Sept. 12, 1967 R. PAVRY ET AL 3,340,694

BUOYANT FENDERS

Filed April 22, 1965 7 Sheets-Sheet 1

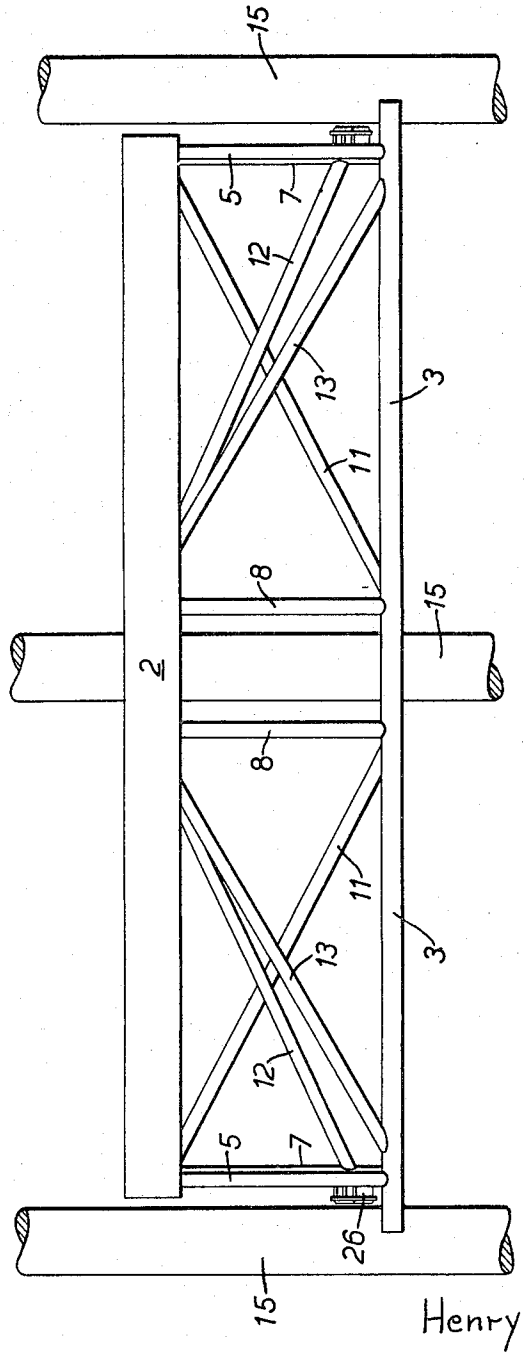


FIG. 1.

Richard Pavry
Henry W. Stephenson
INVENTORS

By Stevens, Davis, Miller & Mosher, ATTORNEYS

Sept. 12, 1967 R. PAVRY ET AL 3,340,694

BUOYANT FENDERS

Filed April 22, 1965 7 Sheets-Sheet 2

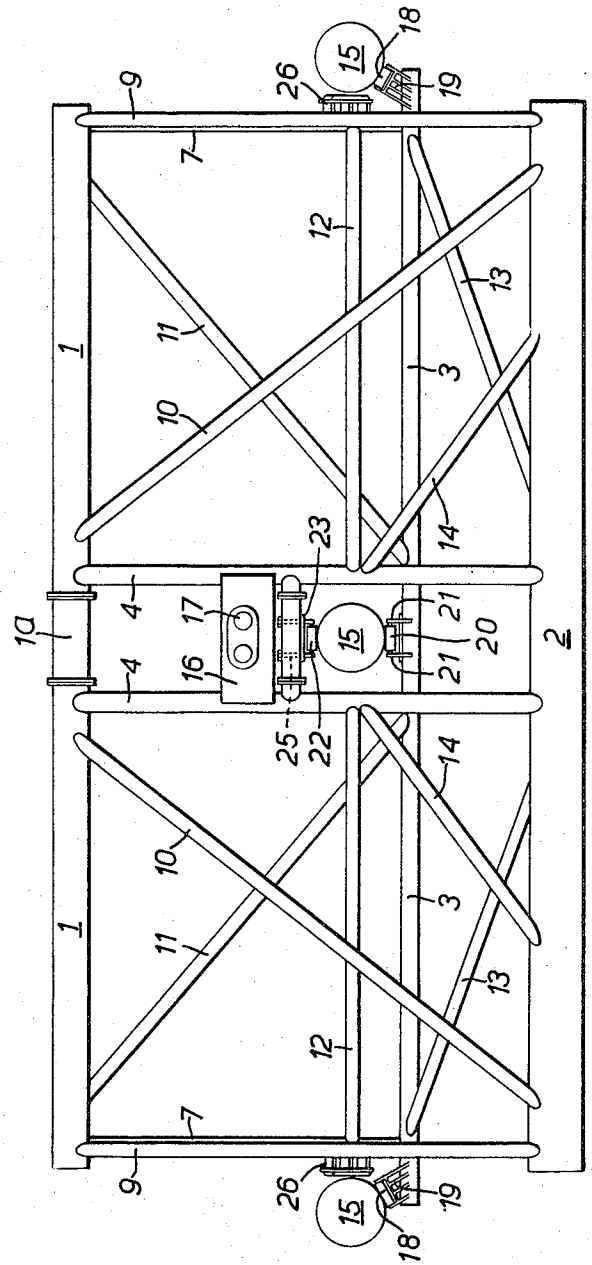


FIG. 2.

Richard Pavry
Henry W. Stephenson
INVENTORS

BY
Stevens, Davis, Miller & Mosher, ATTORNEYS

Sept. 12, 1967 R. PAVRY ET AL 3,340,694

BUOYANT FENDERS

Filed April 22, 1965 7 Sheets-Sheet 3

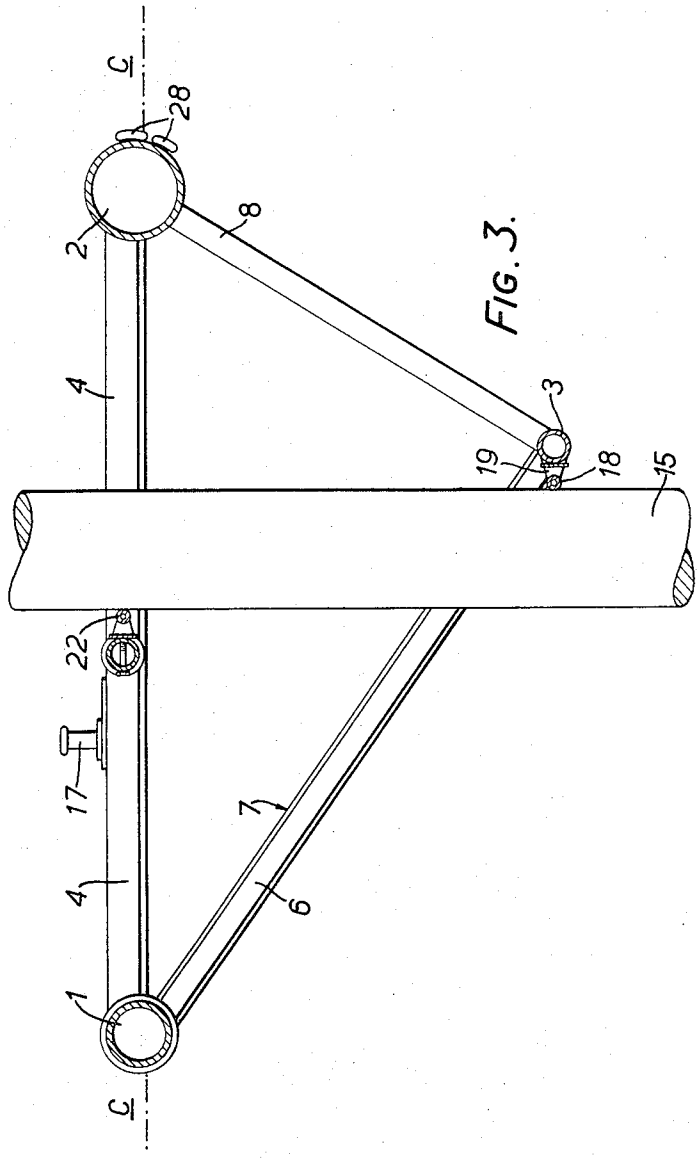


FIG. 3.

Richard Pavry
Henry W. Stephenson
INVENTORS

By
Stevens, Davis, Miller & Mosher, ATTORNEYS

Sept. 12, 1967 R. PAVRY ETAL 3,340,694

BUOYANT FENDERS

Filed April 22, 1965 7 Sheets-Sheet 4

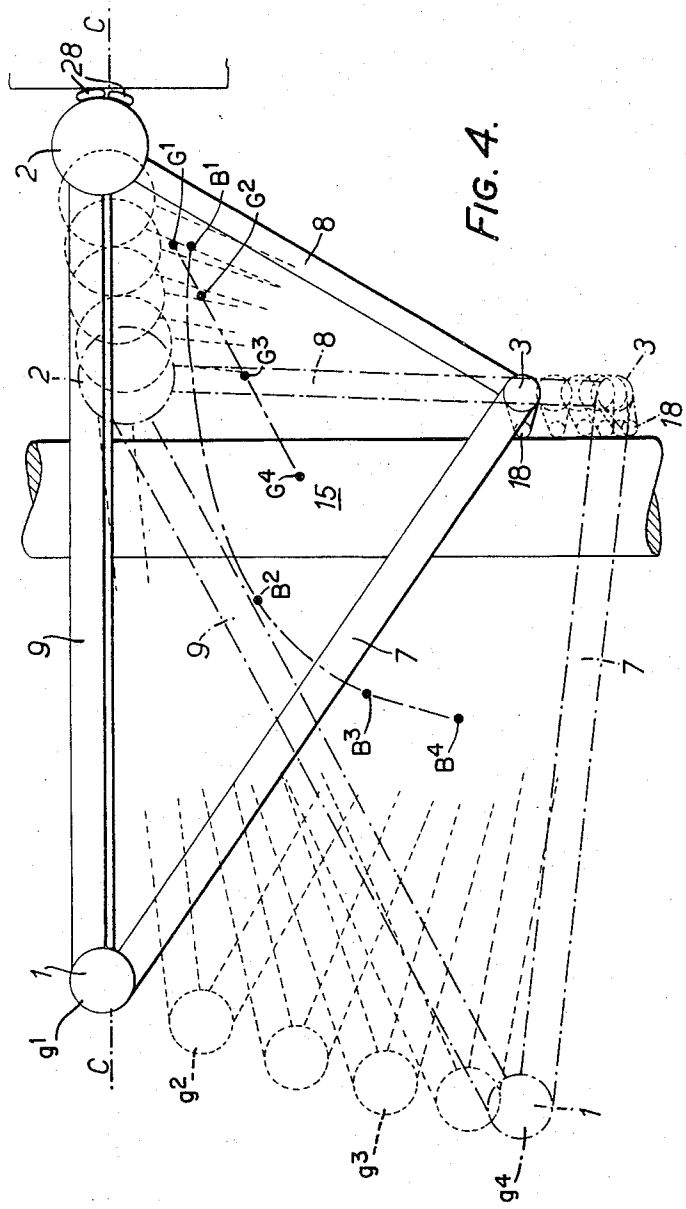


FIG. 4.

Richard Pavry
Henry W. Stephenson
INVENTORS

BY
Stevens, Davis, Miller & Mosher, ATTORNEYS

Sept. 12, 1967 R. PAVRY ETAL 3,340,694

BUOYANT FENDERS

Filed April 22, 1965 7 Sheets-Sheet 5

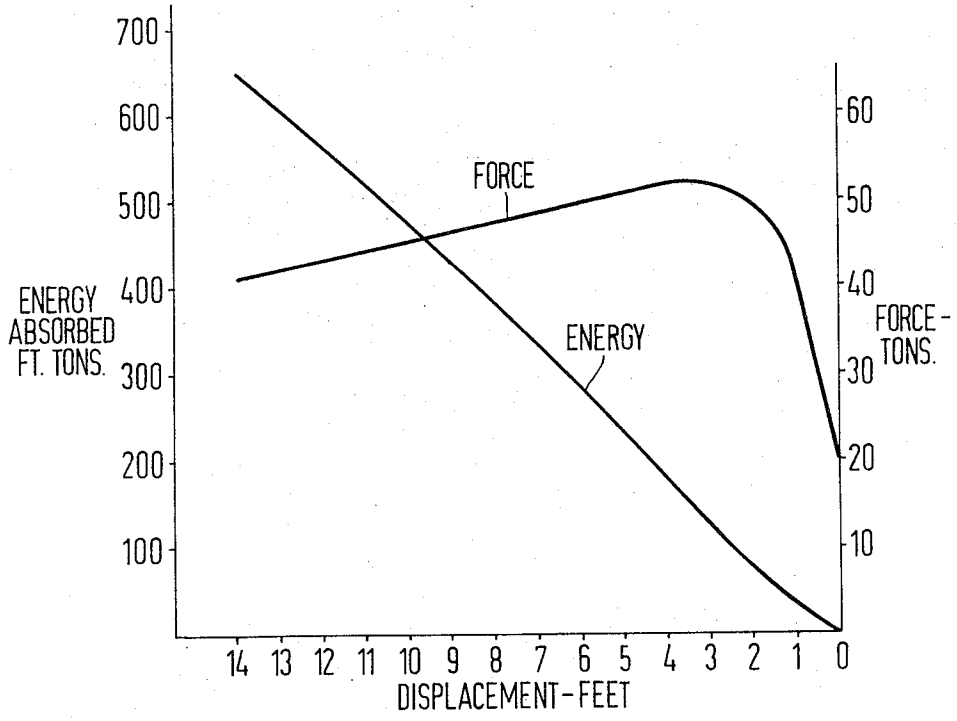


FIG. 5.

Richard Pavry
Henry W. Stephenson
INVENTORS

BY
Stevens, Davis, Miller & Mosher, ATTORNEYS

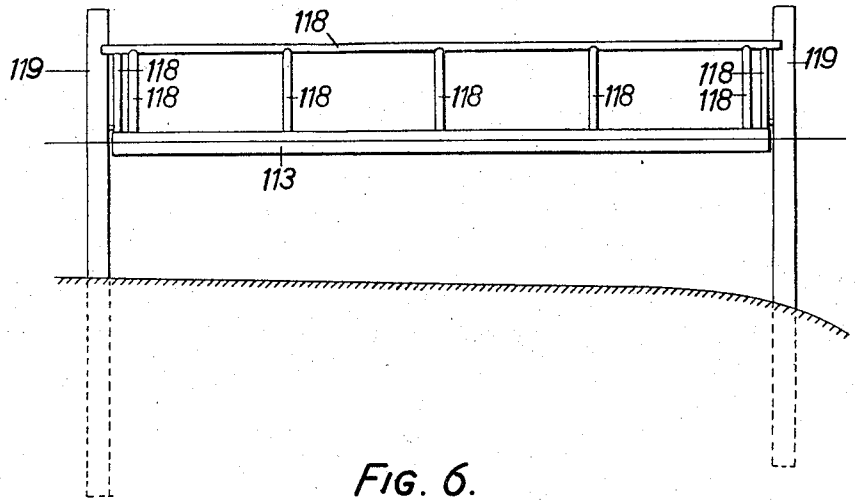


FIG. 6.

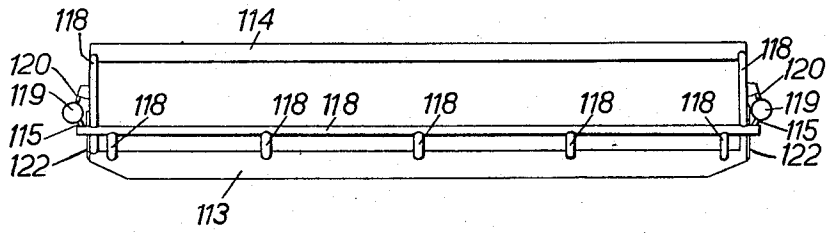


FIG. 7.

Richard Pavry
Henry W. Stephenson
INVENTORS

BY
Stevens, Davis, Miller & Mosher ATTORNEYS

Sept. 12, 1967 R. PAVRY ETAL 3,340,694

BUOYANT FENDERS

Filed April 22, 1965 7 Sheets-Sheet 7

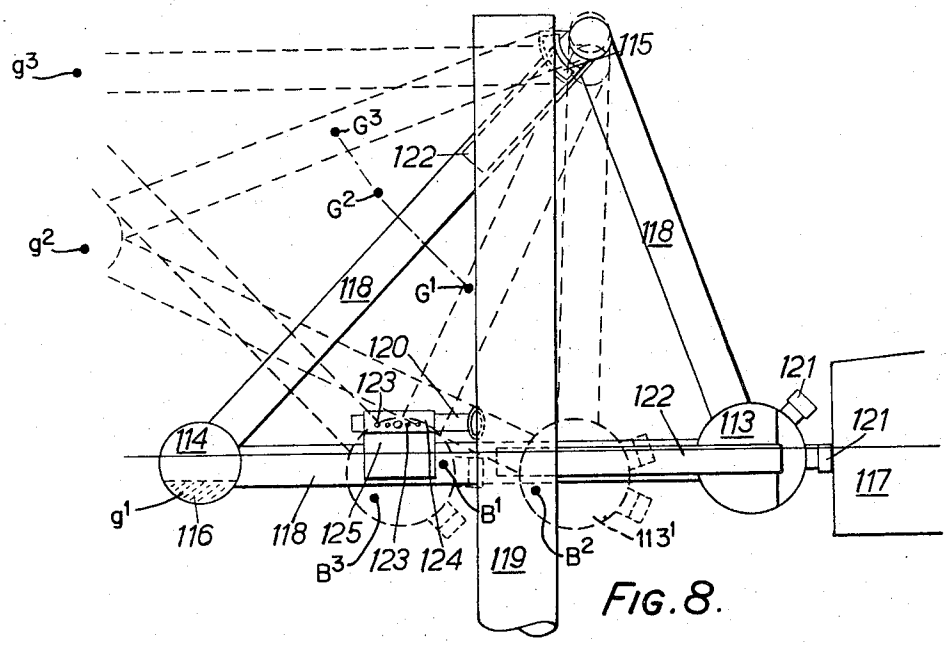


FIG. 8.

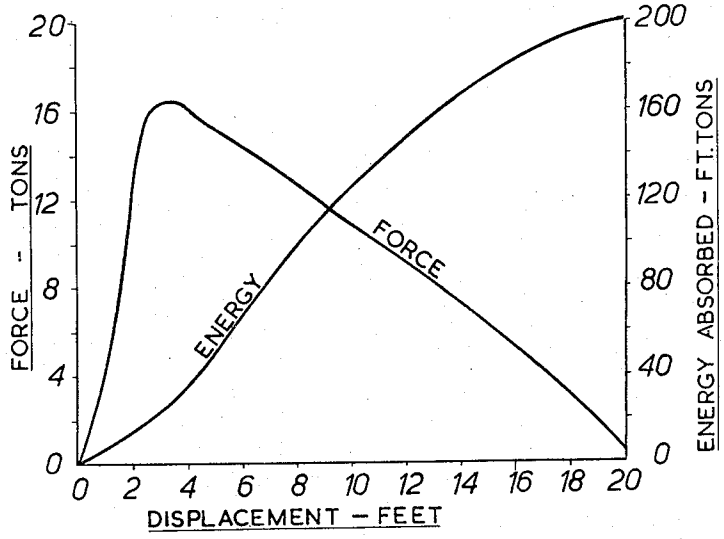


FIG. 9.

Richard Pavry
Henry W. Stephenson
INVENTORS

BY
Stevens, Davis, Miller & Mosher, ATTORNEYS

United States Patent Office 3,340,694 Patented Sept. 12, 1967

3,340,694

BUOYANT FENDERS

Richard Pavry and Henry W. Stephenson, London, England, assignors to John Albert Posford, John Francis Causton Swansbourne, Peter Weston Rowley and said Pavry

Filed Apr. 22, 1965, Ser. No. 450,103
5 Claims. (Cl. 61—46)

ABSTRACT OF THE DISCLOSURE

A buoyant fender comprising fore and aft buoyant tubes, the fore buoyant tube being positioned so that it will be engaged by the hull of a ship, the fender being so constructed that it will yield to the force due to the impact of the ship therewith and absorb the impact by a displacement of the fore buoyant member in the water in which it floats. The fore and aft buoyant members are rigidly connected together by a framework having an axis of articulation which is displaceable in a direction having a vertical component. Two embodiments show in one case an arrangement in which the aft buoyant member is displaceable downwardly in the water, and in another embodiment is displaceable upwardly away from the water level.

This invention relates to fenders for the protection of, and the prevention of damage to, fixed objects by floating objects and vice versa, such as ships berthing at quays, wharves and jetties.

It is useful for example where vessels of large displacement, e.g. oil tankers, bulk carriers and the like are to be berthed. It is a feature of the invention that large, and very large, energy absorptions can be readily and inexpensively achieved. Furthermore, such large energies can be provided with relatively low maximum forces, thus obviating damage to both ship and jetty.

In its preferred form the fender of the present invention, comprises two approximately parallel buoyant members connected rigidly together by a suitable framework and floating in the free-floating position at water level. Between the two parallel members, and similarly rigidly connected to them, but outside the plane in which they lie, are one or more bearings or fulcrums which bear against or are connected to some fixed object. It will be clear that in the free-floating position the equilibrium of the fender will be such that the center of buoyancy and of gravity will lie in a vertical line.

In operation a floating object strikes one of the parallel buoyant members and causes a rotation of the fender about the above mentioned fulcrums. The rotation causes a separation of the centers of buoyancy and of gravity which being no longer on the same vertical line give rise to a restoring couple. The ship or other floating object is thus resisted in its motion by a force which may be so designed as not to damage the ship and which absorbs or negates the ship's energy, thus bringing it to rest without causing damage.

In cases where the level of the water surface varies, whether by reason of tide, river discharge, or other cause, the invention will follow the rise or fall of the water and function effectively at all levels.

For situations where wave action might give rise to hunting or slapping of the fender against its supports and where this is held to be undesirable the fender may be effectively made rigid by an adjustable stop operating in the opposite sense to the above mentioned fulcrums. This has the effect of imparting a rotation, which may be varied at will and from time to time, and hence developing in the fender a couple which locks it to its supports. The effect of this preload or locking couple is to render

the fender rigid in waves without affecting its ability to rise and fall with the water surface.

The efficiency of the fender is further unaffected by the location of the point of impact, which may be broadside, central, off-center, or at one end.

Two embodiments of the invention are illustrated by the accompanying drawings, wherein,

FIGURE 1 is a front elevation view of an embodiment in which the bearings of fulcrums lie beneath the water.

FIGURE 2 is a plan view of FIGURE 1.

FIGURE 3 is a sectional end elevational view of FIG. 1.

FIGURE 4 is a diagrammatic end elevation view of FIGURE 1 illustrating various displacement positions of the fender.

FIGURE 5 is a diagram showing the shape of the force-displacement curve and gives the energy-displacement of the fender of FIGURE 1.

FIGURE 6 is a front elevation view of a second embodiment of the invention in which the bearings or fulcrums lie above the water.

FIGURE 7 is a plan view of FIGURE 6.

FIGURE 8 is an end elevation of FIGURE 6, and

FIGURE 9 shows the load-deflection and energy-deflection characteristics of the embodiment of FIGURE 6.

Referring to the drawings; the buoyant fender comprises a front buoyant member in the form of a straight axis steel tube **2** sealed at its ends, and a rear buoyant tube likewise comprising a steel tube **1** sealed at its ends and of smaller diameter than the front tube. At their ends the said two tubes are bridged by horizontal frame members **9** desirably of relatively smaller diameter steel tubing, so that in plan the buoyant fender is of rectangular form, the axial dimensions of the fore and aft buoyant tubes being substantially greater than the like dimension of the two side frame members. Between the ends of the buoyant tubes are secured a further pair of transverse frame tubular members **4**, which are symmetrical in relation to the transverse center line of the fender, and these are bridged by a platform **16** which may be provided with bollards **17** or other suitable devices useful in the mooring of a ship. Between the aforesaid intermediate transverse frame members and the outer frame members are secured a pair of diagonal struts **10** also desirably of steel tubing, the use of steel tubing for frame members and struts adding to the buoyancy of the upper horizontal part of the fender.

Spaced below the latter mentioned horizontal part of the fender is a horizontal tube **3** to which are welded the lower ends of a pair of downwardly converging tubes **5** and **7** at each end of the framework thereby affording in end elevation a triangulated framework, said downwardly converging tubes and the latter mentioned horizontal tube **3** being totally submerged when the fender is in use.

Desirably, the tubes **7** are of larger diameter than the tubes **5**, i.e. equal to the diameter of the horizontal frame members **4**, this diameter of the tubes **7** adding to the buoyancy of the fender in rear of the tubes **5**.

To obtain the desired rigidity of the fender construction, there are provided parallel with the downwardly converging tubes **5** and **7**, two pairs of further downwardly converging tubes **8** and **6**. Each pair being immediately beneath a respective one of the intermediate tubes **4** of the upper part of the framework, and beneath the junction of the tubes **5** and **7** to the fore and aft main buoyant tubes **2** and **1** and the ends of the tube **3** and aft buoyant tube **1**, are secured diagonally disposed struts **13** and **11** respectively, also desirably composed of steel tubing. Additional diagonal struts **14** may be secured across the first mentioned intermediate pair of transverse tubes **4** and the front buoyant tube **2**.

The foregoing arrangement of fore and aft buoyant

tubes and associated frame members, when viewed in end elevation, provide a right-angled triangulated structure, the hypotenuse side of which comprises the horizontal tubes **9** bridging the fore and aft buoyant tubes **2** and **1**, and when in use, the shorter side of the triangulated structure, i.e. the tubes **5**, is located between three equidistantly spaced vertical aligned piles **15** and the front buoyant tube **2**.

For the purpose of explaining the embodiment now being described, the said vertical piling may be regarded as comprising a central pile and two end piles, the horizontal dimension of the two buoyant tubes **1** and **2** being slightly less than the horizontal dimension between the outer two of the piles **15**, but the horizontal dimension of the lowermost horizontal tube **3** of the framework being greater, e.g. approximately equal to the horizontal dimension between the axes of the two outer piles **15**. The purpose of this is to enable the outer ends of the lowermost horizontal tube to carry anti-friction members, e.g. rollers **18**, adapted to track the two outer piles and making tangential contact therewith, these rollers being carried by brackets **19** projecting rearwardly and outwardly symmetrically with each other from said lowermost tube. In addition, the central pile is tracked by an anti-friction member, e.g. a roller **20** with its axis parallel with the buoyant tubes **1** and **2** and supported by a rearwardly extending pair of brackets **21** welded to the said lowermost tube **3**. These rollers where they abut against the piles may be regarded as affording the axis of articulation of the fender when the front buoyant tube **2** receives the impact of a ship, the maximum permissible arc of rearward displacement A (see FIGURE 4) of the front buoyant tube **2** to absorb adequately the energy due to the force supplied by the ship against the front buoyant tube being substantially less than the arc of downward displacement B of the rear buoyant tube, due to the aforesaid triangulated structure, the chord formed by normal water level C with the diameter of the front tube changing from just below the axis of the front tube to a somewhat greater extent above such axis consequent upon full rearward displacement of the front buoyant tube, the said rollers being imparted a downward movement of translation increasing progressively in dependence upon the displacement of the fender.

Interposed between the aforesaid platform **16** and the rear face of the center pile is provided means to vary the draught of the rear buoyant member when in the free floating position. This means may comprise a roller **22** disposed tangentially with respect to the center pile and carried by a bracket **23** secured to a horizontal strut **24** bridging the aforesaid intermediate frame members **4** secured across the front and rear buoyant tubes. Suitable means, such as screws **25** (see FIGURE 2), are provided with the bracket for the roller **23** to adjust such roller horizontally to enable the rear buoyant tube **1** to be depressed to a desired greater draught than the free floating position. This adjustable roller **23** separates the centers of buoyancy and gravity, and the resulting preload couple locks the fender on to the pile, thus obviating slapping or hunting under the action of the waves.

To facilitate removal of the fender from the piles, the rear buoyant tube **1** includes a flanged removable median part **1***a*, opposed to and longer than the diameter of the center pile **15**, whereby upon removal of the median tubular part and the said plate form, the fender may be displaced forwardly past the center pile.

A certain amount of limited oscillation or lateral deflection of the fender is provided, e.g. by the fitting of thrust blocks, buffers, or the like **26** to the tubes **7**, slightly above the aforesaid lowermost horizontal tube of the framing, and slightly spaced from and opposed to the outer of the two piles. Desirably the tubes **7** are stiffened, to take shocks of impact received by the buffers **26**, by a pair of strut tubes **12** secured at their inner ends to the

fore and aft tubes **4** and at their outer ends to the tubes **7** immediately behind the buffers **26**.

Suitable bolsters are tied to the outer face of the front buoyant tube for engagement with the hulls of ships.

In operation (see FIGURE 4) the fender rotates as a whole about the lower rollers **18** and **20**. The center of buoyancy moves back from normal position B1 to position B2 as the rear tube **1** is submerged to a greater extent than the normal center of gravity *g*1 to *g*2 and the resulting couple creates a restoring force against the ship's hull. Other centers of buoyancy B3 and B4 are those respective to center of gravity positions *g*3 and *g*4, respectively. In spite of the high values of energy absorption obtainable the restoring force is lower than with existing types of fender, as would be expected with the large travel possible, and in consequence nothing more than simple cushioning is required between fender and hull.

As the total buoyancy rises with submersion of the rear tube **1**, a corresponding increase in effective weight is required. This is provided, with an ample margin, by friction between fender and ship. Alternatively, if rollers or other low friction contact is considered to be acting between fender and ship the front tube **2** will rise by a small amount so that the buoyancy shed by the front tube corresponds to the added buoyancy of the rear tube **1**. If necessary the front tube may be partially filled with concrete to give the weight required. In the design of fender illustrated the weight of steelwork in tubes and framing makes this unnecessary.

If preferred, all the rollers may be replaced by pads of abrasion resistant plastic or other compounds without prejudice to the functioning of the fender.

Referring to FIGURES 6 to 9, the tubes **113** and **114** are parallel buoyant members floating at water level and corresponding to the members **1** and **2** in FIGURES 1–3. Differentiating from that embodiment however is the position of the bearings **115** which in this type are above water level. Aid tubes **113** and **114** and said bearing **115** are rigidly connected together by suitable means, in this embodiment by rigid joint Vierendeel trusses **118**.

A further point of difference is the ballasting **116** which if necessary may be placed not in the breasting tube **113** but in tube **114** remote from the floating object **117**.

The bearings **115**, which may be of roller or low friction sliding type, ride on the piles **119** which may be the supports of a wharf or jetty or may be specially provided for the fenders.

Local fendering **121** may be provided on the breasting tube **113**.

In operation the ship barge or other floating object breasts the said local fendering **121** attached to the tube **113**. The fender rotates, the tubes **113** and **114** moving to the left as seen in FIGURE 8 and the fender rotates about the bearings **115**. The tube **113** remains substantially at water level at position **113'** while the tube **114** with ballast **116**, if any, rises above water level from normal position *g*1 to position *g*2, while the normal center of gravity G1 rises to position G2, and when the tube **114** reaches maximum height position *g*1 the center of gravity position is shown at G2. Correspondingly, the position of the center of buoyancy moves from normal position B1 to position B2, and when the center of gravity is at G2, likewise, the center of buoyancy moves to position B3 when the center of gravity is at position G3. The bearings **115** rise slightly on the piles **119**. The effect of the impact of the ship **117** is thus to lift the center of gravity of the fender, absorbing energy from the ship and imparting a retarding force to it.

The energy absorption of the fender is not limited to the energy corresponding to a deflection of the tube **113** to the supports **119**. If the shape of the floating object permits the fender may be pushed through said supports **119** as shown by the dotted positions in FIGURE 8, with consequent increase in energy capacity.

FIGURE 9 shows typical force-deflection and energy-deflection curves for this type of fender.

In order, again, to prevent undue movement in waves or currents a bearing or bearings **120** may be provided on the opposite sides of the supports **119**. Said bearings **120** may be capable of adjustment by means of vernier holes or other means of fine adjustment. By moving the bearing forward, that is towards tube **113**, a small rotation of the fender may be brought about which effectively locks it to said supports **119** and renders it rigid under the action of waves or currents.

To facilitate installation and removal of the fender the bearings **109** or the bearings **120** may be made removable, thus allowing the fender to be floated into or out of position.

For the transmission of longitudinal forces thrust bearings **122** may be provided at suitable points in relation to the supports.

The frictional and other characteristics of the bearings **115**, **120** and **122** and of the local fendering **121** may be as described above for the embodiment of FIGURES 1–4.

For clarity, again, only one fender is shown in FIGURES 6–9, but a plurality of fenders sharing supports may be installed and may be loosely linked by chains or other suitable means to ensure load transference and mutual sharing of any impact.

It will be appreciated from the foregoing that under normal conditions, i.e., with the fender not engaged by a ship, and assuming a reasonably smooth water level, the center of gravity and the center of buoyancy of the fender will be approximately in a common vertical plane containing the axis of symmetry of the fender. Consequently upon the fore buoyant member **2** or **113** being displaced by the impact of the ship, i.e., towards the piles, the center of gravity of the fender will, in the embodiment of FIGS. 1 to 4, fall, and in the embodiment of FIGS. 6, 7 and 8, will rise, it being apparent that the axis of articulation comprising the member **18** of FIG. 4, or bearings **115** of FIG. 8, will have a movement of translation up and down the piles, i.e., a movement having a vertical component.

We claim:

1. A buoyant fender comprising fore and aft buoyant tubes, a triangulated framework fixedly connecting said tubes together so that, in end elevation, the buoyant tubes and the members of the framework comprise one side of the triangle normally arranged horizontally and normally close to normal, i.e. static, water level, piling for locating the buoyant fender, the junction of the other sides of the triangulated structure carrying close thereto means comprising the axis of articulation of the buoyant fender and abuttable against and slidable along the piling, said latter mentioned two sides of the triangulated framework and said means comprising the axis of articulation adapted to extend below water level, the center of gravity and center of buoyancy of the fender being normally substantially in a common vertical plane, and being displaceable relative to each other away from said plane when the fender is displaced about said axis of articulation to absorb the shock of impact of a ship.

2. A buoyant fender comprising fore and aft buoyant tubes, a triangulated framework fixedly connecting said tubes together so that in end elevation the buoyant tubes and the members of the framework comprise one side of the triangle normally arranged horizontally and normally close to normal. i.e., static, water level, piling for locating the buoyant fender, the junction of the other sides of the triangulated structure carrying close thereto means comprising the axis of articulation of the buoyant fender and abuttable against and slidable along the piling, said latter mentioned two sides of the triangulated framework and said means comprising the axis of articulation adapted to extend above water level, the center of gravity and center of buoyancy of the fender being normally substantially in a common vertical plane, and being displaceable relative to each other away from said plane when the fender is displaced about the axis of articulation to absorb the shock of impact of a ship.

3. A buoyant fender comprising substantially parallel fore and aft spaced tubular buoyant members, frame members interposed between and fixedly connecting together the said buoyant members, a portion of said frame members being in dependent relationship with the water level, means carried by said dependent frame members affording an axis of articulation of the fender and which has a movement of translation having a vertical component, the forward buoyant tubular member being positioned to receive the impact of the ship, the plane of movement of translation of said axis of articulation intersecting the plane containing the axes of the said fore and aft buoyant tubes, said point of intersection being nearer the axis of the forward buoyant tube than to the axis of the aft buoyant tube, whereby the downward displacement of the aft tube consequent upon the forward tube being engaged and displaced by the hull of a ship is greater than the aft displacement of the forward tubular member.

4. A buoyant fender comprising a number of inline vertical piles, a forward horizontal buoyant tube and a rear ballasted buoyant tube disposed substantially parallel with each other and positioned fore and aft of the line of vertical piles respectively, frame members extending between and securing the fore and aft tubes fixedly together, additional frame members extending upwardly from the said tubes, an upper horizontal frame member parallel with the buoyant tubes and to which the upper ends of the said upwardly extending frame members are secured, said upper horizontal frame member having its axis located in a vertical plane substantially normal to the plane common to the axes of the said buoyant tubes, said two planes intersecting at a line spaced aft of the front buoyant tube, but being nearer such tube than the rear buoyant tube so as to be in front of, and in juxtaposition to, said line of piles, and riders carried by the upper frame member adapted to track the frontal portion of the piles.

5. A buoyant fender as claimed in claim **4**, including means to adjust said riders relative to the fender in a direction normal to the line of piles.

References Cited

UNITED STATES PATENTS

2,417,849	3/1947	Walters et al.	61—48 X
3,055,182	9/1962	Slemmons	61—48
3,173,270	3/1965	Blancato	61—48

FOREIGN PATENTS

636,643	2/1962	Canada.

DAVID J. WILLIAMOWSKY, *Primary Examiner.*

JACOB SHAPIRO, *Assistant Examiner.*