In an alternative arrangement the control mechanism comprises a valve, actuated by the physical link, to supply and exhaust pressure fluid to and from the cylinder of the length adjusting device.

Preferably said valve comprises a shuttle valve, the cylinder of which is secured to the cylinder of the length adjusting device and the shuttle is directly connected to that end of the physical link remote from the sea bed.

In a preferred embodiment the piston rod of the length adjusting piston and cylinder arrangement is suspended from the lifting arrangement and the cylinder is suspended from the piston and piston rod assembly so as to be free to displace vertically, the tension member is secured to the cylinder, and the shuttle valve is arranged to supply and exhaust pressure fluid to and from the lower end of the cylinder. With such an arrangement the weight of the anchor member, the tension member, and the cylinder is supported by the pressure fluid above the piston head of the length adjusting device and which is maintained at constant pressure by an accumulator. The piston rod displaces vertically with the structure when the structure is oscillating and the shuttle has a fixed position relative to the sea bed whereupon if, from a shuttle valve closure position the structure experiences a vertically upward displacement such displacement is transmitted through the piston rod and piston to urge an upward displacement of the cylinder, which causes an upward displacement of the shuttle cylinder to open the shuttle valve and allow pressure fluid to enter the lower end of the cylinder. The entry of pressure fluid into the lower regions of the cylinder reduces the force difference across the piston head, whereupon the length adjusting device expands until, towards the termination of the upward displacement, the shuttle valve closes.

On a vertically downward displacement of the structure from the shuttle valve closure position the cylinder of the length adjusting device, and the cylinder of the shuttle, are initially lowered with the piston and piston rod of the length adjusting device, the relative displacement between the shuttle and the shuttle cylinder opens the valve to allow pressure fluid to exhaust from the lower end of the cylinder of the length adjusting device and thus the length adjusting device contracts. As the supply of fluid to and from the cylinder of the length adjusting device is directly related to the supply of pressure fluid through the shuttle valve, and as the shuttle of said valve has a fixed position

relative to the sea bed, the expansion and contraction of the length adjusting device effectively compensates for the oscillations of the structure and the anchor member is maintained in a relatively stable position relative to the template.

In a preferred embodiment in accordance with the invention the physical link includes a length adjusting device, conveniently a piston and cylinder arrangement, the length of which when increased or decreased serving to increase or decrease the effective length of the physical link whereupon, in any embodiment where the physical link actuates a valve to control the effective length of the length adjusting device, the mean length of the length adjusting device can be varied by varying the length of the length adjusting device in the physical link so that, with the length adjusting device normally reciprocating to counter the oscillations of the structure, the mean effective length of the length adjusting device supporting the anchor member can be increased to lower the anchor member, without oscillation, into engagement with the template.

The invention will now be described further by way of example with reference to the accompanying drawings in which:—

Fig. 1 shows, diagrammatically and partially in cross-section, one arrangement for lowering an anchor member into engagement with a template.

Fig. 2 shows, diagrammatically and partially in cross-section, an alternative control mechanism in accordance with the invention and,

Fig. 3 shows, diagrammatically and partially in cross-section, a third arrangement for lowering an anchor member into a template.

In the embodiment illustrated in Fig. 1 an anchor member 11 is to be anchored to a template 12 secured to the sea bed to anchor a floating structure, only parts of which are illustrated and identified by the numeral 13. The anchor member 11 is suspended by a tension member, generally indicated by reference numeral 14, and which conventionaly comprises a plurality of tubular lengths connected together in end-to-end relationship.

The anchor member 11, with its tension member 14, is lowered by a lowering arrangement mounted on the floating structure in known manner and, for clarity, only the hook 15 of the lowering arrangement is illustrated in the drawings.

To effect lowering of the anchor member 11 the hook 15 is engaged with the last attached length of tension member 14 and the lowering arrangement lowers the hook 15 to lower the assembly of tension members 14 and anchor member 11. When it is required to attach a new length of tension member 14 a hydraulic lock, generally identified by reference numeral 16, in a collar 17 surrounding the last attached tension member 14 is actuated to lock said tension member 14 with the collar 17 whereupon, when the collar 17 is lowered into engagement with a part 13*a* of the structure, the anchor member 11 and its supporting tension members 14 are thereby supported by the structure part 13*a*. The hook 15 is engaged from the last attached tension member 14, the new length of tension member 14 is secured to the upper end of the last attached tension member 14, the hook 15 is engaged with the upper end of the newly attached length of tension member 14, and the hydraulic lock 16 is then released to allow the lowering arrangement to lower the assembled tension members 14 and anchor member 11.

The lowering of the anchor member 11 is continued, step by step as defined above, adding successive lengths to tension member 14 until the anchor member 11 nears the template (as defined hereinafter) and during this part of the operation the anchor member 11, being suspended solely by the tension member 14 from the lowering arrangement or collar 17, will be subjected to the vertical oscillations of the floating structure at the location of the anchoring arrangement on said structure.

The lowering of the tension member 14 and anchor member 11 is terminated when the anchor member 11, at the lowest point of its oscillations, is some two to three feet above the template 12.

At this stage the hydraulic lock 16 is operated, to secure the collar 17 to tension member 14, the lowering arrangement lowers hook 15 until the collar 17 is resting on structure part 13*a* and wholly supporting the tension member 14 and anchor member 11 and the hook 15 is disengaged from the tension member 14.

A length adjusting device comprising an hydraulic cylinder 18, piston 19, and piston rod 20, is then attached to the hook 15 by passing hook 15 through an opening in the free end of the piston rod 20, whereby the cylinder is suspended from the piston 19 and rod 20, and the assembly 18, 19, 20 is brought into such position that the lower end of the cylinder 18 can be secured with the upper end of the last attached tension member 14 by a pin 21.

With the length adjusting arrangement 18, 19, 20 assembled between hook 15 and the tension member 14, hydraulic fluid is supplied to both ends of the cylinder 18, the supply to the upper end of the cylinder being maintained at constant pressure by an accumulator 22 and the fluid below the piston 19 being supplied to, or exhaused from, said cylinder end via a three-way valve 23 which, in one position, supplies pressure fluid from a reservoir 24 through a pump 25 and constant pressure device 26 to the cylinder below piston 19, in another position allows pressure fluid to exhaust from the cylinder below piston 19 via a conduit 27, back to reservoir 24, and a third position in which the region of the cylinder under piston 19 is closed against the supply and exhaust of fluid therefrom.

The fluid pressures in the upper and lower parts of cylinder 18 are adjusted so that the force across piston 19 is just sufficient to support the weight of cylinder 18 with valve 23, the weight of tension member 14, and the anchor member 11 supported by member 14, whereupon the cylinder 18 has a fixed position relative to piston 19, and at

this stage the hydraulic lock 16 is released so that the tension member 14 and anchor member 11 are wholly supported by the cylinder 18.

With the assembly arranged as described above the anchor member 11, tension member 14, cylinder 18, piston 19 and piston rod 20, all supported by the lowering arrangement 15, will oscillate in direct response to the oscillations of the structure at the anchor member supporting location.

Immediately adjacent the template 12 there is provided a weight 28 and a physical link, in this case a cable 29, extends from the weight 28 over a pulley 30, the bearings for which are presented by the structure, around a pulley 31, the bearings for which are presented by the structure, and that end of the cable 29 remote from weight 28 is secured to the actuating member 23*a* of the valve 23.

Once the connection of the physical link 29 with the actuating member 23*a* of the valve 23 has been completed the apparatus operates as follows.

From a mean position of the actuating member 23*a*, closing the cylinder 18 against the change of volume below the piston 19,

(a) if the structure, at the anchor supporting location, is subjected to an upward displacement such upward displacement is transmitted through the hook 15 to piston rod 20 and piston 19 to raise the cylinder 18 and the valve 23 secured thereto. The valve actuating member 23*a*, having a fixed position relative to the weight 28 by virtue of the physical link 29, displaces relative to the valve 23 to open the cylinder 18 below piston 29 to the supply of hydraulic fluid from constant pressure device 26, the increase in pressure in the lower regions of the cylinder 18 causes a reduction in the force difference across the piston 19 and the piston 19 therefore moves up the cylinder 18 (as viewed in Fig. 1).

The supply of fluid to the lower end of the cylinder 18 is continued whilst the actuating member 23*a* remains downwardly displaced with respect to the valve 23 and the supply of fluid to the cylinder 18, and the balance of the fluid pressures across the cylinder 18, are such that the displacement of piston 19 within cylinder 18 is equal to the rate of displacement of the vertical component of the oscillation of the structure whereby, as the piston and cylinder arrangement 18, 19 and 20 is expanding at a rate equal to the vertical displacement of the structure, the anchor member 11, tension member 14, cylinder 18 and valve 23 are thereby maintained in relatively fixed positions with respect to the template 12. When the upward displacement of the structure terminates the forces across the piston 19 will balance to maintain cylinder 18 fixed with respect to piston 19, the cylinder 18 will be in such position that the valve closure member 23*a* will shut off the supply of pressure fluid to the cylinder 18 and the system will again become stable.

(b) If the structure experiences a downward displacement in the location of the anchor member support means the hook 15 lowers and the whole assembly supported from hook 15 is given an initial downward displacement but, immediately the first part of the displacement occurs, the valve actuating member 23*a* will displace relative to valve 23 to connect that part of cylinder 18 below the piston 19 to exhaust via duct 27 and, as the upper region of the cylinder 18 is continuously open to pressure fluid from the accumulator 22, the piston 19 will move downwardly within the cylinder 18 (as viewed in Fig. 1), thus reducing the effective length of the piston and cylinder arrangement 18, 19 and 20, at the same rate as the downward displacement of the structure, so that once again the cylinder 18, valve 23, tension member 14 and anchor member 11 will be maintained in static positions relative to the template 12. At the end of the downward displacement of the cylinder 18 the valve closure member 23*a* again displaces relative to valve 23 to close the exhaust line from the cylinder 18.

By the above arrangement the piston and cylinder arrangement 18, 19, 20 expands and contracts in direct dependence upon the vertical displacements of the structure at the anchor support location and, thereby, prevents the structure displacements from being transmitted to the anchor member 11 so that the anchor member 1 has a relatively static position relative to the template 12. Once this condition is established the hook 15 can be lowered, to lower the whole of the assembly supported thereby, to engage the anchor member 11 in the template 12.

It will be observed that immediately the hook 15 lowers the piston and cylinder arrangement 18, 19 and 20, with the valve 23, the tension in the physical link 29 will be reduced, thus rendering the valve 23 ineffective. To overcome this problem a length adjusting device, generally indicated by reference numeral 32 acts on the cable 29 to maintain the cable 29 at a predetermined tension, whereby the valve 23 continues to operate to allow the piston and cylinder arrangement 18, 19 and 20 to continue to expand and contract to counter the vertical oscillations of the structure and thus the anchor member 11 is lowered into the template without the transmission of oscillations thereto.

The last attached tension member 14 includes a threaded section 14*a* with a nut 33 thereon and, when the anchor member 11 has been correctly located and locked in template 12, the tension member 14 is placed under a predetermined temperature by an assembly of piston and cylinder arrangements (not shown in Fig. 1), sufficient to prevent oscillation of the structure, and the nut 33 is then run down the threaded section 14*a* into engagement with a structure part 13*b* and tightened against part 13*b*, whereupon the hydraulic assembly can be disconnected from the tension member 14, by simply removing the pin 21, and removed from the anchor location.

The valve illustrated in Fig. 2 ideally suits the operation of the valve 23 illustrated in Fig. 1 and generally comprises a spool valve defined by a

cylinder 34 and a spool 35. The cylinder 34 is secured to the cylinder of the length adjusting device (cylinder 18 in Fig. 1) and a port 34*a* in cylinder 34 aligns with a port 18*a* in cylinder 18, open to the lower end of the cylinder 18.

The spool 35 presents three lands 36, 37 and 38 which separate the volume of cylinder 34 into four chambers A, B, C and D. The chambers B and D are permanently connected to exhaust, the chamber A is continuously open to the pressure fluid source for the upper end of the length adjusting cylinder (the upper part of cylinder 18 in Fig. 1) and the chamber C is permanently connected to a pressure fluid supply, such as that from the constant pressure device 26 in Fig. 1.

The lower end of the spool 35 (as viewed in Fig. 2) extends downwardly from the cylinder 34 and the end of the physical link (such as the cable 29 in Fig. 1) is secured to the lower free end of the spool 35. In a mean position for the valve the land 37 obstructs the port 34*a* to prevent the flow of fluid to and from the cylinder 18.

If now, the cylinder 18 is upwardly displaced, by a vertically upward movement of the structure, the cylinder 34 moves upwardly with the cylinder 18, the spool valve 35 is maintained in a constant location relative to the weight 28, and thus the relative displacement between cylinder 34 and spool 35 brings the port 34*a* into open communication with chamber C and pressure fluid therefore flows from chamber C through port 34*a* and the aligned port 18*a* into the lower regions of cylinder 18 to effect an extrension of the length adjusting device. Flow of fluid from chamber C into the cylinder 18 will continue whilst the cylinder 18, and cylinder 34, are elevated relative to the spool 35 but immediately the upward displacement of the structure terminates the cylinder 18, and cylinder 34, will be downwardly displaced relative to piston 19, due to the flow of pressure fluid from chamber C, and such downward displacement relative to the spool 35 will cause the land 37 to again obstruct the port 34*a*. If the cylinder 18 is downwardly displaced relative to spool 35, the land 37 displaces upwardly to expose the port 34*a* to chamber B, whereupon pressure fluid will flow from the cylinder 18 through aligned ports 18*a* and 34*a* to chamber B and thereby to exhaust, thus effecting a contraction of the length adjusting device, until the downward movement of the cylinders 18 and 34 is arrested and the land 37 again obstructs the port 34*a*.

It will be appreciated that in all conditions for the spool valve the spool 35 is urged upwardly within cylinder 34 by the fluid pressure in chamber A whereupon, the physical link 29 is maintained in tension.

Fig. 2 also illustrates one form for the length adjusting device 32 (shown in Fig. 1) and comprising an hydraulic piston and cylinder arrangement, generally indicated by reference numeral 40, in the physical link cable 29. The device 40 thus comprises an hydraulic cylinder 41 with a piston 42 slidably disposed therein and a connecting rod 43 extending from one end of the cylinder. The physical link 29 extends from the weight 22 over the pulley 30 and is attached to the end of the cylinder 42 remote from piston rod 43. A second part of the physical link cable 29 extends from the free end of the piston rod 43 around roller 31 to the lower end of the spool valve 35. That end of the cylinder 41 from which the connecting rod 43 extends can be supplied with hydraulic pressure fluid from a reservoir 44 through a pump 45 and a valve 46 and said cylinder end can exhaust hydraulic fluid via the valve 46 back to the reservoir 44. In like manner that end of the cylinder 41 remote from piston rod 43 can receive hydraulic fluid pressure from a reservoir 47 through a pump 48 and a valve 49 whilst said cylinder end can exhaust hydraulic fluid through the valve 49 to the reservoir 47.

It will be seen that when the forces across the piston 42 are balanced the piston and cylinder arrangement 41, 42, 43 has a specific length and the spool valve 34, 35 will operate as described above to cause extension and contraction of the length adjusting device to compensate for the oscillations of the structure and, thereby, to maintain the anchor member 11 substantially static with respect to the template 12. However, to lower the anchor member 11 into the template it is only necessary to change the volumes of the hydraulic fluid on each side of the piston 42, thereby to vary the length of the physical link now comprising the two parts of the cable 29 with the device 40 therebetween, such a change in the effective length of the physical link will allow the spool 35 to change its position relative to the weight 28 and thus, in effect, change the position of the mean of the oscillations of the length adjusting device to gradually increase or reduce, the mean length of said device.

It will thus be seen that if the pressure fluid supply to the device 40 causes the device 40 to contract the spool 35 will be drawn downwardly relative to the weight 28, a downward displacement of the spool 35, in lowering land 37, will connect the lower end of the cylinder 18 to the pressure fluid supply so that the cylinder 18, and the structure suspended thereunder, will lower relative to the piston 19 and thus, as the land 37 is progressively lowered by progressive contraction of the device 40, the mean of the oscillations of the piston 19 in cylinder 18, due to the oscillations of the platform, will displace upwardly relative to cylinder 18, cylinder 18 will be progressively lowered with respect to piston 19, and the assembly supported by cylinder 18 will lower until the anchor member 11 is entered into the template 12 and the template 12 secures to the anchor member 11.

It will thus be seen that by using a variable length device in the physical link the anchor member 11, tension member 14, and cylinder 18, can be lowered relative to the structure without any displacement of the hook 15 relative to the structure and an extremely accurate lowering of the anchor member 11 can be obtained thereby.

In the embodiment illustrated in Fig. 3, and after the anchor member 11 has been brought to its location adjacent the template 12, the tension member 14 is secured to the piston rod 50 of a piston 51 slidably displaceable in a cylinder 52, the end of cylinder 52 remote from the connecting rod 50 being secured to a fixed part 13*c* of the structure.

The physical link cable 29 is attached to the free end of a piston rod 53 of a piston 54 slidably disposed in a cylinder 55 secured to a fixed part 13*d* of the structure.

The annular cross-sectional area of the piston and cylinder arrangement 53, 54 and 55, on the piston rod side of the piston 54, is equal to the cross-sectional area of the bore of cylinder 52 and the volume of cylinder 55 below piston 54 is in open communication with the bore of cylinder 52 remote from piston rod 50 via a conduit 56. By this means, any displacement of hydraulic pressure fluid between the cylinders results in equal displacement of the pistons 51, 54 and the piston rods 50, 53.

The volume of cylinder 55 below piston 54 and the volume of cylinder 52 above piston 51 are charged with hydraulic fluid at a pressure defined hereinafter, and the lower regions of the cylinder 52 are charged with hydraulic pressure fluid from a reservoir 57 which maintains a constant pressure, in the cylinder 52 below the piston 51 for all positions of the piston within cylinder 52.

The fluid pressure in the lower end of cylinder 55, and the upper end of cylinder 52, is established at such pressure as to maintain the physical link cable 29 under a predetermined tension and the pressure of the fluid in the lower regions of cylinder 52 is sufficient to suport the tension member 14 and the anchor member 11 suspended from piston rod 50.

The arrangement described above operates as follows:—

With the pressures established as defined above, and in the event of an upward displacement of the structure in the region of the anchor support, the vertical displacement of the structure is transmitted to the cylinder 52 and the piston 54, held to a fixed position relative to the anchorage for the physical link 29 by the physical link 29, is then displaced downwardly with cylinder 55 (as viewed in Fig. 3) to displace pressure fluid from the cylinder 55 below piston 54 to the upper regions of the cylinder 52. The discharge of fluid into the upper region of cylinder 52 cause the piston 51 to be driven downwardly within cylinder 52 (as viewed in Fig. 3), pressure fluid below the piston 51 being driven back to the accumulator 57, and, in view of the above identified dimensions of the piston and cylinder arrangement 53, 54, 55 and the piston and cylinder arrangement 51, 52, the downward displacement of the piston 51, and the assembly supported thereby, is equal to the downward displacement of the piston 54 in cylinder 55, which is equal to the vertical displacement of the structure, and thereby the tension member 14 and anchor member 11 are not displaced upwardly with the structure.

If now the structure is downwardly displaced the pressure fluid below the piston 54 drives piston 54 upwardly within cylinder 55, and pressure fluid flows from the upper region of cylinder 55, whereupon pressure fluid from the accumulator 57 flows into the lower regions of cylinder 52, to displace the piston 51 upwardly within cylinder 52 (as viewed in Fig. 3) by the same amount as the piston 54 rises within cylinder 55, which displacement is equal to the downward displacement of the structure, and thus once again the anchor member 11 and tension member 14 will remain static relative to the template 12.

Whilst the anchor member 11 is being maintained without oscillation relative to template 12 the anchor member 11 may be lowered into engagement with the template 12 by simply adding hydraulic fluid by for example an accumulator 58 acting through a stop-valve 59, to increase the volume of the hydraulic fluid in the lower regions of the cylinder 55 and the upper regions of the cylinder 52, this may initially effect a small increase in the tension in the physical link cable 29 but the major effect will be to increase the volume above the piston head 51, causing piston 51 to be downwardly displaced within cylinder 52, thus lowering the tension member 14 and the anchor member 11. The introduction of fluid into conduit 56 as defined above does not interrupt the transfer of fluid between cylinders 55 and 52 due to displacement of the structure and, in fact, the effect of introducing said hydraulic pressure fluid is simply to change the location of the mean of the oscillations of the piston 51 within cylinder 52 so that a controlled, and well balanced, lowering of the anchor member 11 is effected.

As an alternative to the introduction of pressure fluid into conduit 56 to effect lowering of the anchor member 11 the cylinder 52, instead of being anchored to the fixed part 13*c* of the structure, may be suspended from the hook 15 of the lowering arrangement when the lowering of anchor member 11 into the template will be effected by the lowering arrangement.

Fig. 3 also shows one method for tensioning the tension member 14 after the anchor member 11 has been locked with the template 12 to place said tension member under the desired tension to allow the nut 33 to be engaged correctly with the fixed part 13*b* of the structure and, in this embodiment, cylinders 60 and 61 are supported from fixed locations 13*e* of the structure, pistons 62 and 63 are slidably disposed in cylinders 60 and 61 respectively, and piston rods 64 and 65 attached to pistons 62 and 63 respectively extend downwardly from their respective cylinders 60 and 61 to a platform generally indicated by reference numeral 66. Platform 66 has an opening 67 to allow the tension member 14, and as indicated the connecting rod 50, to pass therethrough. The lower regions of the cylinders

60 and 61 are supplied with pressure fluid, from a common supply, generally indicated by reference numeral 68.

When the anchor member 11 has been properly located and engaged by the template 12 to secure the anchor member 11 pressure fluid is released from the volume comprising the upper regions of cylinder 52 and the lower regions 55 so that the mean position of the piston 51 rises within cylinder 52 and places the tension member 14 under a predetermined tension. At this point a ring 69, resting on the platform 66 and concentric with tension member 14 is locked to tension member 14 by a hydraulic lock 70, hydraulic pressure fluid is supplied to the lower regions of cylinders 60 and 61 from supply 68, to urge pistons 62 and 63 upwardly within their respective cylinders 60 and 61 and, thereby, the platform 66 is urged upwardly to place the tension member 14 under a predetermined pressure.

Conveniently, the piston and cylinder arrangements 60, 62, 64 and 61, 63, 65 place the tension member 14 under an initial tension in the region of sixty tonnes, this tension force in a single tension member 14 will be inadequate to prevent vertical oscillation of the platform due to the sea and wind and such oscillations of the structure are compensated for by the flow of hydraulic fluid from the lower regions of cylinders 60 and 61 to and from the pressure source 68. Thus, by this means, the tension in member 14 is maintain substantially constant irrespective of the displacements of the structure.

When all the anchor members 11 to anchor the structure have been located in their respective templates 12 and the respective tension members 14 have been placed under the initial tension (approximately sixty tonnes per tension member) the fluid pressure in all the pressure sources 68 is increased, the increase in pressure beneath the pistons 62 and 63 of all the anchor support arrangements forces said pistons upwardly within their respective cylinders, this displacement of the pistons draws the structure downwardly in the water and, at the desired tension of some six hundred tonnes per tension member 14 the structure will be so drawn into the water that it is no longer subject to vertical oscillations due to the wind and waves.

Although the present invention has been described by way of example the invention is not limited thereto and many variations and modifications will be apparent to persons skilled in the art.

CLAIMS

1. An anchoring arrangement of the type hereinbefore defined including a length adjusting device, effective between the floating structure and an anchor member to be anchored, and a control mechanism mounted on the structure and connected by a physical link to the sea-bed to continuously monitor the height of the structure, at the anchor member suspension location, above the sea-bed template for the anchor member, said control mechanism serving to adjust the effective length of the length adjusting device in dependence upon variations in said height, whereby, the length adjusting device extends and contracts in dependence upon the vertical oscillations of the structure at the anchor member supporting location to compensate for the vertical oscillations of the structure and, thereby, substantially reduce or eliminate vertical oscillation of the anchor member relative to the template.

2. An anchoring arrangement according to claim 1, whereby the length adjusting device comprises an hydraulic piston and cylinder arrangement arranged in or as a suspension system for the tension member supporting the anchor member.

3. An anchoring arrangement according to claim 2 wherein one part of the piston and cylinder arrangement defining the length adjusting device is suspended from a lowering arrangement for the anchor member assembly and the other part of the piston and cylinder arrangement is attached to the tension member supporting the anchor member.

4. An anchoring arrangement according to claim 2, wherein the piston and cylinder arrangement defining the length adjusting device constitutes a suspension for said tension member and one part of the said piston and cylinder arrangement is secured to the structure and the other part of said device is attached to the tension member for the anchor member; the stroke of the piston in the piston and cylinder arrangement being greater than the amplitude of the oscillation of the structure, at the point to which the piston and cylinder arrangement is supported, plus the displacement of the anchor member and tension member necessary to lower the anchor member into the template for effective securement, said control means operating the piston and cylinder arrangement so that the piston displaces within the cylinder in dependence upon the vertical oscillations of the structure, to reduce or eliminate vertical oscillation of the anchor member relative to the template and, thereafter, with the piston and cylinder arrangement oscillating to maintain a non-oscillating condition of the anchor member relative to the template, the mid-point of the oscillations of the piston within the cylinder is lowered, relative to the cylinder, to lower the anchor member into the template.

5. An anchoring arrangement according to any of the preceding claims, wherein the control mechanism comprises a piston and cylinder arrangement.

6. An anchoring arrangement according to claim 5, wherein the piston and cylinder arrangement defining the control mechanism is an hydraulic arrangement.

7. An anchoring arrangement according to claim 5 or 6, wherein one part of the control mechanism piston and cylinder arrangement is fixed relative to the structure and the other part is attached to the sea-bed whereby the piston

reciprocates within the cylinder in direct response to the oscillations of the structure at the control mechanism location, with displacement of fluid to and from the cylinder, at one side or the other side of the piston, controlling the length adjusting device.

8. An anchoring arrangement according to claim 7, wherein one end of the cylinder defining the control mechanism is open to one end of the cylinder defining the length adjusting mechanism, thus permitting free flow of fluid between said cylinders.

9. An anchoring arrangement according to claim 3, wherein the control mechanism comprises a valve, actuated by the physical link, to supply and exhaust pressure fluid to and from the cylinder of the length adjusting device.

10. An anchoring arrangement according to claim 9, wherein said valve comprises a shuttle valve the cylinder of which is secured to the cylinder of the length adjusting device and the shuttle is connected to that end of the physical link remote from the sea-bed.

11. An anchoring arrangement according to claim 10 as dependent upon claim 3, wherein the piston rod of the length adjusting piston and cylinder arrangement is suspended from the lowering arrangement, the cylinder is suspended from the piston and piston rod assembly so as to be free to displace vertically, the tension member is secured to the cylinder, and the shuttle valve is arranged to supply and exhaust pressure fluid to and from the lower end of the cylinder, and an accumulator is provided to maintain a constant fluid pressure in the upper end of the cylinder to enable the weight of the anchor member, the tension member, and the cylinder to be supported by the pressure fluid above the piston head of the length adjusting device.

12. An anchoring arrangement as claimed in claim 11 and wherein the shuttle has a fixed position relative to the sea-bed in the length direction of the physical link whereupon if, from the shuttle valve closure position, the structure experiences a vertically upward displacement, such displacement is transmitted through the piston rod and piston of the length adjusting device to urge an upward displacement of the cylinder, which causes an upward displacement of the shuttle cylinder to open the shuttle valve and allow pressure fluid to enter the lower end of the cylinder, to cause the length adjusting device to expand until, towards the termination of the upward displacement, the shuttle valve closes, and so that on a vertically downward displacement of the structure from the shuttle valve closure position the cylinder of the length adjusting device, and the cylinder of the shuttle, are initially lowered with the piston and piston rod of the length adjusting device, the relative displacement between the shuttle and the shuttle cylinder opens the valve to allow pressure fluid to exhaust from the lower end of the cylinder of the length adjusting device and thus cause the length adjusting device to contract until, towards the termination of the downward displacement, the shuttle valve again closes.

13. An anchoring arrangement according to claim 9, 10, 11 or 12, wherein the piston and cylinder arrangement of the length adjusting device is controlled by the control mechanism to lower the anchor member into the template.

14. An anchoring arrangement according to claim 13 wherein the physical link includes a link length adjusting device, the length of which when increased or decreased serves to increase or decrease the effective length of the physical link whereupon the mean length of the length adjusting device supporting the anchor member can be varied so that, with the former normally reciprocating to counter the oscillations of the structure, the mean effective length of the length adjusting device supporting the anchor member can be increased to lower the anchor member, without oscillation, into engagement with the template.

15. An anchoring arrangement according to any one of the preceding claims, including a tensioning means for tensioning the tension member when the anchor member is locked with the template.

16. An anchoring arrangement according to claim 15, wherein the tensioning means comprise a fluid pressure operated piston and cylinder arrangement one end of whicdh is anchored to the fixed structure and the other end of which is connected to the tension member so that, when the said piston and cylinder arrangement is contracted, the tension member is tensioned.

17. An anchoring arrangement according to claim 16, wherein the piston and cylinder arrangement for tensioning the tension member and the length adjusting device are arranged in tandem.

18. An anchoring arrangement substantially as hereinbefore described with reference to Figs. 1 and 2 of the accompanying drawings.

19. An anchoring arrangement substantially as hereinbefore described with reference to and as illustrated in Fig. 3 of the accompanying drawings.

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