Dec. 6, 1966 W. O. GRAY ETAL 3,289,623

FRICTIONAL RESISTANCE REDUCTION USING NON-NEWTONIAN FLUID

Filed March 9, 1965 2 Sheets-Sheet 1

FIG. 1

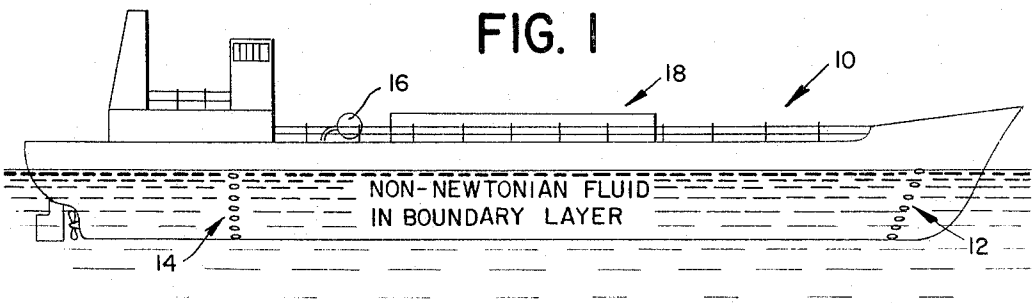


FIG. 2

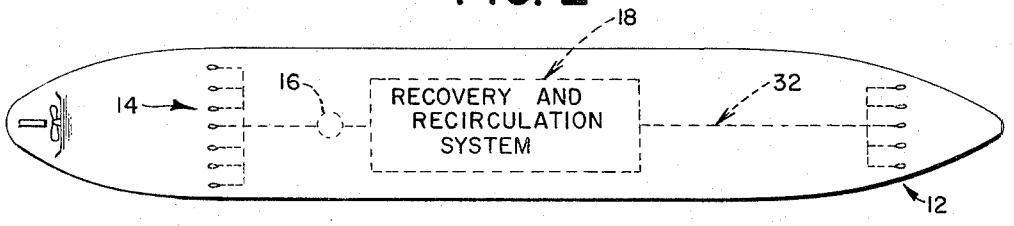
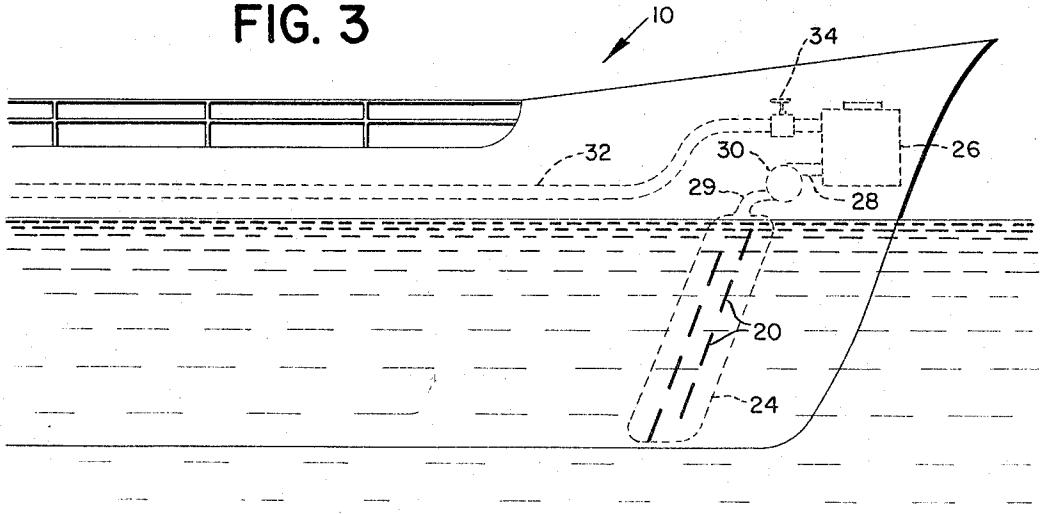


FIG. 3



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Filed March 9, 1965 2 Sheets-Sheet 2

FIG. 4

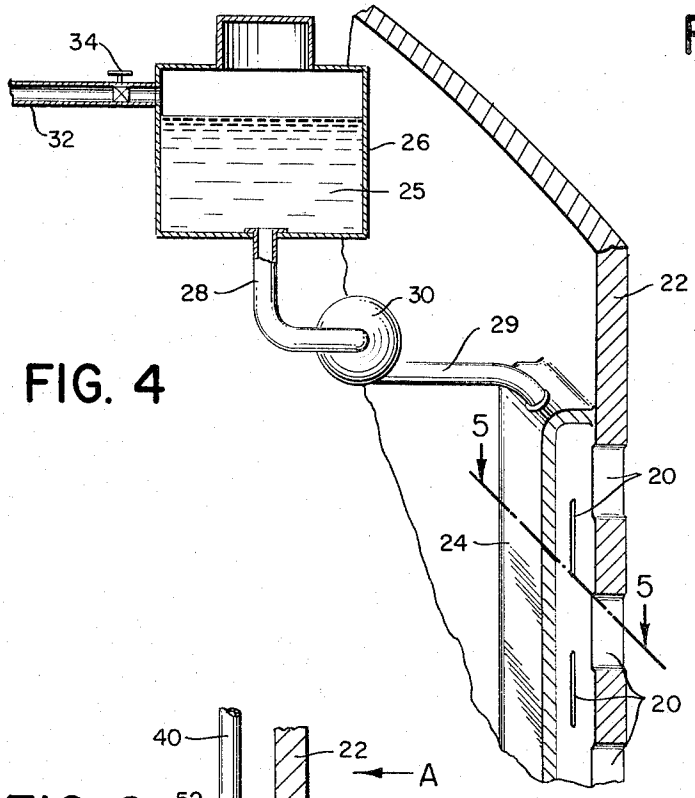


FIG. 5

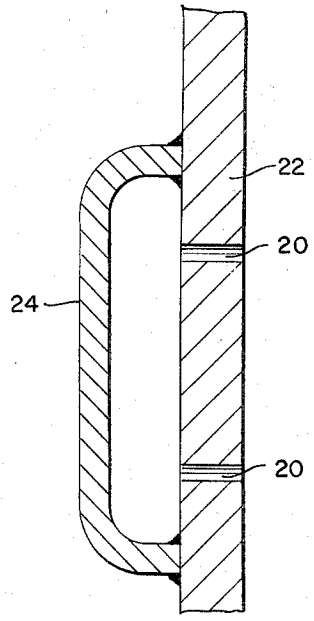


FIG. 6

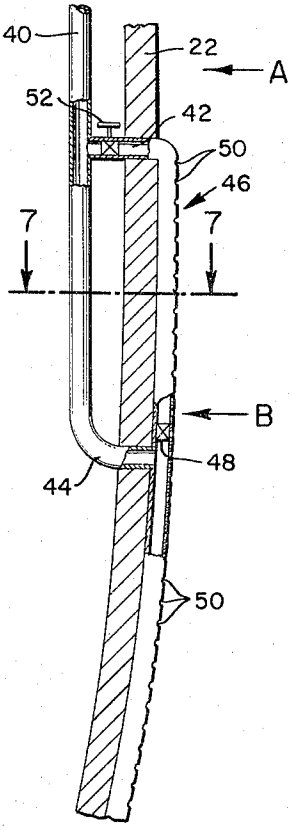
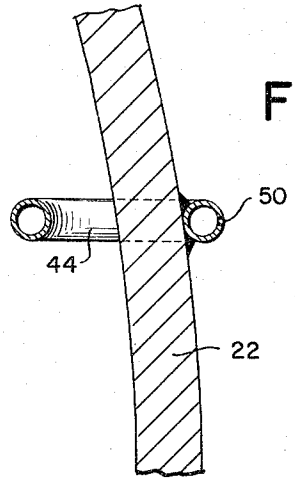


FIG. 7



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FRICTIONAL RESISTANCE REDUCTION USING NON-NEWTONIAN FLUID

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2 Claims. (Cl. 114—67)

This invention relates in general to a method and apparatus for reducing the frictional resistance of a ship, and in particular to improvements in means and methods for frictional resistance reduction wherein the boundary layer shear characteristics of the vessel supporting liquid is altered by the addition thereto of a non-newtonian fluid.

In general, the shear characteristics of fluids may be divided into two basic classes. The great majority of common fluids such as water may be broadly classified as newtonian fluids wherein the shearing stress is a fixed ratio to the rate of shear. Non-newtonian fluids are a class of fluids for which the shearing stress is no longer a fixed ratio to the rate of shear. Non-newtonian fluids could require either more or less shearing force for a given rate of shear than the same rate of shear in a newtonian fluid. Obviously, the present invention having as its purpose the reduction of frictional resistance is directed toward the introduction into the boundary layer of a vessel, such as a ship, of a non-newtonian fluid which will effect a reduction in the shearing stress from that of the supporting and surrounding fluid for any given rate of shear thereof.

With these general relationships in mind, the invention includes in a ship, such as a tanker, means for introducing relatively small amounts of a non-newtonian fluid, as for instance a long-chain polymer such as polyethylene oxide, into the water adjacent the bow of the ship. Such introduction of a non-newtonian fluid at the bow alters the shear characteristics of the fluid in the boundary layer of the ship rearwardly toward the stern thereof to decrease the overall frictional drag of the vessel.

It has been found that a substantial reduction in frictional resistance of vessels may be anticipated by this addition of a small quantity of a non-newtonian fluid in the order of three, or substantially less, parts per million relative to the surrounding volume of water. This relatively small quantity of non-newtonian fluid makes it economically sound as a means for increasing ship speed or conversely decreasing the required power to maintain a given vessel speed.

In accordance with the invention, a reservoir of non-newtonian fluid such as a polyethylene oxide of long-chain polymers is provided with an outlet conduit and suitable pumping arrangement to direct a small quantity of the fluid in the reservoir to a series of slots, nozzles, etc., disposed at the bow end of the ship. The flow of the non-newtonian fluid in the reservoir is metered and limited in nature so that a small depletion of the contents stored therein results. The material thus supplied to the bow exterior through the ship's hull is dispersed fairly uniformly in the relatively thin boundary layer of the sea water adjacent the bow portion of the ship. Thereafter, as the advance of the ship continues, the dispersion of the non-newtonian fluid in the boundary layer increases toward the rear of the ship. If desired, all or a portion of the boundary layer fluid may be pumped back into the ship interior where the recovery of the non-newtonian fluid may be accomplished through the use of suitable filter or other separating means.

Accordingly, it is a principal object of this invention to provide an improved method and apparatus for reducing the frictional resistance of a vessel.

It is another object of the invention to provide a novel method by which the shear characteristics of the boundary layer surrounding the ship may be altered from newtonian characteristics to non-newtonian characteristics.

It is another object of the present invention to provide a novel means for introducing a relatively minute quantity of non-newtonian fluid through a bow portion of a ship's hull to provide a substantially uniform dispersion of such fluid in a forward portion of the boundary layer.

A further object of the invention is to provide a novel ship speed increasing means which is simple in design, trouble-free in operation, economical to install, and has a minimum of moving parts.

These and other objects and advantages of the invention will become apparent and the invention will be fully understood from the following description and drawings in which:

FIG. 1 is a diagrammatic side elevation view of a typical vessel incorporating the invention;

FIG. 2 is a schematic top plan view of a ship embodying the invention showing the recovery and recirculation system;

FIG. 3 is an enlarged fragmentary view of the bow portion of the vessel;

FIG. 4 is an enlarged perspective view partially in section (along line 4—4 of FIG. 5) showing the fluid introduction slots at the bow of the vessel;

FIG. 5 is a fragmentary cross-sectional view taken along line 5—5 of FIG. 4;

FIG. 6 is a view similar to FIG. 4 showing a further embodiment of the invention as it would be applied to ships traveling in a ballast condition; and

FIG. 7 is a cross-sectional view taken along line 7—7 of FIG. 6.

Referring to the FIGS. 1–5 in particular, a typical ship such as a vessel **10** includes a bow having a fluid introduction means generally indicated at **12** and optionally at its stern a fluid recovery means generally designated **14**. A fluid recovery pump **16** (see FIG. 2) receives fluid from the recovery means **14** and discharges to a recovery and recirculation system **18**. The recovery and recirculation system **18** supplies non-newtonian fluid via a forwardly extending conduit **32** to the fluid introduction means **12**.

Referring to FIGS. 3, 4 and 5 in particular, the forward end of the conduit **32** is attached to a reservoir **26** having an outlet conduit **28**. A pump **30** connected to conduit **28** delivers the non-newtonian fluid **25** within the reservoir **26** via a discharge conduit **29** to a fluid supply manifold **24** extending vertically on the interior of the ship's hull plate **22**. In this way the fluid in the reservoir **26** is supplied under pressure to the interior of the manifold **24** so that it may be discharged in minute quantity in the desired amounts through a plurality of thin staggered slots or nozzles **20**, **20** extending through the ship's hull plate **22**. The arrangement and size of the staggered slots or nozzles **20** is such that the structural integrity of the hull plate is undisturbed due to the fact that the slots extend in several vertical planes. In this way a fine uniform dispersion of the non-newtonian fluid into the boundary layer of the ship at a forward bow portion of the hull is assured. While the invention has shown a simple slotted arrangement for the controlled introduction of the non-newtonian fluid, those skilled in the art will readily appreciate that alternate nozzle or slot means may be employed for such purpose without departing from the scope of the invention. For instance, it would also be within the scope of this invention to provide one or more perforated conduits connected to the conduit **29** and attached directly to the exterior of the ship's hull in place

of the illustrated slot **20** arrangement as will be discussed later in connection with FIG. 6.

In operation, a non-newtonian fluid **25** which will alter the shear characteristics of the surrounding liquid is contained in the reservoir **26** and pumped via conduits **28** and **29** to the interior of the manifold **24**. Suitable metering orifices (not shown) may be provided as required in the conduit system **28**, **29** to limit the flow of fluid from the reservoir **26**. The non-newtonian fluid is thus discharged in small amounts through the slots **20** and gradually disperses in the ship's boundary layer of water to reduce the shear characteristics in a decreasing non-newtonian fashion. Thereafter, as the ship progresses under these conditions of reduced hull friction, the stern fluid recovery means **14** may or may not be activated to recover the bow introduced non-newtonian fluid. Should it be desirable to recover a portion or all of the non-newtonian fluid, it may be pumped from the boundary layer at the stern of the ship by operation of the pump **16** and the recovery and recirculation system **18** and be reintroduced via the conduit **32** and a valve **34** into the reservoir **26**. Other suitable valves (not shown) similar to valve **34** are provided to permit closing off the system of the invention when its use is not desired. The recovery and recirculation system **18** may include a centrifugal separator for separating the non-newtonian fluid having a density different from that of the water or may alternatively or additionally include use of a filter separation means for a similar recovery of the non-newtonian from the water prior to its reintroduction to the reservoir **26**.

Referring to FIGS. 6 and 7, an alternate embodiment is shown which is particularly useful in the practice of the invention on ships traveling in a ballast condition. This form of the invention includes a non-newtonian fluid supply conduit **40** having an upper branch portion **42** and a lower branch portion **44** which communicate with a generally vertical conduit **46** secured to the outer surface of the ship hull **22**. The conduit **46** includes a plug **48** positioned therein at a level approximating the ballast water line of the ship indicated by the level of the arrow B. The conduit **46** also includes a plurality of small outlet apertures **50** through which the non-newtonian fluid from the supply conduit **40** may be discharged to the boundary layer.

In operation of the vessel under a normal load condition indicated by the vertical level of the arrow A, a valve **52** would be opened so that non-newtonian fluid will be discharged from the apertures **50** over the entire length of the conduit **46**. Under ballast operating conditions of the ship, valve **52** is closed so that non-newtonian fluid is only emitted from the lower portion of conduit **46** below the level of the plug **48** and therefore below the ballast level B. Supply conduit **40** may be connected to a pressure pump such as pump **30** of FIG. 4 or if sufficient static head is present it may be connected directly to the supply reservoir.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. Apparatus for reducing the frictional resistance of a liquid-supported vessel in a ballast as well as loaded condition comprising, in combination, a hull having a bow and a stern and means carried by said vessel for introducing a small quantity of non-newtonian fluid at the bow into the adjacent vessel supporting liquid to thereby alter the shear characteristic of said liquid from a newtonian to a non-newtonian relationship wherein the shearing stress is no longer a fixed ratio to the rate of shear; said introducing means including, a substantially vertical conduit affixed to the exterior of the hull and having a plurality of fluid discharge apertures throughout the length thereof, said conduit extending above and below the ballast water line of said hull, plug means in said conduit in the area of said ballast water line for fluid isolating the upper portion of said conduit from the lower portion thereof, and valve means for controlling the flow of non-newtonian fluid to the upper portion of said conduit above said plug means to thereby prevent the discharge of fluid from said upper portion during travel of the vessel in a ballast condition while permitting discharge of fluid from the lower portion of said conduit during travel in a ballast condition.

2. Apparatus in accordance with claim **1** including means for recovering the non-newtonian fluid from the vessel supporting liquid at the stern of said hull, and means for recirculating said non-newtonian fluid to the introducing means at the bow of said hull.

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