U-TUBE STABILIZER HAVING ADJUSTABLE CROSSOVER DUCT AND END CHAMBERS

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Filed: Nov. 26, 1971

Appl. No.: 202,497

U.S. Cl. .............................................. 114/125
Int. Cl. .............................................. B63b 43/06
Field of Search ................................. 114/121, 122, 125

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ABSTRACT
A passive U-tube stabilizing tank adjustable in frequency for matching the natural frequency of the tank to the natural roll frequency of an associated vessel. The stabilizing tank is filled to a predetermined level with stabilizing liquid, above the level of the crossover duct. The effective length of the crossover duct, and the effective length of the respective end chambers are variable by means of horizontally oriented gate valves cooperating with a plurality of vertical plates located in the end chambers. The natural frequency of the tank is varied by moving the gate valves with respect to the vertical plates.

8 Claims, 3 Drawing Figures
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BACKGROUND OF THE INVENTION
The U-tube stabilizer had long been known in the prior art as a device useful in countering the roll of watergoing vessels. Such a “connected” dynamic system is intended to operate so that the tank liquid oscillates 90° out of phase with the driving force, in this case, the roll of the ship. In this manner, the liquid in the end chambers of the U-tube acts to counteract the roll of the ship.

The passive U-tube stabilizer is not, however, without its disadvantages. During various sea states, and under varying loading, a ship’s roll often changes in its natural frequency from its calculated or observed natural frequency at the design condition. In fact, a ship often rolls at natural frequencies quite far removed from the design natural frequency. While the damped free-surface tank is able to successfully cope with such changes in roll frequency, the U-tube is ordinarily not. With the known U-tube stabilizers oscillated at other than the design frequency, the phase lag will be somewhat higher or lower than 90°, and hence the stabilizing effect is diminished to some extent. In some extreme cases the oscillation of the liquid may even cause a destabilizing rather than a stabilizing effect on the ship.

There are known passive stabilizers which attempt to vary the frequency of the U-tube to match the varying roll frequency of the ship. The stabilizers typically provide a valved air cross-connection between the upper ends of the two chambers, where changes in the valving controls the liquid oscillation in the U-tube. While these devices are to some extent capable of changing the U-tube frequency, they are known to greatly restrict the transfer of liquid between the end chambers. The rise and fall of liquid in the end chambers tends to be insufficient to provide the significant force necessary to counteract the roll of the ship.

It is toward the elimination of the above-noted problems that the present invention is directed.

SUMMARY OF THE INVENTION
The present invention relates to a U-tube stabilizing tank equipped, for the first time, with means for matching the U-tube frequency to the frequency of roll of the ship without degrading the stabilizing effect of the tank.

It has been found that the natural frequency of liquid transfer within a U-tube stabilizer is a function of the relative lengths of the crossover duct and the end chambers. The natural frequency of oscillation of liquid in a U-tube stabilizing tank increases as the length of the crossover duct decreases. The tank of the present invention, basically, a U-tube stabilizer comprising two end chambers connected at their lower ends by means of a crossover duct. A series of horizontally spaced vertical plates are secured to the inner walls of the respective end chambers and run coextensive thereto, separating each end chamber into a series of horizontally spaced vertical channels.

In the preferred embodiment of the present invention, a horizontally oriented gate valve is slidably mounted on the inner walls of the crossover duct adjacent the upper wall thereof. The respective gate valves are adapted to travel horizontally and selectively close from the bottom, one or more of the vertical channels of the end chambers. By closing selected vertical channels, the effective length of the crossover duct is thereby increased, while the effective length of each end chamber is correspondingly decreased. The flow of tank liquid is restricted to those channels not sealed by the gate valves.

By changing the liquid flow from one end chamber to the other in accordance with the teachings of the present invention, the frequency of oscillation of the liquid is altered. Yet there is substantially no “choke” effect on the free transfer of stabilizing liquid as there is an unrestricted uniform area crossover duct through which the stabilizing liquid flows and unrestricted uniform area end chambers into which the stabilizing liquid flows. This capability enables the frequency of the U-tube stabilizer to be matched to the frequency of the roll of the ship without detracting from the stabilization effects. And the number of distinct frequencies of oscillation is a function only of the number of vertical channels provided. When the roll frequency of the ship changes due to varying loading conditions or sea states, the gate valves are simply activated and positioned so as to match the natural frequency of oscillation of the tank to the roll of the ship, thereby maintaining the desired 90° phase relationship between the ship’s roll and the liquid oscillation, without substantially affecting the transfer of tank liquid.

Accordingly, it is the main object of the present invention to provide a passive U-tube stabilizer which may be quickly and efficiently matched in frequency to the roll frequency of the associated vessel.

It is a further object of the present invention to provide a passive U-tube stabilizer whose natural frequency may be incrementally varied over a relatively wide range of frequencies.

It is yet a further object of the present invention to provide a passive U-tube stabilizer whose natural frequency can be varied without changing the liquid level in the tank.

Still another object of the present invention is to provide a passive U-tube stabilizer whose natural frequency may be incrementally varied by changing the length of the crossover duct and the lengths of the end chambers.

These and other objects of the present invention, as well as many of the attendant advantages thereof, will become more readily apparent when reference is made to the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS
FIG. 1 is an enlarged cross-sectional view of the inventive variable frequency U-tube stabilizer;
FIG. 2 is a sectional view of the inventive stabilizer taken along line 2—2 of FIG. 1; and
FIG. 3 is a sectional view taken along the line 3—3 of FIG. 1.

DETAILED DESCRIPTION OF THE DRAWINGS
With reference to FIGS. 1 through 3, the inventive variable frequency U-tube stabilizer tank will be described. The U-tube stabilizer is shown generally at 10 and comprises two end chambers 20 and 22 interconnected at their respective lower ends by a horizontal crossover duct 24. As shown in the figures, two vertical plates 26 and 28 are fixedly secured to the top inner walls 33 of the respective end chambers 20 and 22, each plate extending entirely across the width and sub-
stantially the entire height of the end chambers. The vertical plates 26 and 28 are arranged parallel to the longitudinal bulkhead components of the end chambers, and define a series of three vertical chambers 30, 32 and 34 within each end chamber. A liquid 36 is housed in the stabilizer 10 and oscillates between end chamber 20 and end chamber 22, being transferred through the crossover duct 24. The vertical plates 26 and 28 extend to the respective tops of the end chambers and terminate at their lower ends substantially at the level of the top of the crossover duct 24. A set of three vents 38 is provided at the top of each upstanding end chamber, with one vent in each of the three vertical channels 30, 32 and 34, to prevent pressure buildup in the end chambers when the liquid 36 oscillates in the tank 10.

A gate valve arrangement shown generally as 40 in provided at each end of the crossover duct 24 and associates with the respective end chambers 20 and 22. The gate valves 40 are capable of restricting the flow of liquid 36 through one or more of the sets of channels 30, 32 and 34. Each gate valve 40 comprises a door 42 slidably mounted on a set of tracks 44 secured to the inner wall 31 of the crossover duct 24, as most clearly illustrated in FIG. 3. The doors 42 are horizontally and simultaneously moved by means of a winch 46 and a pair of cables 48. As seen in FIGS. 1 and 2, each cable 48 is continuous, is controlled by the winch 46, and is attached to the associated door 42 at both ends thereof. A pulley arrangement 50 is secured at each end of the tank 10, substantially at the height of the respective gate valves 40, and serves to reverse the direction of the cable 48. Hence, by activating the winch 48, the cables 48 act on the respective doors 42 to adjust the positions of the doors relative to the vertical plates 26 and 28. As can best be seen in FIG. 2, the cables 48 associate with the winch 46 so that the respective doors 42 move simultaneously and in the same sense.

When the doors 42 are in the positions illustrated in FIG. 1 and 2, the doors contact only the vertical plates 28, thereby substantially sealing off only the most inboard channel 30. But it should be appreciated that the doors can be moved further outboard to contact both vertical plates 26 and 28, thereby sealing off the two most inboard channels 30 and 32, thereby deactivating the tank entirely. Or the doors could be completely retracted from the regions of the end chambers to make full use of the lengths of the end chambers. It should be apparent therefore, that the inventive tank is extremely versatile, and that the number and range of incremental frequencies of oscillation for matching the frequency of the tank to that of the ship may be varied by changing the number and spacing of the vertical plates 26 and 28.

Now, the function of the gate valves 40 and the vertical plates of the inventive U-tube stabilizer tank 10 will be described. With the gate valves 40 in their fully open position, liquid oscillates through the crossover duct and is free to pass into any of the three vertical channels 30, 32, and 34 of the end chambers. The effective lengths of the crossover duct under these conditions is represented by w1 in FIG. 1; and the corresponding frequency of oscillation is f1. As actually shown in FIG. 1, the gate valves 40 have been moved outboard so as to abut the first vertical plate 28. Liquid oscillating through the crossover duct may therefore enter only through the most outboard two of the vertical channels 32 and 34, with substantially no liquid entering the most inboard channel 30. The effective length of the crossover duct is therefore w2, and the U-tube then has a natural frequency f2. With the gate valves moved to abut the second vertical plate 26, liquid can transfer only through the most outboard of the vertical channels 34. The crossover duct is therefore increased in length to w3, and the natural frequency of the tank becomes f3. Naturally, with the gate valves in their most outboard position, complete deactivation of the U-tube system is accomplished, such gate valve positioning being useful when the loading condition or sea state causes the ship to roll at frequencies so far removed from the frequency band of the inventive stabilizer that stabilization cannot be practiced.

The vertical plates 26 and 28 are substantially evenly spaced from the inboard and outboard walls of the end chambers. And the tank is designed so that with the gate valves in one of their intermediate positions, the tank is matched to the average roll frequency of the ship. Then, if the roll frequency of the ship changes due to loading conditions or sea state, the gate valves are adjusted accordingly. As mentioned previously, the natural frequency of oscillation of the liquid in a U-tube stabilizing tank increases as the length of the crossover duct decreases. And since w1 < w2 < w3, f1 > f2 > f3. Therefore, in order to increase the natural frequency of the inventive stabilizing tank, as may be necessary after the ship's cargo has been discharged, the valve gates should be moved inboard.

Above, the preferred embodiment of the present invention has been described. In such an embodiment, a passive U-tube stabilizer is equipped with means for quickly and simply varying the relative lengths of the crossover duct and the end chambers, thereby bringing about a change in the natural frequency of the tank and permitting the matching of the tank to the roll of the ship over a wide band of roll frequencies. And while the lengths of the crossover duct and the end chambers are varied to effect a change in the frequency of liquid transfer, the liquid is still allowed to transfer without restriction from one end of the tank to the other. Accordingly, the frequency of the invention U-shaped stabilizer may be changed without adversely effecting the moment developed thereby. A specific embodiment of this invention has been described, but for purposes of illustration only. It should be understood that many alterations and modifications may be practiced by those skilled in the art without departing from the spirit or scope of the invention. Accordingly, it is the intent that the present invention not be limited by the above, but be limited only as defined in the appended claims.

What is claimed is:
1. A passive U-tube stabilizing tank containing a predetermined quantity of stabilizing liquid and particularly suited for use across the beam of ships, the tank comprising: a pair of end chambers; a crossover duct interconnecting said end chambers near the lower portion thereof, for transferring said stabilizing liquid between said end chambers, and associating with said end chambers so as to define a substantially U-shaped stabilizing tank; a plurality of vertical channels within each of said end chambers, plates being secured to the top inner walls of said end chambers, being substantially parallel to the inboard and outboard walls thereof, and extending from the top of said end chambers downward to substantially the top of said crossover duct;
and gate means associating with each of said end chambers and said plates for selectively blocking all transfer of said stabilizing liquid through one or more of said channels in each end chamber, or for entirely retracting from the regions of said end chambers.

2. The stabilizing tank as defined in claim 1, and further comprising: vents in the tops of each channel of said end chambers for preventing pressure buildup in the stabilizing liquid.

3. The stabilizing tank as defined in claim 1, wherein said gate means lie parallel to and adjacent the top of said crossover duct.

4. The stabilizing tank as defined in claim 1, and further comprising winch means for simultaneously and correspondingly moving each of said gate means.

5. The stabilizing tank as defined in claim 4, wherein said winch means associates with first and second cables, the ends of which are connected to the respective inboard and outboard ends of said gate means.

6. The stabilizing tank as defined in claim 5, wherein said winch and said cables are wholly enclosed within the confines of said stabilizing tank.

7. The stabilizing tank as defined in claim 1, wherein each gate means comprises: a track; a door slidably mounted on said track and adapted to travel substantially perpendicular to said plates; and means for moving said door.

8. The method of stabilizing a vessel against roll when the frequency of roll of said vessel changes substantially, and wherein the vessel is equipped with a liquid housing passive U-tube stabilizing tank having a variable length crossover duct and variable length end chambers, the method comprising the steps of: determining the instantaneous frequency of roll of said vessel; and varying the relative lengths of said crossover duct and said end chambers, thereby changing the natural frequency of oscillation of said liquid, and thereby matching the frequency of oscillation of said liquid to the frequency of roll of the vessel.

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