Jan. 30, 1968 B. A. HILLIARD 3,366,087

ANTI-PITCH SYSTEMS

Original Filed Nov. 9, 1964

FIG. 1

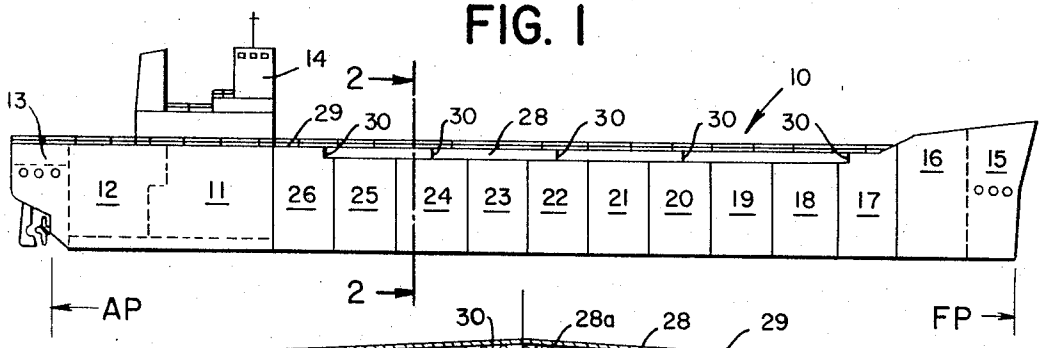


FIG. 2

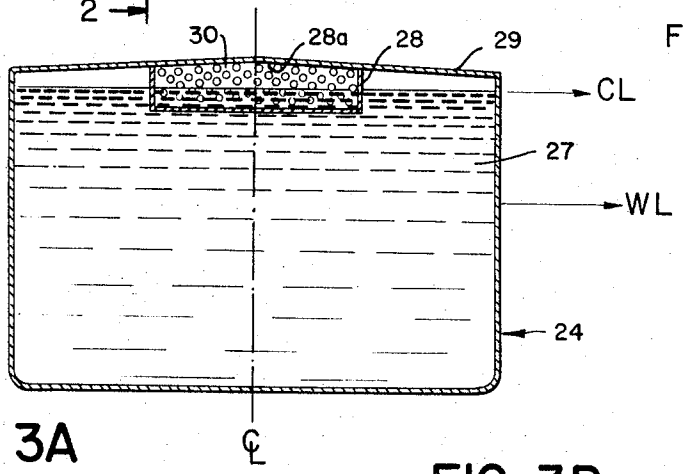


FIG. 3A

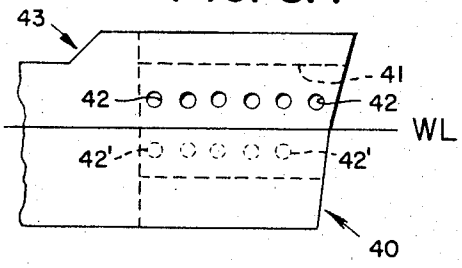


FIG. 3B

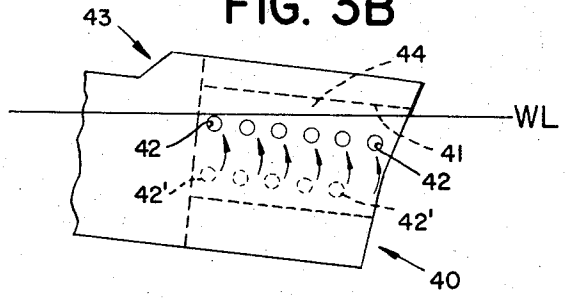
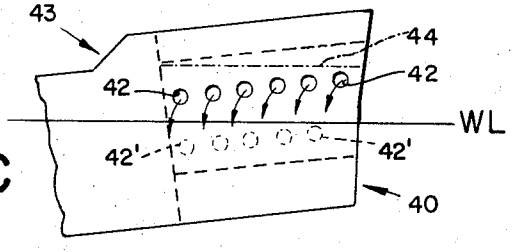


FIG. 3C



INVENTOR.
BRYANT A. HILLIARD

BY Donald F. Cobbs

ATTORNEY

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ANTI-PITCH SYSTEMS

Bryant A. Hilliard, Norwalk, Conn., assignor to Esso Research and Engineering Company, a corporation of Delaware

Original application Nov. 9, 1964, Ser. No. 409,703, now Patent No. 3,286,677, dated Nov. 22, 1966. Divided and this application June 2, 1966, Ser. No. 566,172
3 Claims. (Cl. 114—125)

ABSTRACT OF THE DISCLOSURE

A pitch stabilization system for a liquid cargo tanker employs orifice means through the bow hull plates of the forepeak cargo tank above the normal waterline. Sea water enters and exits from the forepeak tank in phase opposition to the normal pitching of the tanker to reduce the total pitching movement of the ship. Additional orifice means may be employed below the normal waterline to enhance fluid flow to and from the tank. A similar stabilization tank may be provided at the stern of the ship.

This application is a divisional application of Ser. No. 409,703, filed Nov. 9, 1964, now U.S. Patent No. 3,286,677.

The present invention relates to systems for reducing the pitching (alternate falling and rising of the bow and stern) of a vessel and, more particularly, to passive motion stabilizing systems employing the alternate transfer of a liquid ballast toward and away from the bow and stern actions of a vessel to create a damping or stabilizing moment in opposition to the pitching moments of the waves of a rough sea.

In the interest of economical ship operation, that is, to minimize power requirements and fuel consumption, it is desirable to keep the ship on as even a keel as possible at all times, or, in other words, to reduce rolling (transverse motion) and pitching (end-to-end motion) as much as possible. Accordingly, to the specific end of reducing unnecessary power expenditure, it is especially desirable to minimize power losses attributable to the motion of the vessel caused by rough seas. Additionally, the reduction of rough motion of a ship increases the comfort of the passengers and crew, and substantially reduces various deleterious stresses induced in the vessel structure, itself.

Many passive devices (that is, non-power consuming devices as contrasted with active or power consuming devices) for reducing rolling have been heretofore successfully employed, however, passive systems for reducing pitching have not been available. Accordingly, it is an object of the present invention to provide new and improved systems of pitch stabilization, and, more specifically, it is an object of the invention to provide passive stabilization systems which require no expenditure of generated power, as would otherwise be required in the operation of an active stabilizing device, a gyroscope, for example.

In accordance with the specific principles of the invention, a pitch damping or stabilizing moment may be generated by a controlled, longitudinal or end-to-end shifting of a liquid cargo or ballast, in opposition to an unstabilizing, significant pitching moment of a wave. Specifically, this is advantageously accomplished by providing a "timing structure" which may include a longitudinal duct extending between forwardmost and rearmost liquid cargo holds and having baffles or orifices therein. The "timing structure" is of predetermined physical dimensions sufficient to generate a "stabilizing" wave, creating an advantageous free surface effect, and a weight moment within the vessel, itself, when the liquid ballast is shifted end-to-

end, which "stabilizing wave" and weight moment will each have a period substantially equal to that of the significant pitching wave, but will be laggingly out of phase with the pitching wave by half its period, so as to be substantially vectorially opposed thereto. The new system is extremely effective in damping a wide range of encountered pitching frequencies due to the energy damping characteristics of the generated wave, which are, in effect, superimposed upon the out of phase weight moment produced by the liquid transfer. This novel system of pitch stabilization may be characterized as a closed system in which the liquid stabilization medium is typically a cargo or a ballast contained entirely within the vessel, itself.

An alternate system for effectively stabilizing the pitching motion of a rough sea, in accordance with the invention, is characterized as an open system. This system is similar to the closed system in that it involves the employment of a "timing structure" for the generation of a stabilizing moment in vectorial opposition to the pitching waves. However, the stabilizing medium employed in the open system is sea water rather than a liquid cargo. Specifically, in the open system, a stabilizing weight moment and a stabilizing buoyant moment are created by the transfer of sea water to and from stabilizing tanks located at the waterline in the bow of the ship (or in both the bow and stern) through orifices of predetermined area sufficient to create the necessary, optimum phase lag between the generated weight and buoyant moments and the pitching wave of the sea. More specifically, as sea water rushes into the stabilizing tank on a downward pitch, air is entrapped in the tank and a buoyant moment is created tending to damp the downward pitch. Conversely, on an upward pitch, the gravitational flow of water from the tank creates a weight moment tending to damp the upward pitch.

For a more complete understanding of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawing in which:

FIG. 1 is a schematic representation of a liquid cargo carrying ship embodying a closed stabilizing system in accordance with the principles of the present invention;

FIG. 2 is a cross-sectional view of the closed stabilizing system, taken along line 2—2 of FIG. 1, showing the timing structure;"

FIG. 3*a* is a schematic representation of an open stabilizing system with the ship in calm water; and

FIGS. 3*b* and 3*c* are schematic representations of the shifting of sea water to and from stabilizing tanks in the bow or stern of a ship embodying the open system to generate stabilizing buoyant moments and to generate stabilizing weight moments.

Referring to FIG. 1, the stabilizing system of the present invention may be embodied to advantage in a liquid cargo carrier or tanker **10**. Such a vessel is of substantial size; exemplary hull dimensions between the forward and aft perpendiculars, designated FP, AP, respectively, being about 500–1000 feet; the molded beam being about 75–200 feet; and the molded depth being about 40–90 feet. Located at the stern of the ship are the engine room **11**, boiler room **12**, steering gear **13**, and superstructure **14**, while forepeak tank **15** and forward compartments **16** are located at the bow. Independent cargo carrying tanks **17–26** are centrally located and are typically laden with a liquid cargo **27**, such as oil.

In accordance with the principles of the invention, a longitudinal duct or conduit **28** is installed in the central cargo carrying section and extends for a major portion of the ship's length between the forwardmost cargo tank **17** and the rearmost cargo tank **26**. In the illustrated preferred embodiment, the duct is disposed symmetrically with respect to the centerline of the ship and is located

substantially above the waterline and in intersection with the cargo level CL, advantageously located immediately below the deck **29**, as shown in FIG. 2. Maintenance of the cargo level beneath the upper wall **28***a* of the duct **28** provides a free surface. As will be understood, this arrangement accommodates stabilizing wave generation and utilization of a free surface effects of generated waves to damp pitching motion.

As a very important aspect of the invention, a plurality of baffles or orifice plates **30** are included in the duct and constitute what has ben characterized as a "timing structure." The number of plates and the effective areas of the orifices are empirically determined by the specific geometry and size of the ship, as well as the ranges of characteristics of the waves (amplitude, frequency, period) which are expected to be encountered at sea. More specifically, the significant pitch creating forces of a rough sea, those causing the alternate rise and fall of the bow and stern, will cause the liquid cargo **27** to be transferred from end-to-end through the duct **28**. The weight forces of the transfer of this cargo and the free surface effects of the moving cargo create a weight moment and energy damping moment, respectivey, which may be utilized for pitching stabilization. Through predetermined proportioning of the "timing structure," in accordance with the invention, the moments generated by the cargo shift are made to lag substantially the unstabilizing moment of the wave forces which normally cause the ship to rise and fall. When the lag of the moments generated by the weight transfer and the free surface effect is carefully controlled and maintained substantially 180° out of phase with the unstabilizing pitching moments, the generated moments have a damping effect and tend to minimize significantly the pitching movement of the vessel over wide ranges of frequency of encountered waves. The effectiveness of this closed system over wide frequency ranges is believed to be due, in a large measure, to the combinative effect of the superimposition of the moment caused by the free surface effect upon the moment caused by the weight transfer of the cargo.

In accordance with the principles of the invention, an alternative open system may be used in lieu of the closed system or in addition to the closed system, which, as should be understood, will be inactive when the cargo holds are empty. As shown schematically in FIGS. 3*a*–3*c*, an extremity **40** (the bow, or in some instances the bow and stern) of the ship **43** is fitted with a stabilizing tank **41**, the major portion of which is located above the water line. Orifices **42** are provided in the tank at locations above the waterline, and, as will be understood, they accommodate admission and expulsion of surrounding sea water, through gravitational flow, to and from the tank **41**. The function of the restrictive openings **42** corresponds generally to that of the "timing structure" of the above-described closed system.

Operation of the open system is broadly analogous to the closed system, in that stabilizing moments are created by the shifting of a liquid medium in neutralizing, vectorial opposition to the unstabilizing moment caused by the sea. Specifically, in calm water, as shown in FIG. 3*a*, the ship **43** is on an even keel and the tank **41** is substantially empty. However, upon encountering a rough sea and being subjected thereby to a downward pitch by wave forces, the sea water will tend to rush into and fill the stabilizing tank **41** at a rate controlled by the "timing structure." In accordance with the inventive principles, the controllably admitted inrushing water will entrap and compress substantial quantities of air **44** in the tank **41**, in a manner whereby the stabilizing buoyant moment of the ship and tank **41** will tend to damp the downwardly directed, unstabilizing moment of the rough sea. Thereafter, as the ship is subjected to an upwardly directed pitch, due to the rough sea and as shown in FIG. 3*c*, the filled tank **41** will tend to exhaust at a rate controlled by the orifices **42** its acquired sea water due to gravity and due to the expulsive forces in the overlying layer of compressed air **44**, in a manner that the anti-pitch or stabilizing weight moment of the previously admitted water is 180° out of phase with the falling pitch.

In accordance with the principles of the invention, the size and number of the orifices are predetermined to ensure that the buoyant moment and weight moment generated by the exchange of ballast to and from the surrounding sea are substantially 180° out of phase (lagging) with the rising and falling pitching moments, respectively, of the waves. More specifically, in the open system, a rising pitch (FIG. 3*c*) is effectively stabilized by a weight moment timingly controlled by the exhausting of sea water through the orifices, which stabilizing weight moment will be lagging the unstabilizing, upward pitching moment by 180° due to the restrictive effect of the orifices **42**. A falling pitch (FIG. 3*b*) will be counteracted by the timingly controlled buoyant moment, which stabilizing buoyant moment will be lagging the unstabilizing, downward pitching moment by 180° due to the restrictive effect of the orifices **42**. In other words, the generated buoyant stabilizing moment is in phase with the downwardly directed pitch, while the generated weight stabilizing moment is in phase with upwardly directed pitch.

In some instances it might be found desirable or necessary to provide additional orifices **42′** (shown in outline) below the waterlines to provide additional exhaust capacity to the stabilizing tank, as shown in FIGS. 3*b* and 3*c*. As will be understood, the orifices **42′** accommodate the establishment of a water level within the tank, itself, coincident with the waterline of the ship.

In accordance with the principles of the invention, a ship may be provided with passive pitch stabilizing systems which tend to keep a ship on an even keel by naturally generated stabilizing moments. Accordingly, the tabilization realized with the inventive systems requires no power from the ship and enables the ship's power to be used more efficiently for propulsion purposes. Moreover, the new stabilization systems reduce stresses on the ship structure and substantially increase passenger comfort as can readily be appreciated.

It should be understood that the specific structures herein illustrated and described are intended to be representative only, as certain changes may be made therein without departing from the clear teachings of the disclosure. Accordingly, reference should be made to the following appended claims in determining the full scope of the invention.

What is claimed is:

1. In combination, a liquid cargo tanker having hull plates and internal bulkheads forming a plurality of internal liquid cargo tanks including a forepeak tank, said forepeak tank defining a liquid containing chamber extending vertically above and below the normal waterline and horizontally from the port to the starboard side of the bow of said tanker, said normal waterline horizonally intersecting the vertical height of said forepeak tank, said forepeak tank including a plurality of horizontally aligned orifice means formed in said hull plates on the port and starboard side of said forepeak tank, said orifice means being arranged above said waterline and disposed in a manner whereby sea water is admitted into said forepeak tank when the bow of said tanker is subjected to a downwardly directed pitch to control the moment associated with said forepeak tank in a manner in which it is substantially opposed to said downwardly directed pitch and whereby said admitted water is expelled from said tank when the bow of said tanker is subjected to an upwardly directed pitch to control the weight moment associated with said forepeak tank in a manner in which it is substantially opposed to said upwardly directed pitch, said orifice means thereby timingly controlling stabilizing moments associated with said tank to maintain said mo-

ments substantially opposed to the pitching moments of the sea to damp pitching motions of said tanker.

2. A tanker having a reduced tendency to pitch in rough seas in accordance with claim 1 including horizontally aligned auxiliary orifice means below said waterline on both the port and starboard sides of said forepeak tank.

3. A tanker in accordance with claim 1 including an additional stabilizing tank formed in the aft portions of the hull of said tanker in intersecting relation with said waterline, said additional stabilizing tank including further orifice means above said waterline.

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MILTON BUCHLER, *Primary Examiner.*

T. M. BLIX, *Assistant Examiner.*