

FLUKED BURYING DEVICES.

The present invention relates to cable-mounted fluked burying devices for increasing both the penetration and holding capacity of a drag embedment marine anchor and cable system.

5 Such fluked burying devices are disclosed in US Patent No. 3,685,479 which shows a first fluked burying device for mounting on a wire hawser and a second fluked burying device for mounting in a chain cable to form an integral link thereof. The fluked burying devices interact with seabed soil to impress axial forces in the cable which increase holding capacity directly. The devices also increase holding
10 capacity indirectly by impressing transverse forces in the cable which counteract penetration resistance thereof to promote deeper penetration of the anchor with consequent increase in capacity.

Disadvantages of the first fluked burying device include slippage of clamping means attaching the device to the wire hawser and both handling and operational
15 damage arising from localised bending of the wire hawser due to lack of articulation at both forward and aft ends of the device.

Disadvantages of the second fluked burying device include: a requirement for structural adaptation to carry high transmitted loads in the anchor cable which are considerably in excess of those contributed by the device; a requirement for costly
20 connecting shackles to provide an adequate degree of articulation while carrying high transmitted loads; and a Classification Society requirement for the application of a high proof load to the device and to the shackles, on completion of manufacturing, equal to that required for the associated chain cable. The last-mentioned Classification Society requirement applies to all devices which are integral with the
25 chain and through which chain tension is transmitted.

It is an object of the present invention to provide a fluked burying device for increasing the penetration and holding capacity of a drag embedment marine anchor and chain cable system which overcomes the above-noted disadvantages. It is a further object of the present invention to provide a modified fluked burying device
5 capable of acting, additionally, as a substitute for a marine anchor used in a drag embedment marine anchor and chain cable system.

According to the present invention, a fluked burying device includes a plane of symmetry and comprises a body member and a fluke member attached thereto at an acute angle of inclination to a longitudinal axis of said body member, and includes
10 attachment means for holding said body member in a fixed position on a chain cable comprising a series of links, whereby said longitudinal axis is maintained substantially aligned with an axis of said chain cable, said body member being adapted to maintain said chain cable extending in a defined attitude therein, said attachment means including first contact points on said body member for transferring
15 axial load therefrom to corresponding points on a link of said chain cable and second contact points on said body member for transferring transverse load therefrom to corresponding points on a link of said chain cable.

Preferably, said defined attitude comprises alternate links of said chain cable being maintained in a plane at right angles to said plane of symmetry.

20 Preferably, said first contact points transfer axial load to corresponding points on a first link of said chain cable and said second contact points transfer transverse load to corresponding points on a second link of said chain cable.

Preferably, said second contact points are positioned such as to constrain induction of bending stresses in said link of said chain cable during operation of said

fluked burying device to be similar to that which occurs in a wildcat of a windlass for tensioning said chain cable.

Preferably, said second contact points are positioned on said body member at two locations to bear on two of said links spaced apart such as to oppose turning
5 moment induced in said fluked burying device during interaction with a seabed soil while penetrating therein with said chain cable taut.

Preferably, said two positions of said second contact points are spaced apart by not less than 12 times bar diameter of said links and, preferably, not less than 20 times said bar diameter.

10 Preferably, said second contact points are positioned such that said corresponding load transfer points on a link lying in a plane at right angles to said plane of symmetry are spaced from said plane of symmetry by a distance in the range of 0.8 to 1.0 times the nominal diameter of said link.

Preferably, said second contact points are positioned such that said corresponding
15 load transfer points on a link lying in a plane at right angles to said plane of symmetry are separated from a central point of a crown section, lying in said plane of symmetry, of said link by a distance in the range of 0.4 to 0.6 times the nominal diameter of said link measured in a direction parallel to said axis of said chain cable.

Preferably, said attachment means comprises a pocket in said body member
20 arranged of accommodate a link of said chain cable.

Preferably, said pocket constrains said link of said chain cable to lie in a plane at right angles to said plane of symmetry.

Preferably, said fluked burying device is formed substantially in two halves for opposed sideways assembly on said chain cable.

Preferably, said first contact points are located adjacent said fluke member whereby tensile loading impressed in said chain cable by said fluked burying device substantially bypasses the portion of said body member lying forward of said first contact points.

- 5 Preferably, said body member comprises two elongate members each disposed substantially parallel to said plane of symmetry and each extending along one of two opposed sides of said chain cable.

Preferably, said elongate members are plate-like.

- 10 Preferably, said pocket comprises an elongate slot perforating each of said plate-like elongate members to accommodate said link.

Preferably, said elongate members are spaced apart by a distance between 1.06 and 1.1 times the nominal diameter of said link.

Preferably, said body member has a width less than that of a link of said chain cable, measured transverse to said chain cable.

- 15 Preferably, said elongate members each have a width less than a bar diameter of a link of said chain cable and, further preferably, less than 0.5 times said bar diameter, measured transverse to said chain cable.

- 20 Preferably, said elongate members are splayed apart at an extremity such that a link of said chain cable emergent from said extremity can swing freely sideways from said plane of symmetry through an angle of up to 20°, with 12° further preferred.

Preferably, said emergent link can swing in said plane of symmetry through an angle of up to 90° from said longitudinal axis.

Preferably, said fluked burying device including said second contact points at two spaced locations also includes a roll stabilizer.

Preferably, a fluked burying device terminating said chain cable includes a yaw stabilizer.

Preferably, said fluked burying device is arranged such that a straight line containing a centre point of a forward crown section, lying in said plane of symmetry, of a link in a foremost pocket in said body member and a point of projection onto said plane of symmetry of a foremost point of said fluke member is inclined to said longitudinal axis at an angle in the range of 25° to 35° , with 30° further preferred.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings wherein:

- 10 Fig.1 shows an oblique front view of a fluked burying device;
Fig. 2 shows an oblique rear view of the fluked burying device of Fig.1;
Fig. 3 shows a plan view of the fluked burying device of Fig. 1;
Fig. 3A shows a detail of Fig. 3 to a larger scale;
Fig. 4 shows a side view of the fluked burying device of Fig. 1;
15 Fig. 5 shows a view of the fluked burying device of Fig. 1 in direction X of Fig. 4;
Fig. 6 shows a section Y-Y of the fluked burying device of Fig. 4;
Fig. 6A shows effective footing width W of inclined studless chain cable;
Fig. 7 shows a side view of a modification of the fluked burying device of Fig. 1;
Fig. 8 shows fluked burying devices installed in a deep layer of soil;
20 Fig. 8A shows fluked burying devices installed in a shallow layer of soil over rock;
Fig. 9 shows an oblique view of the fluked burying device of Fig. 1 with roll stabilizers;
Fig. 10 shows an oblique view of the fluked burying device of Fig. 7 with yaw stabilizers.

Referring to Figs. 1 to 6, a fluked burying device **1** is formed in two parts **2, 3** comprising a port half **2** and a starboard half **3**, arranged for opposed attachment to each other about and in parallel with chain cable **4**. Fluked burying device **1** is symmetrical about a plane of symmetry **5** (Figs. 4 and 5) which contains axis **6** of chain cable **4** which extends internally within shank **7** thereof. Plane of symmetry **5** is vertically orientated when fluked burying device **1** is buried in seabed soil **38** of seabed **39** (Fig.8). Port and starboard halves **2, 3** include shank **7** and fluke **8**. Shank **7** comprises forward shank **7A**, extending forward of fluke **8**, and aft shank **7B**, extending aft of fluke **8**. Shank **7** and fluke **8** are formed respectively by plates **9** and **10** joined together at junction **11**. Plate **9** of shank **7** has three slots **12A, 12B, and 12C** (Figs. 1, 2 and 4) formed therein to function as pockets for accommodating links **17A, 17B, and 17C** respectively of chain cable **4**. Links **16** are held in plane of symmetry **5** whereas links **17** are held at right angles thereto. Slots **12A, 12B, and 12C** are axially aligned in a plane **13** (Fig. 4) disposed at right angles to plane of symmetry **5**. Longitudinal axis **14** of fluked burying device **1** is defined by the intersection of plane of symmetry **5** with plane **13** (Figs. 3 and 4). Thus, slots **12A, 12B, and 12C** hold axis **6** substantially coincident with axis **14**.

Port and starboard halves **2, 3** of fluked burying device **1** are assembled with plates **9** in parallel with plane of symmetry **5** and with corresponding slots **12A, 12B, and 12C** registering with each other. Halves **2** and **3** and are fastened together sideways about chain cable **4** by means of bolts **15** passing through plates **9** and spacers **15A** which serve to maintain sufficient clearance for links **16** (Fig. 5) of chain cable **4** lying in plane of symmetry **5** to avoid clamping of links **16** by plates **9**. Thus, spacers **15A** space plates **9** apart by a distance in the range of 1.05 to 1.1 times the nominal diameter **D** (Fig. 4) of chain cable **4**. Slots **12A, 12B, and 12C** provide a

loose fit about corresponding links **17A**, **17B**, and **17C** to provide sufficient clearance in a direction parallel to axis **14** (Fig. 4) to allow chain cable **4** to stretch under extreme loading without being restrained by slots **12A**, **12B**, and **12C**.

Plate **9** has lower extension **9A** and upper extension **9B**, at junction **11**, provided to support fluke **8**. Tapered plate ribs **18** are welded to plates **9** and **10** to increase the bending resistance of fluke **8**. Plate rib extensions **18A** bearing against each other at plane of symmetry **5** take compressive loading between halves **2** and **3** of fluked burying device **1** (Figs. 2 and 3). Distance **E** (Fig. 4) separating forward end **12D** of slot **12C** from aft end **12E** of slot **12B** is chosen to provide minimal clearance between forward end **12D** and link **17C** and minimal clearance between aft end **12E** and link **17B**. Forward end **12D** of slot **12C** bearing on link **17C** constitutes aft stop point **19A** which prevents fluked burying device **1** from being pushed aft on chain cable **4** when fluke **8** is subjected to soil loading during forwards embedment of fluked burying device **1**. Aft end **12E** of slot **12B** bearing on link **17B** constitutes forward stop point **19B** to arrest fluked burying device **1** from being pushed forward on chain cable **4** when fluke **8** is subjected to soil loading during rearwards recovery of fluked burying device **1**. Thus, stop points **19A** and **19B** act together to locate fluked burying device **1** in a fixed position axially on chain cable **4** while the before-mentioned allowance for stretching ensures that axial loading can be transferred only via stop points **19A** or **19B** irrespective of the magnitude of tension in chain cable **4**.

Since links **17A**, **17B**, and **17C** are fitted loosely in respective slots **12A**, **12B**, and **12C**, relative movement between chain cable **4** and fluked burying device **1** causes either stop point **19A** to bear on link **17C** or stop point **19B** to bear on link **17B** to act as the sole point of transfer of axial force into chain cable **4** from plate **9** of fluked burying device **1** during forwards embedment and rearwards recovery respectively.

Importantly, location of stop point **19A** proximal to junction **11** eliminates direct stress in almost the whole of forward shank **7A** arising from soil loading on fluke **8**. Since tensile loading impressed in chain cable **4** aft of fluked burying device **1** bypasses both forward shank **7A** and aft shank **7B**, no direct tensile stresses resulting therefrom are additionally induced therein.

Transverse reaction bearing forces between shank **7** and links **17A** and **17C** of taut chain cable **4** acting through bearing contact points **A** at the forward ends of slots **12A** and bearing contact points **B** at the aft ends of slots **12C** (Fig. 4) provide a resisting moment to counteract a moment arising from loading of fluke **8** which tends to rotate fluked burying device **1** in plane of symmetry **5** relative to forward and aft portions of axis **6** of chain cable **4** external to fluked burying device **1**. Bearing contact points **A** and **B** are separated by a moment arm distance **L** (Fig. 4) approximately equal to 20 times the nominal bar diameter **D** (Figs. 4 and 6) of links **16** and **17** of chain cable **4** although, for a fluked burying device **1** pocketing only two of links **17**, distance **L** could be as low as approximately 12 times diameter **D**. The bending moment induces bending stresses in shank **7** which predominate in forward shank **7A** (Fig. 4) when concentrated loading occurs at tip **20** of fluke **8** due to lodging, say, on an obstruction such as a rock. However, peak tensile bending moment stresses are not boosted by added direct stresses with the result that shank **7** and, particularly, forward shank **7A** may be of lighter and thus lower cost construction. This advantageous arrangement arises from the separation distance **M** (Fig. 4), approximately equal to 15D, provided between the forward application points **A** of transverse loading and the points **19A** of axial loading and is an important aspect of fluked burying device **1**.

Plate **10** of fluke **8** is inclined to plate **9** of shank **7** at an angle α (Fig. 5) in the range 90° to 115°, with 95° preferred. Junction **11** between plate **10** of fluke **8** and plate **9** of shank **7** is inclined to axis **14** at angle β (Fig. 4) which is in the range of 35° to 60°, with 50° preferred. Leading edge **21** of fluke **8** is inclined to junction **11** at an angle γ (Fig. 1) in the range 45° to 75°, with 60° preferred. A straight line **22** (Fig. 4), in plane of symmetry **5**, joining centre **23** of a forward crown section **24** of pocketed link **17A** to a point of projection **25** of tip **20** of fluke **8** onto plane of symmetry **5**, is inclined to axis **14** at an acute angle δ and forms, aft of tip **20**, an acute angle ϵ with a projection line **26** of junction **11** onto plane of symmetry **5**. Angle δ is in the range of 25° to 35°, with 30° preferred and angle ϵ is in the range of 60° to 85°, with 80° preferred for fluked burying device **1** and 65° preferred for terminal fluked burying device **1A** (Fig. 7) described below.

The length of junction **11** is approximately 17 times diameter **D**. The length of trailing edge **27** of fluke **8** is approximately 13 times diameter **D**. Thus, when diameter **D** equals 50mm, the fluke area of fluked burying device **1** projected on a plane (not shown), containing junction **11** and at right angles to plane of symmetry **5**, is approximately 0.9 square metre.

Forward extremity **28** of plates **9** of forward shank **7A** and rearward extremity **29** of plates **9** of aft shank **7B** each have a radius **R** (Fig. 4) made equal to 1.5 times diameter **D**. This allows forward emergent link **16A** (Figs. 1,2, 4 and 5) to pivot on link **17A**, which is restrained in slot **12A**, through some 180° in plane of symmetry **5** and allows link **17D** (Fig. 4) to pivot simultaneously on link **16A** through some 180° in a plane transverse to plane of symmetry **5**. Similarly, rearward emergent link **16B** (Figs. 2 and 4) can pivot on link **17C**, which is restrained in slot **12C**, but through only about 150° in plane of symmetry **5** due to chain cable **4** being restrained by making

contact with fluke **8**, while link **17E** remains able to pivot simultaneously on link **16B** through some 180° in a plane transverse to plane of symmetry **5**.

Transverse loading contact points **A** and **B** (Figs. 3 and 3A) between plates **9** of shank **7** and links **17A** and **17C** are located at positions which normally occur when such chain links are loaded in a wildcat (also known as a cable-lifter or gypsy) of a windlass. These load transfer points are known from Figure 14 in published paper number 3813 of the Offshore Technology Conference, Houston, May, 1980, by A. Berg and A. Taraldsen, of Det Norske Veritas, which indicates that a central point of a load transfer area on a link lies at a distance of approximately **0.9D** from a transverse plane containing the central axis of the chain link and separated by a distance of approximately **0.5D** from the centre of a crown section of the link measured in a direction parallel to the central axis of the link. Accordingly, contact points **A** and **B** in shank **7** are arranged to be spaced by distance **X** (Fig. 3A) from plane of symmetry **5** and located such as to be separated from central point **23** of crown section **24** of link **17A** or link **17C**, respectively, by distance **Y** measured in a direction parallel to axis **6** of chain cable **4**. Distance **X** is in the range 0.8D to 1.0D and distance **Y** is in the range 0.4D to 0.6D so that links **17A** and **17C** are loaded as if in a wildcat.

In a 5-pocket wildcat, commonly adopted for service in the offshore drilling industry, the angular displacement between adjacent supported and unsupported chain links is 36° . When fluked burying device **1** is embedded in seabed soil **38**, link **16A** can become displaced angularly in plane of symmetry **5** through a maximum of 30° from adjacent supported link **17A** due to coming into alignment with line **22** (Fig. 4) when a localised force is applied at tip **20** of fluke **8** by, say, a rocky obstruction. Therefore, the transverse component of tension in chain cable **4** which gives rise to

induction of bending stresses in supported link **17A** is less than would occur in a wildcat by a factor $\sin 30^\circ / \sin 36^\circ = 0.85$. Thus, constraint in slots **12A** enables links **17A** (and, similarly, **17C**) to be operated at 15 per cent lower bending stress for equivalent axial tension than occurs in a wildcat.

5 Forward extremity **28** and rearward extremity **29** of plates **9** are splayed apart from lines **A1** and **B1** just aft and forward of points **A** and **B** respectively (Figs. 4 and 5) through a bend angle Θ (Fig.3) of 20° to allow links **16A** and **16B** to pivot through angle Θ out of plane of symmetry **5** before being arrested by the splayed extremities **28** and **29**. This allows azimuthal veering of chain cable **4** to be accommodated
10 without bending link **16A** or link **16B**. Since spacing **1.1D** between plates **9** is less than width **1.5D** of a wildcat groove, the above-noted spacing of bearing points **A** and **B** from plane of symmetry **5** is maintained despite extremities **28** and **29** being splayed apart.

The component of force acting transversely on fluked burying device **1** or terminal
15 fluked burying device **1A** when link **16A** has pivoted 20° sideways out of plane of symmetry **5**, due to azimuthal veering of chain cable **4** while taut, is 34 per cent of tensile loading in chain cable **4**. This is sufficient to turn fluked burying device **1** or terminal fluked burial device **1A** into the direction of veering when embedded in seabed soil **38** with the result that peak pivoting of link **16A**, in actuality, is
20 considerably less than 20° . Thus, link **16A** (and, similarly, link **16B**) is subjected only to tensile loading during such veering.

The above described combination of support, constraint, and freedom of articulation accorded links **17D**, **16A**, and **17A** and links **17C**, **16B**, and **17E** by plates **9** at extremities **28** and **29** enables chain cable **4** issuing from shank **7** of
25 fluked burying device **1** to function normally, without incurring a penalty by way of

increased bending stresses in links **17A** or **17C**, and so fulfil the function of two heavy and expensive shackles which are thus rendered unnecessary.

The penetration resistance of chain cable **4** moving in direction **P** (Figs. 6A and 8), inclined at angle θ to axis **6**, in seabed soil **38**, is proportional to area **AP** of unit length of chain cable **4** viewed obliquely in direction **P**, where **AP** is gross area, neglecting internal apertures in chain cable **4** through which, in practice, soil is unable to flow. The width **W** (Fig. 6A) of a unit length of rectangular strip footing of area equal to **AP** is the effective footing width of chain cable **4** moving in direction **P**. **W** is a measure of the penetration resistance of chain cable **4** in seabed soil **38**.

When viewed in direction **P**, links **17** appear to close and merge together as θ decreases, thus indicating that **W** varies inversely and non-linearly with θ (Fig. 6A). With respect to studless chain, in which width **WL** of link **17** is $3.35D$, it may be determined that for $0^\circ \leq \theta \leq 10^\circ$, $3.35D \geq W \geq 3.25D$; for $\theta = 30^\circ$, $W = 2.69D$; and for $\theta = 90^\circ$, $W = 2.48D$. Thus, substantially maximum penetration resistance, being $3.25/3.35 \times 100 = 97$ per cent, remains present when θ is as high as 10° and, similarly, 80 per cent of maximum penetration resistance remains present for θ equal to 30° . Accordingly, width **WS** (Fig. 6) of shank **7** is restricted to being not greater than width **WL**, which is equal to $3.35D$ for studless chain, so that shank **7** does not add to the penetration resistance of chain cable **4** at the critical stage of penetrating into a firm seabed surface **40** when θ is small. Further, adoption of a lesser width for shank **7** in the range of $1.9D$ to $2.2D$ is preferred when θ increases as high as 30° , which is known to occur when a series of several fluked burying devices **1** penetrate deeply to depth **Z** (Fig. 8) below seabed surface **40**.

Plates **9** and **10** are of thickness **t9** (Figs. 6) and **t10** (Fig. 5) respectively and may be of equal thickness for economy of fabrication. Thickness **t9** of plates **9** is chosen

to be less than diameter **D** so that width **WS** of shank **7** is less than $3.35D$. Preferably, thickness **t9** is chosen to be not more than $0.6D$, and preferably less than $0.5D$, to minimise the penetration resistance added by shank **7** to chain cable **4** at higher angles of inclination to axis **6** of the penetration direction **P** of chain cable **4**.

5 Referring now to Fig. 7, terminal fluked burying device **1A** is a modification of fluked burying device **1** better suited for use as a terminal device at the end of chain cable **4**. Shank **7** of terminal fluked burying device **1A** is made hook-shaped in side view and lengthened to accommodate five links **17** of chain cable **4** in five slots **12**. Fluke **8** is enlarged and offset from plane **13** and axis **14** such that furthest aft point
10 **30** of junction **11** lies on or below plane **13**. Shank **7** of fluked burying device **1A** is splayed apart adjacent forward extremity **28A** in the same manner as for fluked burying device **1**. Also, links **16A** and **17A** are supported and loaded in the same manner as for fluked burying device **1**. The increased offset loading of fluke **8** results in higher bending moments in shank **7**. These induce higher stresses which
15 are accommodated by increasing appropriately the section depth of plates **9** with distance from end **28A** of shank **7** and adding doubler plates **31** between plates **9** to act as spacers which increase the strength of shank **7** without increasing width **WS** thereof. Two contoured spacer plates **32** are welded to each of plates **9** to act both as spacers and provide stop points **19C** and **19D** which differ from previously shown
20 stop points **19A** and **19B** in that penultimate link **33** and ultimate link **34** of chain cable **4**, lying in plane of symmetry 5, are restrained thereby. Heavy bolts **35** pass through plates **9** and spacer plates **32** to prevent spacer plates **32** from being forced apart by large forces transferred thereto from ultimate link **34**. Ultimate link **34** may also serve as a lug for attachment of a pendant line to facilitate installation. Plates **9**
25 of shank **7** are extended to tip **20** of fluke **8** by way of tapered stiffeners **36** and **37** to

enable terminal fluked burying device **1A** to withstand high concentrated loading applied at tip **20**. Thus, terminal fluked burying device **1A** is, in essence, a marine drag embedment anchor constructed in two halves for assembly sideways onto chain cable **4** with chain cable **4** therein acting as a parallel load-bearing element and providing sufficient articulation to eliminate both a need for a conventional heavy and expensive shackle and the high penetration resistance penalty associated with such a shackle.

Fluked burying devices **1** and **1A** may be fitted with roll stabilizers **42** and yaw stabilizers **43** respectively (Figs. 9 and 10).

Roll stabilizers **42** (Fig. 9) comprise rectangular plates **43** attached one at each side of fluked burying device **1** to edge **44** of fluke plate **10** at a position approximately midway along the length of edge **44** with edge **45** of plate **43** being aligned with edge **44**. Plates **43** lie in plane **46** which is disposed at right angles to plane of symmetry **5** (Figs. 3 and 5) and which is inclined at an angle Δ to axis **14** of fluked burying device **1**. Plane **46** intersects plane of symmetry **5** in line **46A**. Angle Δ is subtended by line **46A** and axis **14** and is in the range of 0° to 40° , with 20° preferred. The area of plate **43** is in the range of 8 to 12 per cent of the area of each plate **10** with 10 per cent preferred. Soil incident on plate **43** produces a force parallel to plane of symmetry **5** which gives rise to a roll moment about axis **6** of chain cable **4**. Any rolling action of fluked burying device **1** causes one of plates **43** to bury deeper in soil **38** than the other and so gives rise to a net imbalance in roll moments about axis **6** acting in opposition to the rolling action, thus providing a roll stabilizing effect. Fluked burying device **1** need be stabilized only in roll since tension in chain cable **4** resists yaw misalignment, between axis **14** of fluked burying

device **1** and those portions of axis **6** of chain cable **4** adjacent and external to fluked burying device **1**, by giving rise to a large countervailing moment.

Yaw stabilizers **46** (Fig. 10) comprise substantially triangular plates **47** attached one at each side of terminal fluked burying device **1A**. A forward apex **47A** of triangular plate **47** is attached to edge **48** of fluke plate **10** at a position approximately midway along the length of edge **48**. Upper edge **49** of triangular plate **47** lies in plane **50** containing fluke plate **10** which is extended locally to support triangular plate **47**. Triangular plate **47** is located in plane **51** which is inclined at angle Ω to plane of symmetry **5** (Figs. 3 and 5) such that the intersection (not shown) between plane **51** and plane of symmetry **5** is at right angles to axis **14** of terminal fluked burying device **1A**. Thus, when angle α (Fig. 5) of fluked burying device **1A** equals 90° , angle Ω is included between edges **48** and **49**. Angle Ω is in the range of 10° to 35° , with 20° preferred. The area of triangular plate **47** is in the range of 8 per cent to 20 per cent of the area of each fluke plate **10**, with 14 per cent preferred.

Any rolling of terminal fluked burying device **1A** causes yaw to occur due to a lack of a countervailing moment being produced from through tension in chain cable **4**, as previously mentioned for fluked buying device **1**. Thus, terminal fluked burying device **1A** is subject to a roll-yaw couple. Since the resistance in soil **38** to rolling of terminal fluked buying device **1A** is greater than the resistance to yawing, it is easier and more effective to stabilize in yaw than in roll. Stabilization in yaw preventing fluke point **20** of fluked burying device **1A** from moving sideways along a helical roll-yaw path that would otherwise occur under the influence of a roll-yaw couple. Any rolling action of fluked burying device **1** causes one of triangular plates **47** to bury deeper in soil **38** than the other and so gives rise to a stabilizing net imbalance in yaw moments about the articulation contact point between links **16A** and **17A** of

chain cable **4** adjacent foremost end **28A** of shank **7**. This acts against incipient rolling action by preventing fluke point **20** from moving sideways along the unstable helical roll-yaw path.

Several fluked burying devices **1** may be used in conjunction with terminal fluked burying device **1A** (Fig. 8) to enable the full load carrying capability of any size of chain cable to be exploited fully. Each fluked burying device **1** effectively cancels adjacent penetration resistance of chain cable **4** in seabed soil **38** to allow terminal fluked burying device **1A** to achieve penetration depth **Z** below seabed surface **40** sufficient for the load contributions of each device, in aggregate, to match the breaking load of chain cable **4**. In seabeds **39** having penetrable soils **38** of limited vertical extent overlying impenetrable rock layer **41** (Fig. 8A), an extended series of fluked burying devices **1** may be deployed and installed against layer **41**, again with the load contributions from each device, in aggregate, being able to match the breaking load of chain cable **4**.

Terminal fluked burial device **1A**, now simply referred to as fluked burial device **1A**, may also be used in place of fluked burying device **1** to exploit the advantage of having a fluke offset from axis **6** of chain cable **4**. A series of fluked burying devices **1A** may, for example, be used on a hard sea bed surface **40** where offset flukes **8** are able to penetrate almost fully before underside **41** (Fig. 7) of shank **7** bears on surface **40** of seabed **39** to resist or even arrest further embedment.

It will be readily appreciated that variations of the above described fluked burying devices are possible within the scope of the present invention. For example, plates **9** of shank **7** may be provided with a different number of slots **12** than shown in the accompanying drawings. Also, additional elongated split spacers (not shown) between plates **9**, split about plane of symmetry **5**, may be provided along the

periphery of shank **7** to enable external welding along the split line to be performed, after assembly of fluked burying device **1** onto chain cable **4**, if so desired for long term service.

The present invention provides numerous advantages. Since fluked burying devices **1** and **1A** are each constructed in two halves for final assembly on chain cable **4**, the number deployed and the spacing between devices can be selected to suit soil conditions and user preferences. The devices are readily and cheaply transportable in gauge in standard shipping containers while disassembled. Incorporating chain cable **4** within fluked burial devices **1** and **1A** and the splaying of plates 9 of shank 7 to provide an adequate degree of articulation eliminates need for expensive shackles. The use of chain cable **4** as a major load-bearing element within devices **1** and **1A** allows a significant reduction in stresses to be achieved which results in reduced structural cost. The ability to distribute loading along a length of chain cable **4** by using a multiplicity of fluked burying devices **1** in conjunction with a terminal fluked burying device **1A** allows high holding capacity to be obtained from seabeds having shallow or deep sediment conditions in a manner and at a low cost hitherto unobtainable.

Claims

1. A fluked burying device (1, 1A) includes a plane of symmetry (5) and comprises a body member (7) and a fluke member (8) attached thereto at an acute angle of inclination to a longitudinal axis (14) of said body member (7), and includes
5 attachment means (12A, 12B, 12C, 19A, 19B) for holding said body member (7) in a fixed position on a chain cable (4) comprising a series of links (16, 17), whereby said longitudinal axis (14) is maintained substantially aligned with an axis (6) of said chain cable (4), said body member (7) being adapted to maintain said chain cable (4) extending in a defined attitude therein, said attachment means (12B, 12C) including
10 first contact points (19A, 19B, 19C, 19D) on said body member (7) for transferring axial load therefrom to corresponding points on a link (17B, 17C) of said chain cable (4) and second contact points (A, B) on said body member (7) for transferring transverse load therefrom to corresponding points on a link (17A, 17C) of said chain cable (4).
- 15 2. A fluked burying device (1, 1A), according to claim 1, wherein said defined attitude comprises alternate links (17) of said chain cable (4) being maintained in a plane at right angles to said plane of symmetry (5).
3. A fluked burying device (1, 1A), according to claims 1 or 2, wherein said second contact points (A, B) are positioned such as to constrain induction of bending
20 stresses in said link (17A, 17C) of said chain cable (4) during operation of said fluked burying device (1, 1A) to be similar to that which occurs in a wildcat of a windlass when tensioning said chain cable (4).
4. A fluked burying device (1), as claimed in claims 1 to 3, wherein said second contact points (A, B) are positioned on said body member (7) at two locations to bear
25 on two of said links (17A, 17C) spaced apart such as to oppose turning moment

induced in said fluked burying device (1) during interaction with a seabed soil (38) while penetrating therein when said chain cable (4) is taut.

5. A fluked burying device (1), according to claim 4, wherein said two locations of said second contact points (A, B) are spaced apart by not less than 12 times bar diameter (D) of said links (16, 17) and, preferably, not less than 20 times said bar diameter (D).

6. A fluked burying device (1, 1A), according to claims 1 to 5, wherein said second contact points (A, B) are positioned such that said corresponding load transfer points on a link (17A, 17C) lying in a plane at right angles to said plane of symmetry (5) are spaced from said plane of symmetry (5) by a distance in the range of 0.8 to 1.0 times the nominal bar diameter (D) of said link (17A, 17C).

7. A fluked burying device (1, 1A), as claimed in claims 1 to 6, wherein said second contact points (A, B) are positioned such that said corresponding load transfer points on a link (17A, 17C) lying in a plane at right angles to said plane of symmetry (5) are separated from a central point of a crown section, lying in said plane of symmetry (5), of said link (17A, 17C) by a distance in the range of 0.4 to 0.6 times the nominal bar diameter (D) of said link (17A, 17C) measured in a direction parallel to said axis (6) of said chain cable.

8. A fluked burying device (1, 1A), according to claims 1 to 7, wherein said attachment means (12A, 12B, 12C, 19A, 19B) comprises a pocket (12A, 12B, 12C) in said body member arranged of accommodate a link (17A, 17B, 17C) of said chain cable (4).

9. A fluked burying device (1, 1A), according to claim 8, wherein said pocket (12A, 12B, 12C) constrains said link (17A, 17B, 17C) of said chain cable (4) to lie in a plane at right angles to said plane of symmetry (5).

10. A fluked burying device (1, 1A), as claimed in any preceding claim, wherein said fluked burying device (1, 1A) is formed substantially in two halves (2, 3) for opposed sideways assembly on said chain cable (4).

11. A fluked burying device (1, 1A), as claimed in any preceding claim, wherein said first contact points (19A, 19B, 19C, 19D) are located adjacent said fluke member (8) whereby tensile loading impressed in said chain cable (4) by said fluked burying device (1, 1A) substantially bypasses that portion of said body member (7) lying forward of said first contact points (19A, 19B, 19C, 19D).

12. A fluked burying device (1, 1A), as claimed in any preceding claim, wherein said body member (7) comprises two elongate members (9, 10) each disposed substantially parallel to said plane of symmetry (5) and each extending along one of two opposed sides of said chain cable (4).

13. A fluked burying device (1, 1A), as claimed in claim 12, wherein said elongate members (9, 10) are plate-like.

14. A fluked burying device (1, 1A), according to any preceding claim, wherein said pocket (12A, 12B, 12C) comprises an elongate slot (12A, 12B, 12C) perforating each of said plate-like elongate members (9,10) to accommodate said link (17A, 17B, 17C).

15. A fluked burying device (1, 1A), as claimed in claims 12 to 14, wherein said plate-like elongate members (9, 10) are spaced apart by a distance between 1.06 and 1.1 times the nominal diameter of said link (16, 17).

16. A fluked burying device (1, 1A), as claimed in any preceding claim, wherein said body member (7) has a width less than that of a link (16, 17) of said chain cable (4), measured transverse to said chain cable (4).

17. A fluked burying device (1, 1A), as claimed in claims 13 to 16, wherein said plate-like elongate members (9, 10) each have a thickness (t9) less than bar diameter (D) of a link (16, 17) of said chain cable (4) and, further preferably, less than 0.5 times said bar diameter (D).

18. A fluked burying device (1, 1A), according to claims 13 to 15 and 17, wherein said elongate members (9, 10) are splayed apart at an extremity (28, 29) such that a link (16A, 16B) of said chain cable (4) emergent from said extremity (28, 29) can swing freely sideways from said plane of symmetry (5) through an angle (Θ) of up to 20°, with 12° further preferred.

19. A fluked burying device (1, 1A), according to claim 18, wherein said emergent link (16A, 16B) can swing in said plane of symmetry (5) through an angle of up to 90° from said longitudinal axis (14).

20. A fluked burying device (1), according to any preceding claim, wherein said fluked burying device (1) includes roll stabilizers (42).

21. A fluked burying device (1A), according to any preceding claim, wherein said fluked burying device (1A) includes yaw stabilizers (46).

22. A fluked burying device (1, 1A), according to any preceding claim, wherein said fluked burying device (1, 1A) is arranged such that a straight line (22) containing a centre point of a forward crown section, lying in said plane of symmetry (5), of a link (17A) in a foremost pocket (12A) in said body member (7) and a point of projection (25) onto said plane of symmetry (5) of a foremost point (20) of said fluke member (8) is inclined to said longitudinal axis (14) at an angle (δ) in the range of 25° to 35°, with 30° further preferred.