

Sept. 21, 1971

FENG H. HSU

3,606,853

SYSTEM FOR REDUCING DYNAMIC TENSION IN ANCHOR LINE

Filed April 1, 1969

5 Sheets-Sheet 2

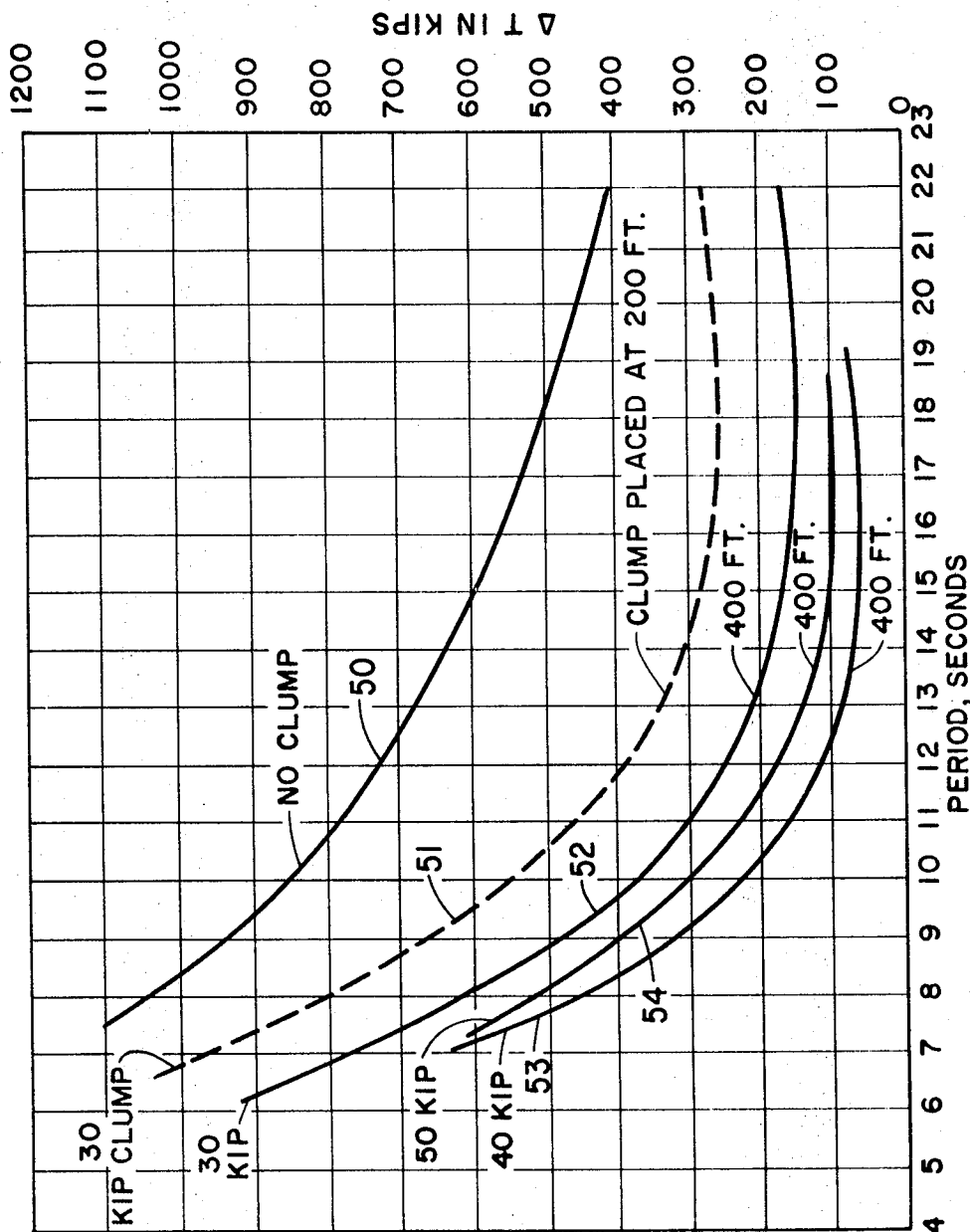


FIG. 3

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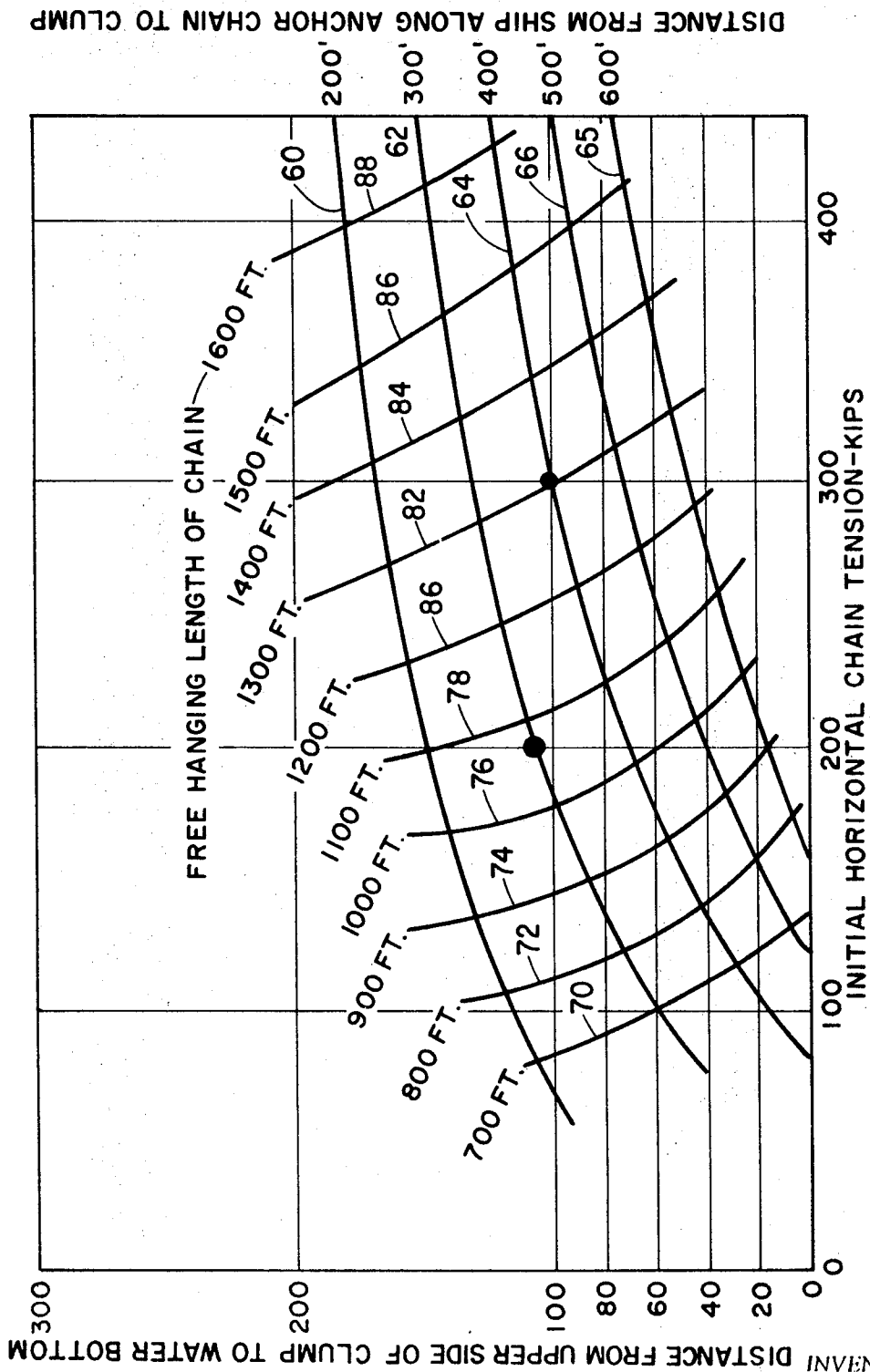


FIG. 4

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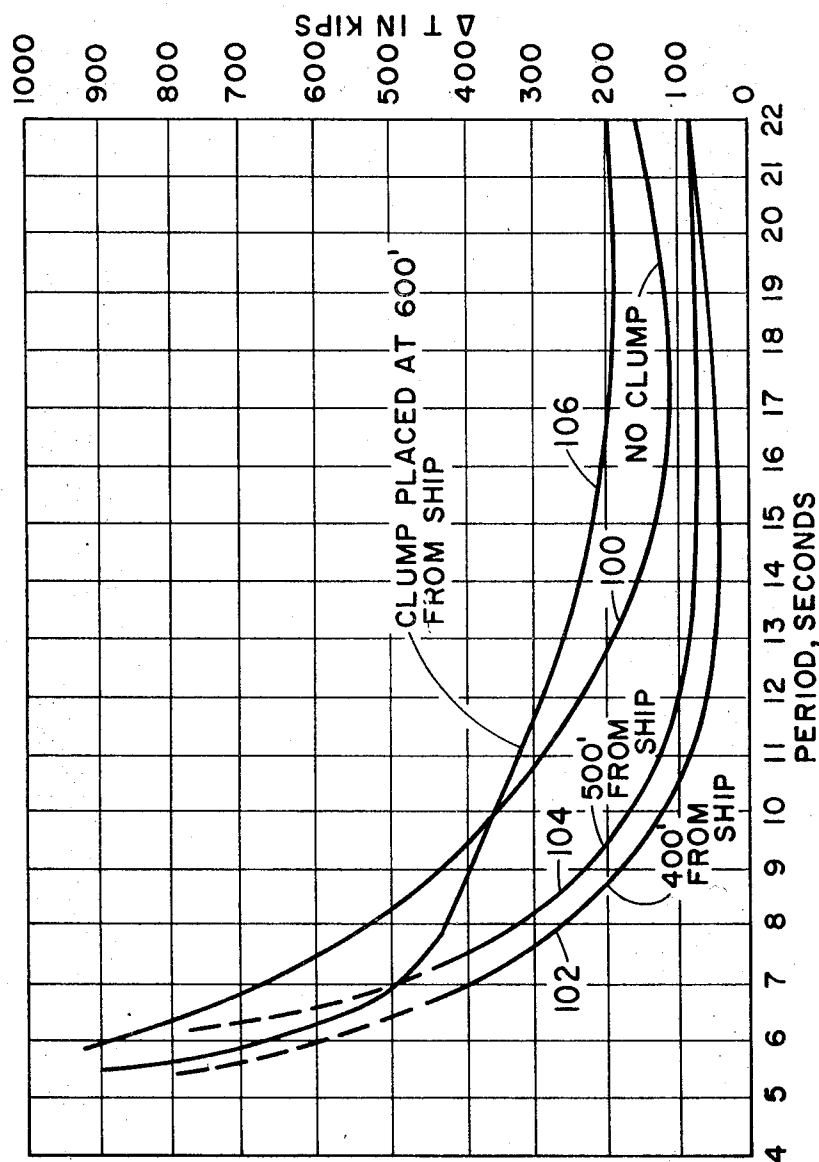


FIG. 5

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5 Sheets-Sheet 5

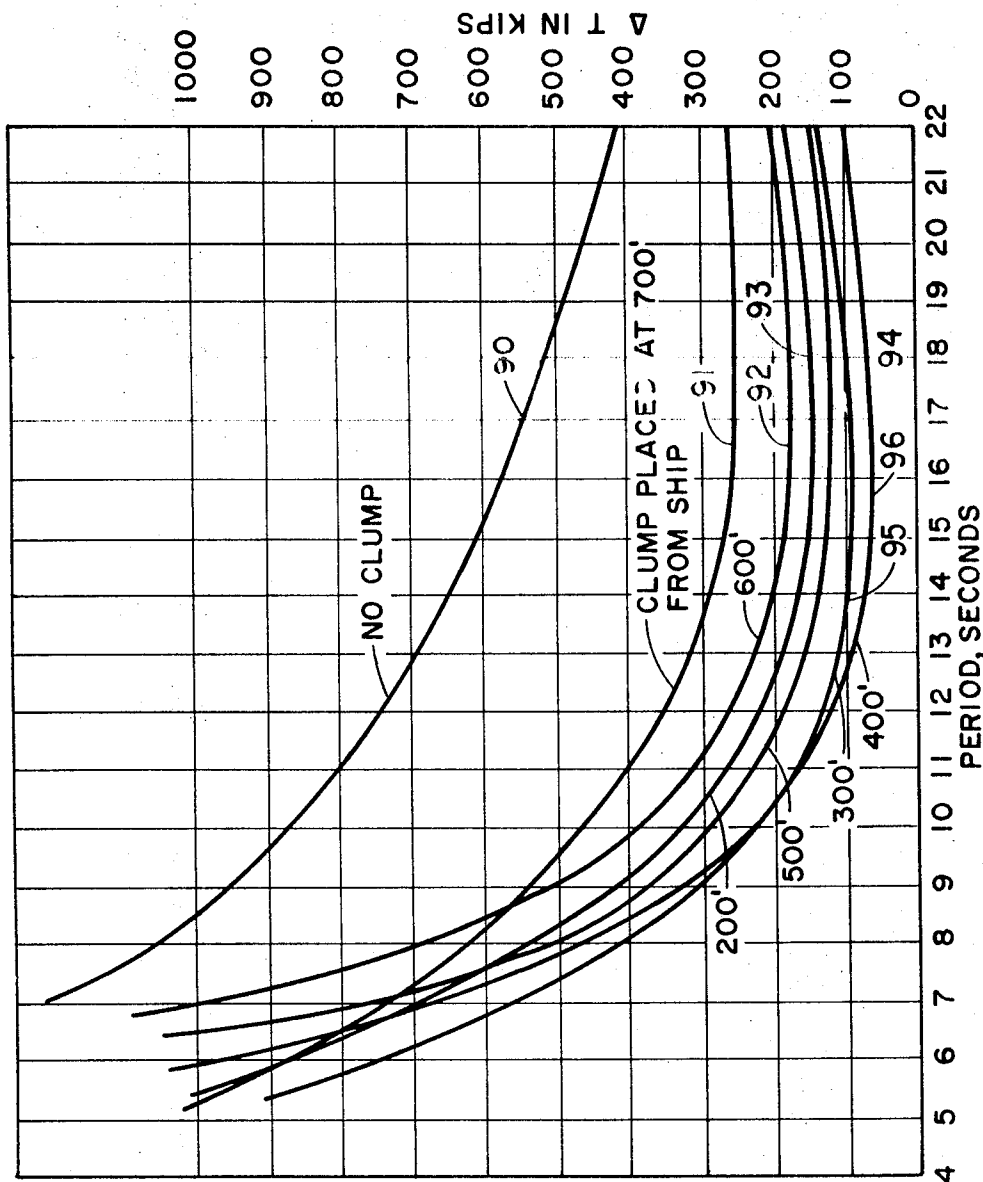


FIG. 6

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SYSTEM FOR REDUCING DYNAMIC TENSION IN ANCHOR LINE

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6 Claims

ABSTRACT OF THE DISCLOSURE

This is a system for reducing the dynamic tension in an anchor line connecting a floating vessel to an anchor. A weight clump is connected to the anchor line. The clump must be (1) within critical weight limits and (2) located properly; otherwise dynamic tension can be increased instead of decreased. The weight of the clump should be between about $1\frac{1}{2}$ and about three times the weight per unit length of anchor line times the depth of the body of water. The weight clump should be located from the ship a distance of about at least $\frac{1}{3}$ (about not over about $\frac{1}{2}$) of the free-hanging length of the anchor line.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention is concerned with a system for anchoring a ship with an anchor line to an underwater anchor. It is particularly concerned with a system for reducing the dynamic tension in such anchor line by the addition of a clump of proper weight in relation to the anchor line and the depth of water. It is further particularly concerned with the proper positioning of such weight clump.

(2) Setting of the invention

The search for oil and gas has caused many wells to be drilled in water-covered areas such as the continental shelf of the North American Continent. Many of these wells are now being drilled from floating vessels upon which the drilling equipment is carried. The vessel floats on the body of water and is subjected to the various forces imposed thereon by wind, waves and currents. In order to carry out reasonable drilling operations, the floating vessel must be maintained rather closely on position. One of the more common ways of maintaining such floating platforms on position is by the well-known use of anchor lines which connect the vessel to anchors in the bottom of the body of water.

These drilling vessels are different from ordinary sea-going ships in many respects. When the sea gets rough, ordinary sea-going ships can go to port, or if they are not maintained in a particular position it is not ordinarily of particular importance. However, the drilling vessel must be maintained in a relatively fixed position insofar as the drilling derrick in relation to a subsea well is concerned. The vessel of course may be turned into the waves about the rotary drilling rig. However, the vessel cannot ordinarily be moved except in the event of hurricane where loss of life or the vessel itself might be imminent. Thus, the floating vessel must be able to withstand rough seas and not be moved too far from its position.

The forces acting upon a floating drilling vessel by the combined action of wind and waves can be composed of two components, namely, an average drift component and an oscillatory component. The static behavior of a mooring chain has been thoroughly studied for years. Most of the present day technical know-how of mooring a vessel in open ocean is evolved from the study of the static catenary behavior of mooring chains. However, in actual situations of mooring a vessel in heavy seas such as required in anchoring a floating drilling rig, sharp periodical varia-

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tions of chain tensions have been observed. The sharp variations of chain tension is clearly outside the range of the static catenary predictions. In this specification this sharp variation of chain tensions will be called dynamic tension.

It has frequently been found that chains which were considered safe from a strength standpoint when designed, under static catenary behavior, actually failed during the storms. I have observed that it is the change in dynamic tension which cause this failure. I have also discovered a system whereby this change in dynamic tension can be greatly reduced.

BRIEF DESCRIPTION OF THE INVENTION

This is a system for reducing dynamic tension in a mooring system for a vessel floating on a body of water. In such system the vessel is anchored by a plurality of anchoring chains or cables which extend from the ship to anchors on the bottom of the body of water. The dynamic tension in the anchoring line is reduced by attaching a weight clump to the anchoring line. This weight clump must be properly positioned and be a proper size or there is the danger that the dynamic tensioning will be increased rather than decreased. In a preferred embodiment, I have found that an effective weight clump should be from about $1\frac{1}{2}$ to about three times the weight of one foot of the anchor line times the depth of water in feet. The weight clump is preferably attached near the center of the free-hanging part of the anchoring line. The weight clump can be located anywhere from a point about $\frac{1}{3}$ to a point about $\frac{1}{2}$ of the length of the free-hanging anchoring line, beginning from the vessel.

DRAWINGS

A better understanding of the invention can be had from the description of the drawings in which:

FIG. 1 illustrates an anchoring line on a ship with a clump attached thereto;

FIG. 2 illustrates the layout of a model for obtaining data concerning the weight clump and dynamic response of an anchoring line;

FIG. 3 is a set of curves showing dynamic tension for different periods in anchoring lines for different size weight clumps;

FIG. 4 is a set of curves illustrating horizontal chain distance, distance from the bottom of the body of water for weight clumps placed at different distances from the floating vessel and for different length of free-hanging lines;

FIG. 5 is a set of curves similar to that of FIG. 3;

FIG. 6 is a set of curves illustrating dynamic tension for different periods in an anchoring line for a 40 kip clump placed at different positions along an anchoring line.

PREFERRED EMBODIMENTS OF THE INVENTION

Attention is directed to FIG. 1 with illustrates a floating vessel 10 supported on a body of water 12 which has a bottom 14. An anchor 16 is embedded in the bottom 14. An anchor line or chain 18 connects ship 10 to anchor 16. A weight clump 20 is connected at point 22 to anchor chain 18. It will be noted that anchor chain 18 is partly lying on the bottom beginning at anchor 16 to about point 24. The part of the anchor chain from point 24 to the ship will be referred to herein ordinarily as the "free-hanging" section.

Before discussing the proper size or weight of weight clump 20 and its positioning along anchoring line 18, it is believed that a few comments concerning the problems involved are appropriate. The forces acting upon a floating vessel by the combined action of wind and waves can be considered as composed of two components. These are an average drift component and an oscillatory com-

ponent. The response of the vessel then can be considered as having a drift motion component and an oscillatory motion component. The basic functions to be performed by a mooring system are to (a) keep the vessel from drifting away and (b) change the relative heading of the vessel with respect to the sea in order to reduce the oscillatory motion of the vessel.

The static behavior of a mooring chain has been studied for years. Most of the present-day technical know-how of mooring a vessel in open ocean is evolved from the study of the static catenary behavior of mooring chains. However, in actual situations of mooring a vessel in heavy seas, sharp periodic variations of chain tensions have been observed. This sharp variation of chain tensions (usually called dynamic tension) is clearly outside the range of the static catenary predictions. It is the dynamic response of the chain that is responsible for this phenomena.

A study has been made on the dynamic chain response in mooring a vessel during a nuclear blast in the Pacific Ocean. The computer program developed by that study is too slow and is very expensive to use. Further, the investigations made in such study concerning the boundary conditions of the sea floor do not include the fact that a considerable portion of the chain is lying on the sea bottom. In view of the slowness of the computer program and the fact that the program boundary conditions do not fit the actual situation, I adopted a model experimental study. This model experimental study was necessary because there was no readily available mathematical way of doing it. With length, weight, time, drag and inertia forces properly scaled, the model I developed is actually an analog computer. Attention will next be directed to FIG. 2 which illustrates such a model.

The model includes a tank 26 which was about 20 feet long and about 2 feet wide and 2 feet deep. The bottom of the tank was covered with a sand layer 28 about 1/2" deep. An anchor rod 30 is provided at one end of the tank. At the other end of the tank is a chain driving unit 32. Chain driving unit 32 is provided with a revolving plate 34. A vertical rod 36 is attached at point 38 to plate 34. The lower end of rod 36 is connected to an anchor chain 40 which extends from rod 36 to anchor 30. An adjustable and rotatable pivot 37 is fastened to the driving unit 32. The rod 36 is led through the pivot 37 at the end opposite the end connected to anchor chain 40. Pivot 37 was primarily to keep the upper end of rod 36 from wobbling. A strain gauge 42 is provided in anchor chain 40. Circle 44 shows one motion of the upper end of the chain 40 as disc 34 is rotated. The strain gauge 42 is connected to a recorder 46 so that a record can be made of the tension in anchor line 40 as a function of the motion of the end of the anchor line. The model was scaled so that the water depth would represent 215 feet and the chain length about 1,800 feet. The force was scaled so that 1 gram read on strain gauge 42 represented a force of 1.750 kips.

The model of FIG. 2 was used to run several experiments. Some of the results of such experiments are shown in FIG. 3. There, the abscissa represents period in seconds and the ordinate represents change in tension in kips. It is to be noted that the periods most frequently encountered by a floating vessel are in the range from about 7 to about 15 seconds. The anchor line of the model corresponded to a 3" chain weighing about 90 pounds per foot. The top of the clump was at a level which corresponded to about 90 feet above the bottom of the body of water. Curve 50 illustrates the change in tension when no clump was used. Curve 52 corresponds to a 30 kip clump weight; curve 53 illustrates a 40 kip weight and curve 54 illustrates a 50 kip clump. These clumps were located a distance corresponding to 400 feet from the floating vessel on an anchor line having a free-hanging section of about 1,200 feet. The initial static average tension on the anchor line corresponds to about 300 kips. It is seen that

when no clump was used, the increase in kips varied from about 500 for an 18 second period to nearly 1,000 for an 8 second period. (Dotted curve 51 illustrates the change in dynamic tension for a 30 kip clump placed 200 feet from the vessel. This curve will be discussed later in connection with the proper placing of the clump.)

It is clear from the curve of FIG. 3 that a 40 kip clump is superior to either the 30 or the 50 kip clumps. For example, in a period of 14 seconds the anchor line with the 40 pound clump had an increase of about 80 kips, the anchor line with the 50 kip clump about 110 and the anchor line with the 30 kip clump had about 180 kips increase in tension. At this same period the anchor line with no clump had over 600 kips increase. It is seen then that the 40 kip clump was most effective for reducing the dynamic tension. As the result of my studies I have concluded that the effective clump should be between about 1 1/2 to 3 times the weight of one foot of the anchor line times the water depth. For example, in the chain weighing 90 pounds per linear foot and water 215 feet deep, the minimum size clump should be about 30 kips and the maximum about 60. Smaller clumps become less and less effective. If the clumps become too large they become objectionable because the distance between the clump and the bottom of the body of water becomes so small that the clump will contact the bottom during the dynamic motion of the chain. This contact with the bottom should be avoided because the dynamic tension will be increased by the interaction between the clump and the bottom.

Attention is next directed to FIG. 4. There, the abscissa is horizontal chain tension in kips, and the ordinate is the distance from the upper end of the clump to the bottom of the sea in feet. The more nearly horizontal curves 60, 62, 64, 66 and 68 represent different locations for a 40 kip clump. Thus, curve 60 represents a clump 200 feet from the ship along the anchor line; curve 62, 300 feet; curve 64, 400 feet; curve 66, 500 feet; curve 68, 600 feet. The more nearly vertical curves 70, 72, 74, 76, 78, 80, 82, 84, 86 and 88 represent free-hanging lengths of chain of 700 feet, 800 feet, 900 feet, 1,000 feet, 1,100 feet, 1,200 feet, 1,300 feet, 1,400 feet, 1,500 feet and 1,600 feet, respectively. It is desired that the weight clump be at least about 250-300 feet from the vessel so that it does not interfere with the normal operations of such vessel. For a 200,000 pound chain tension in 215 feet of water, a 40 kip clump 300 feet from the vessel will be a little over 100 feet above the bottom of the sea. If the clump were placed 500 feet from the vessel for this same tension, the top of the clump will be only 40 feet from the bottom of the sea. This is the limit which the clump should be placed inasmuch as a 40 kip clump would ordinarily be about 20 feet in height. As it is desired that the clump never touch bottom, then one, under these conditions, would not place the clump over 500 feet from the vessel. FIG. 5 has curves 100, 102, 104 and 106 on a graph in which the ordinate is in change in tension and the abscissa is in period. Curve 100 represents ΔT where no clump was used. Curves 102, 104 and 106 represent ΔT for a 40 kip clump placed 400 feet, 500 feet and 600 feet, respectively from the vessel. As one could see from FIG. 5, with the clump placed at 500 feet, the dynamic tension is reduced, whereas at 600 feet, the dynamic tension is actually increased above that dynamic tension which would occur if no clump was used. In these instances, the anchor chain represented a length of about 1,800 feet, with the free-hanging portion about 1,000 feet. From the data of FIGS. 4 and 5, then, one should not place the clump closer than about 1/3 of the free-hanging length of chain from the vessel and not over about 1/2. Under usual operating conditions, this will prevent the clump from being in the way of the operations of the vessel and will also ordinarily be supported above the bottom of the body of water.

Attention is next directed to FIG. 6 for a further con-

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sideration of the proper placement of the weight clump. There, the abscissa is in seconds representing period and the ordinate is in change of tension in kips. The average tension on the chain was 300 kips, the clump weight 40 kips. The chain was 3" and weighed 90 pounds per foot. Shown on this chart are curves 90, 91, 92, 93, 94, 95 and 96, which represent no clump, a clump placed at 700 feet from the ship, at 600, at 200, at 500, at 300 and at 400, respectively. It is seen that the anchor chain with no clump has the greatest change in dynamic tension and that the anchor line with a clump placed 400 feet from the vessel had the least dynamic change as shown on curve 96. As the clump was moved either closer or further than 400 feet from the vessel, the change in dynamic tensioning increased. The data here, as in the other cases, was obtained in water simulated to be 215 feet deep and an anchor chain about 1,800 feet long. The more effective placement of clumps was between about 200 feet and 600 feet. In view of the fact that approximately 200 feet in chain should be allowed to turn the vessel into the storm direction, the most desirable placement of the clump would be at about 400 or 500 feet. In this case, the clump placed at 400 or 500 feet will not interfere with vessel turning, nor will it contact the bottom. These distances represent about $\frac{1}{3}$ and $\frac{2}{3}$ of the length of the free-hanging portion of the anchor chain.

It is thus seen that the weight of the clump should be between about $1\frac{1}{2}$ and about three times the weight per unit length of anchor line times the depth of the body of water. The clump should be located from the ship a distance from about $\frac{1}{3}$ (but not over about $\frac{1}{2}$) of the free-hanging length of the anchor chain.

While the above embodiments of the invention have been described with considerable detail, it is to be understood that various modifications of the device can be made without departing from the scope or spirit of the invention.

I claim:

1. A system for reducing the dynamic tension in a

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mooring system for a vessel floating on a body of water which comprises:

anchor means on the floor of said body of water;
an anchor line connecting said anchor to said floating vessel;

a weight clump attached to said anchor line at a point such that under all operational tensions, said weight clump is above the bottom of said body of water, the weight of said clump being at least about $1\frac{1}{2}$ times the product of the weight of one foot of said anchor line times the depth of water in feet.

2. A system as defined in claim 1 in which said weight clump is attached to a segment of said anchor line, said segment beginning at about one-third, and ending at about one-half, of the length of the free-hanging portion of the anchor line from said vessel.

3. A system as defined in claim 1 in which said weight clump is attached to the anchor line at about the mid-point of the free-hanging length of the anchor line.

4. A system as defined in claim 1 in which the weight of said clump is in the range of from about $1\frac{1}{2}$ to about 3 times the product of the weight of one foot of said anchor line times the depth of water in feet.

5. A system as defined in claim 4 in which said weight clump is attached to a segment of said anchor beginning at about one-third, and ending at about one-half, of the length of the free-hanging portion of the anchor line from the vessel.

6. A system as defined in claim 4 in which said weight clump is attached to about the mid-point of the free-hanging length of the anchor line.

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