April 2, 1963 **K. C. RIPLEY** **3,083,674**

LINEAR-RESPONSE FLUME STABILIZER

Filed Oct. 13, 1961 2 Sheets-Sheet 1

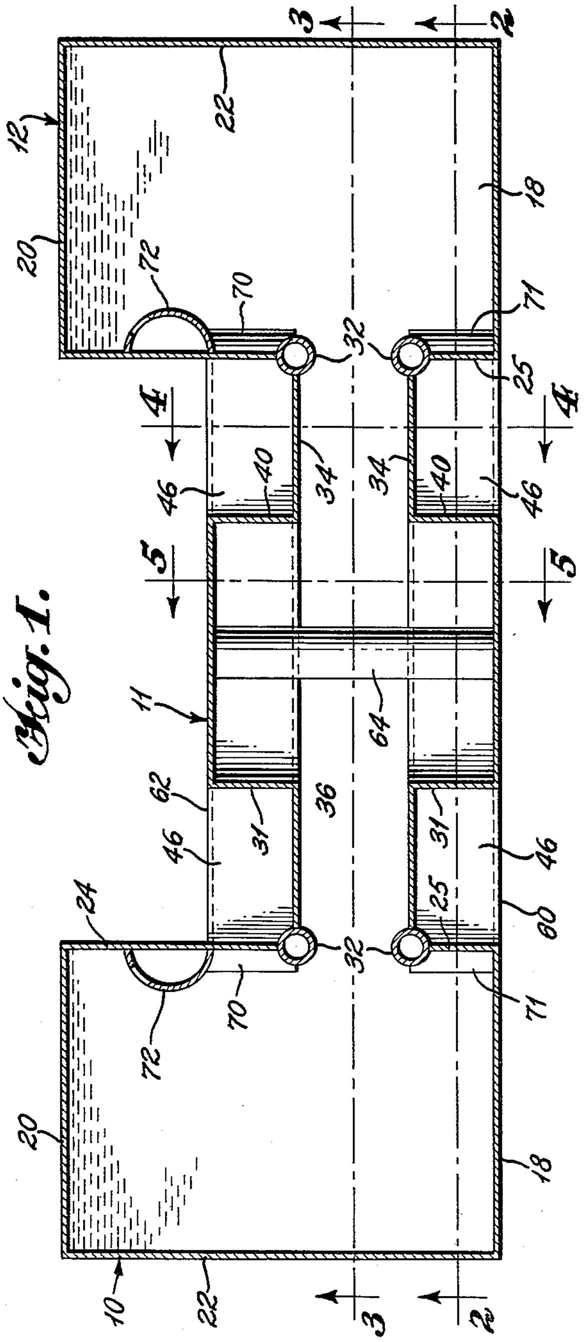

Fig. 1.

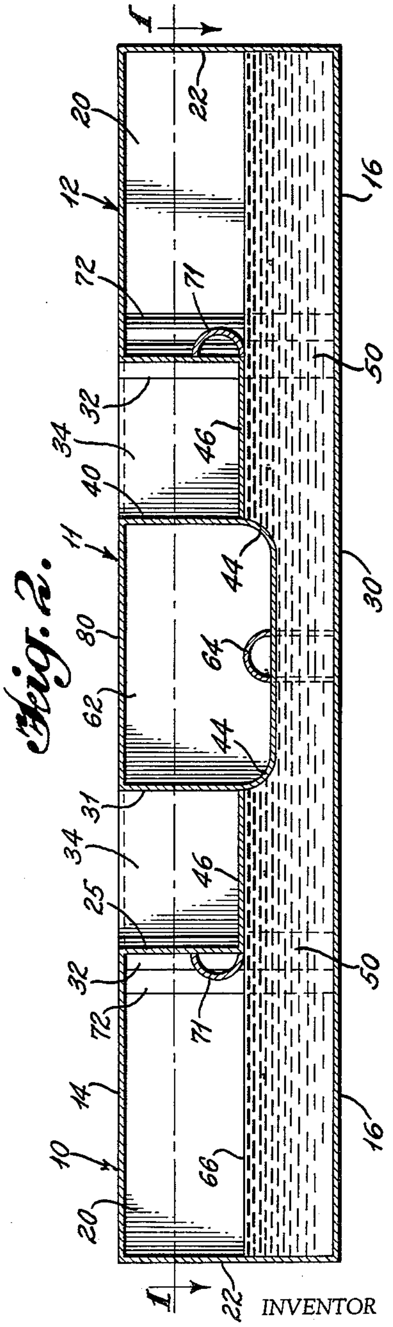

Fig. 2.

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2 Sheets-Sheet 2

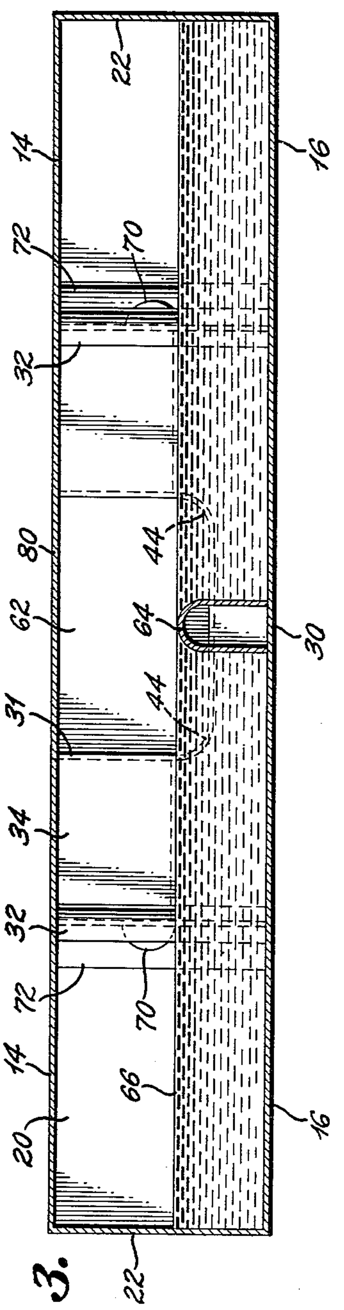

Fig. 3.

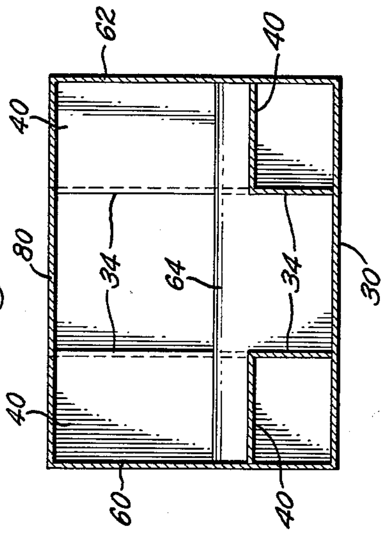

Fig. 5.

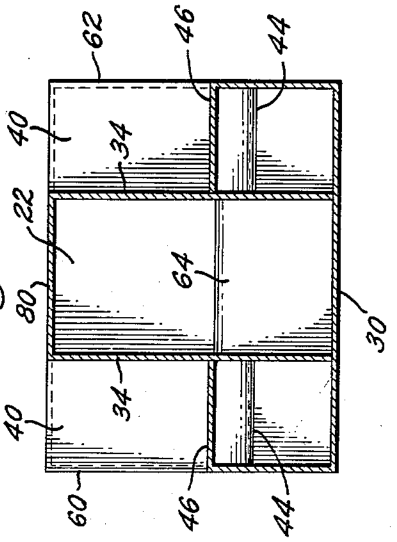

Fig. 4.

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LINEAR-RESPONSE FLUME STABILIZER

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5 Claims. (Cl. 114—125)

The present invention relates to improved roll stabilizing apparatus for ships and other water-going vessels adapted to function in a substantially linear fashion to produce well stabilized roll regardless of the water conditions encountered.

Shipowners and users have long appreciated the desirability of stabilizing their vessels against rolling as a consequence of an upsetting movement imparted by wave action of the water. The extent to which any ship is subjected to rolling is dependent largely upon the roll characteristics of the ship, including its own damping properties, and the frequency and amplitude of the waves exciting the ship. Rolling, of course, can best be described as an oscillation of the ship about its longitudinal axis.

First efforts to stabilize ships against rolling were manifested as passive stabilization systems very simply designed as U-tubes. The principal aim of such systems was to transfer a quantity of liquid, usually water, between a pair of wing tanks located on opposite sides of a ship, this being by means of an interconnecting and submerged crossover duct. Quite early it became evident that in order to produce a stabilizing moment in opposition to the upsetting moment imparted by the wave action of the sea water or other body of water, it was necessary for the system to develop stabilizing moments in an appropriately phase relationship with respect to the upsetting moments of the sea. This was achieved through the use of throttling techniques applied either to the liquid being transferred from wing tank to wing tank, or by means of throttling of the air in the spaces above the wing tanks in a suitably timed and phased manner as the water was transferred between the wing tanks. The early approaches to this problem tended to treat the operation of the entire system in a linear fashion, but it soon became evident that the response of such a system was inherently non-linear, the percent stabilization falling off significantly at large angles of stabilized roll. The early systems, though operative, were objectionable because of erratic performance, noise resulting from throttling the air, and the practice of allowing frequent adjustment in the throttling.

In more recent times, roll stabilization systems have been designed utilizing activation, and the principal proponents of such systems are those favoring the activated fin stabilizer. In this system, a pair of fins project from opposite sides of the ship below the water line, and are controlled by an arrangement of gyroscopes and motors to produce stabilizing moments in opposition to the upsetting moment imparted by the sea. Activated fin systems have been designed and operated quite successfully, but they have several inherent disadvantages. The system requires a large amount of costly and complex apparatus and consequently its use is prohibitive except for expensive luxury passenger ships. From an operational standpoint, the system is condition-responsive and thus, activation of the fins occurs after the event or else occurs in a pre-calculated pattern subject to error correction. In either case, the fins tend to hunt. Moreover, a fin stabilizer is designed to operate almost independently of the ship, and so compensates rather fully for the ship inertia forces and the ship static stability forces, as well as the ship damping forces. Therefore, it must be designed to handle exceptionally large loads.

Quite recently, an invention was made in the passive stabilization art which represented a substantial improvement over passive stabilization systems heretofore known. The improved passive stabilization system is designed to operate at or near the resonant rolling condition of a ship and therefore works in conjunction with the natural damping characteristics of the ship, to augment damping by a large factor. The dissipation of energy in this improved system occurs during the transfer of the water from one wing tank to another, but takes place in a non-linear fashion. Hence, the system has proven beneficial in reducing roll under all circumstances encountered at sea. In this improved system the conventional U-tube design was departed from and a flume was established across the ship. No reliance was placed upon throttling of the air in the space above the liquid in the flume, but rather the air pressure throughout the system was maintained in substantial equalization at all times. In place of appreciable damping of air, the system operated on the principle of non-linear dissipation of energy by forcing the liquid to pass through specially designed nozzles while it was being transferred from one side of the ship to the other. Although this improved system contributes a stabilizing moment under all conditions encountered in the sea, more recent studies have shown that the response of the system by being non-linear means that its effectiveness in terms of percent roll reduction falls off significantly as the severity of the sea builds up to the more extreme storm conditions (State 6 sea and beyond). At large angles of roll, the nozzles choke the water to such an extent that a sufficient amount of water is not transferred during each rolling cycle.

It is the principal aim of the present invention to provide a still further improved passive stabilization system which is more complex than systems heretofore known in that it does not rely upon a single mode of operation but rather employs two integrated modes of operation. As a result, the system of the present invention responds in a substantially linear fashion regardless of the sea conditions encountered, by automatically adjusting to changing sea conditions. For its basic design the present invention employs some of the principles heretofore known that are effective for producing substantial roll stabilization in mild sea conditions, and also includes features which implement and complement the basic design to yield progressively larger amounts of stabilizing moment as the sea conditions become more severe. In essence, the present invention comprises two essentially non-linear responding modes of operation in a manner that the resultant operation is substantially linear.

The foregoing is accomplished by utilizing a pair of wing tanks located on opposite sides of a ship and interconnected by a complex duct structure which includes one or more passages designed with special nozzles to dissipate energy from transferring water non-linearly, and also a passage in the nature of a flume which includes a weir or sill.

It is therefore a principal object of the present invention to provide a passive stabilization system that is characterized by a complex crossover duct with one portion of the duct functioning as a submerged crossover duct including a nozzle for the non-linear dissipation of energy from the transferring water, and another portion of the duct functioning as a flume crossover duct including a weir whereby the resultant operation of the two portions of the crossover duct will coact to produce a substantially linear response under all conditions encountered at sea.

It is a further object of the present invention to provide a substantially improved passive stabilization system that will operate effectively and efficiently and yet will be simply constructed and have the necessary durability to withstand the large forces that it will encounter in operation.

Other and further objects of the present invention will become more readily apparent from the following detailed description of a preferred embodiment of the present invention when taken in conjunction with the appended drawings, in which:

FIGURE 1 is a view in section taken along line 1—1 of FIGURE 2 showing the novel passive stabilization system of the present invention;

FIGURE 2 is a view in section taken along the line 2—2 of FIGURE 1;

FIGURE 3 is a view in section taken along line 3—3 of FIGURE 1;

FIGURE 4 is a view in section taken along line 4—4 of FIGURE 1; and

FIGURE 5 is a view in section taken along line 5—5 of FIGURE 1.

Referring now to the drawings, a preferred detailed embodiment of the present invention will be described illustrating the preferred mode for carrying out the present invention. As shown in the drawings, the passive stabilization system is comprised of a pair of wing tanks generally designated by the numerals **10** and **12** and an interconnecting complex crossover duct generally designated by the reference numeral **11**. The wing tanks **10** and **12** are located on opposite sides of a ship and are usually arranged above the water line. As will be appreciated, the principal function of the stabilization system is to produce a stabilizing moment at each side of the ship appropriately phased and in opposition to the upsetting moment imparted to the ship by the sea. Therefore, it would naturally follow that the higher in the ship the system is located, the more effective it will be.

The wing tanks are made as rectangular boxes having a top **14**, a bottom **16**, fore and aft walls **18** and **20**, and an outboard or end wall **22**. The wall opposite end wall **22** is present in two sections **24** and **25**.

The complex crossover duct **11** interconnecting the two wing tanks **10** and **12** defines a pair of submerged crossover duct portions with a flume crossover duct portion between them. A floor **30**, which forms a continuation of the bottoms **16** of the wing tanks, is provided for all the duct portions. A pair of pipes **32** are located at the free edges of walls **24** and **25**. These pipes **32** are spaced apart and extend from the bottom **16** to the top **14**. A pair of duct walls **34** extend between the pipes **32** attached to walls **24** and the pipes **32** attached to walls **25**. Walls **34** extend from the floor **30** to the top of the duct except for a U-shaped cutout **31** in their mid-portions. A U-shaped wall section **40** is attached normal to each wall **34** at its cutout edge **31**. The U-shaped wall section **40** extends from the plane of the top of the wing or side tanks **10** and **12** and terminates spaced from the floor **30**. The corners **44** of each U-shaped wall **40** are rounded. Flat plates **46** are located spaced from the floor **30** and above the bottom of the U-shaped wall **40** and extend from the walls **24** and **25** to the U-shaped wall **40**. The wall **25** terminates spaced from the bottom **16** and defines an entrance **50** into the side passage of the duct defined on the outside of the central wall **34** attached to plates or walls **25**. The walls **24** have the lower corner adjacent plate or wall **34** cut out to define an entrance into the side passage of the duct defined on the outside of the central wall **34** attached to plates or walls **24**. A wall **60**, in the plane of walls **18**, is attached to and forms a continuation of these walls **18**; a wall **62** is attached to the walls **24** between its vertical edges.

A sill or weir **64** extends across the entire duct in the mid-portion and rises to a predetermined height. The top of the weir **64** is rounded in the manner illustrated and in the preferred embodiment is designed to a height exactly equal to the level of the liquid **66** in the system. In the central portion of the duct, the weir is attached to the floor **30**, but in the side portions of the duct, the weir is attached to the U-shaped wall **40**. A curved plate **70** is attached at one edge to the lower cutout edge of wall **24** and at its other edge to an intermediate line on wall **24**. Similarly, a curved plate **71** is attached at one edge to the lower edge of wall **25** and at its other edge to an intermediate line on wall **25**. A vertical curved wall section **72** is attached to top **14**, bottom **16**, and at one edge to wall **24** in line with wall **62** and its other edge to an intermediate line on wall **24**. The wall sections **72** are provided with a series of vertically spaced holes to allow water in the stabilizer free ingress and egress to the interior of the wall section **72**. Finally, a top plate **80** is attached to walls **34**, walls **40** and pipes **32** and forms a continuation of the tops **14** of the wing tanks.

The complex crossover duct defines a pair of submerged duct portions bounded by walls **34**, walls **60** and **62**, floor **30**, the curved bottom part of walls **40**, and walls or plates **46**. The entrances **50** to these submerged duct portions are provided with nozzle designs constituted by pipes **32** and curved plates **70**, **71** and **72**. The center part of each submerged crossover duct portion is characterized by a nozzle design provided by plates **40** and floor **30**.

The complex crossover duct also defines a central flume passage bounded by walls **34**, walls **40** and walls **60** and **62**. Midway, the flume passage is obstructed by the weir **64**. The flume passage also provides a continuous air passage above the level of liquid **66** for free interchange of air between the wing tanks.

The operation of the system is substantially as follows. The system as portrayed in the drawings is located in a ship or other vessels substantially normal to the longitudinal axis of the ship or, in other words, athwartship. As the ship rolls due to an upsetting moment imparted by the sea, the liquid **66**, usually water, is caused to flow from one wing tank through the complex crossover duct to the other wing tank and back again as the upsetting moment is applied to the other side of the ship. At small angles of roll the bulk of the liquid transfer will be through the submerged crossover duct portions on each side of the complex crossover duct. As the water transfers through the submerged duct portions, the nozzle designs coact with the water to dissipate energy from it in a non-linear fashion due to the velocity squared damping characteristic of the nozzle designs. The weir **64**, during these times, will block any substantial transfer of water between the wing tanks through the flume duct portion located in essence between and above the submerged crossover duct portions. It will be appreciated, however, that a small amount of water will flow over the weir **64** during these times, but the energy dissipation will be quite small compared to that which is taking place in the submerged crossover duct portions. As a consequence, the system will generate a stabilizing moment appropriately phased to oppose the upsetting moment imparted by the sea.

As the upsetting moment imparted by the sea becomes greater and the ship tends to roll at higher angles, the submerged crossover duct portions will experience a choking characteristic and more water will be transferred via the flume duct portion over the weir **64**. Although the submerged crossover duct portions will actually be transferring a larger amount of water at larger angles of stabilized roll, the efficiency of transfer will be reduced. On the other hand, the water will be transferred through the flume duct portion in greater quantities and with improved efficiency so that the overall transfer of water through the complex crossover duct will be sufficient to impart linearity to the system. That is to say, the increase in upsetting moment will be met with a substantially linear increase in the stabilizing moment. This represents a decided improvement over prior known passive stabilization systems in which the efficiency decreases as the roll angle increases.

It is possible to modify the system described above by eliminating certain structural parts. For instance, the plates 46, 70 and 71; the walls 25; and the portion of walls 24 from pipe 32 to plate 72 can be removed. The plates 60 and 62, in these circumstances, will be rectangular and extend from floor 30 to the plane of tops 14. The plate 80 will also be rectangular and coextensive with floor 30. These removals will make the entrance regions to the submerged crossover duct portions flumes.

Although the present invention has been shown with reference to a single preferred embodiment, it will be appreciated that changes and modifications can be made which do not depart, in principle, from the inventive concept herein taught. For instance, the submerged crossover duct portions of the complex crossover duct have been shown provided with simple nozzle designs at their entrances and a main nozzle design in their midportions. It is possible to design the submerged crossover duct portions so that the principal energy dissipation occurs at the entrances to the submerged crossover duct portions as opposed to occurring in their mid-portions. This can be accomplished simply by including substantial nozzle designs at their entrances. Accordingly, such changes and modifications, as will appear obvious to one skilled in the art, are deemed to come within the purview of the invention.

What is claimed is:

1. A passive stabilization system for a ship or other vessel comprising a pair of wing tanks adapted to be located on opposite sides of a vessel and a complex crossover duct interconnecting said wing tanks for transferring liquid therebetween, said duct including a submerged portion characterized by restriction means defined therein adapted to act upon liquid transferring therethrough to dissipate energy therefrom and a flume portion characterized by a weir adapted to block the transfer of a substantial amount of liquid therethrough at small angles of stabilized roll.

2. A passive stabilization system for a ship or other vessel comprising a pair of wing tanks adapted to be located on opposite sides of a vessel and a complex crossover duct interconnecting said wing tanks for transferring liquid therebetween, said duct including a submerged portion characterized by restriction means defined therein located in the central part thereof adapted to act upon liquid transferring therethrough to dissipate energy therefrom and a flume portion characterized by a weir adapted to block the transfer of a substantial amount of liquid therethrough at small angles of stabilized roll.

3. A passive stabilization system for a ship or other vessel comprising a pair of wing tanks adapted to be located on opposite sides of a vessel and a complex crossover duct interconnecting said wing tanks for transferring liquid therebetween, said duct including a pair of submerged portions characterized by restriction means defined therein adapted to act upon liquid transferring therethrough to dissipate energy therefrom and an intermediate flume portion characterized by a weir adapted to block the transfer of a substantial amount of liquid therethrough at small angles of stabilized roll.

4. A passive stabilization system for a ship or other vessel comprising a pair of wing tanks adapted to be located on opposite sides of a vessel and a complex crossover duct interconnecting said wing tanks for transferring liquid therebetween, said duct including a submerged portion characterized by restriction means defined therein located in the central part thereof, and further restriction means defined therein located at the entrances to said submerged portion adapted to act upon liquid transferring therethrough to dissipate energy therefrom and a flume portion characterized by a weir adapted to block the transfer of a substantial amount of liquid therethrough at small angles of stabilized roll.

5. A passive stabilization system for a ship or other vessel comprising a pair of wing tanks adapted to be located on opposite sides of a vessel and a complex crossover duct interconnecting said wing tanks for transferring liquid therebetween, said duct including a pair of submerged portions characterized by restriction means defined therein adapted to act upon liquid transferring therethrough to dissipate energy therefrom and an intermediate flume portion having an enlarged region overlying in part said submerged portions characterized by a weir adapted to block the transfer of a substantial amount of liquid therethrough at small angles of stabilized roll.

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