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[54] **LATERAL THRUST UNITS**

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[52] **U.S. Cl.**................................ **137/832,** 137/833
[51] **Int. Cl.**.. **F15c 3/00**
[58] **Field of Search**.................... 137/81.5, 803–842

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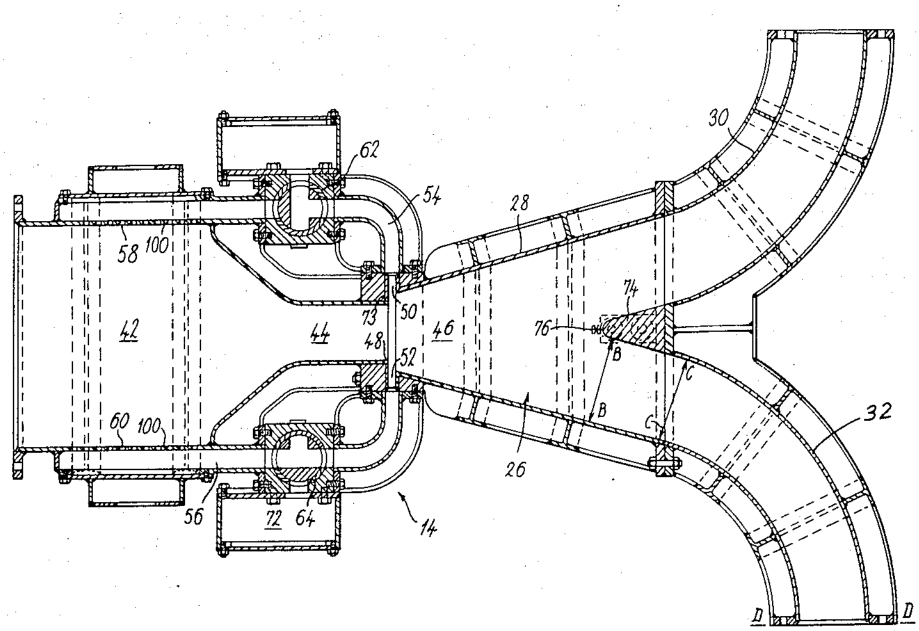
[57] **ABSTRACT**

A digital rapid response lateral thrust unit in which the deliberately unstable nature of the design is overcome by bleeding off relatively large proportions of the incoming liquid flow for reintroduction as control jets. These jets are effective to divert the liquid flow to one or other of two tapering outlet ducts, the split flow zero thrust condition being achieved by cutting off the supply of control fluid and connecting together the discharge slots for the control jets. Use of the unit as a simple flow diverter in a liquid transfer assembly is also described.

12 Claims, 5 Drawing Figures



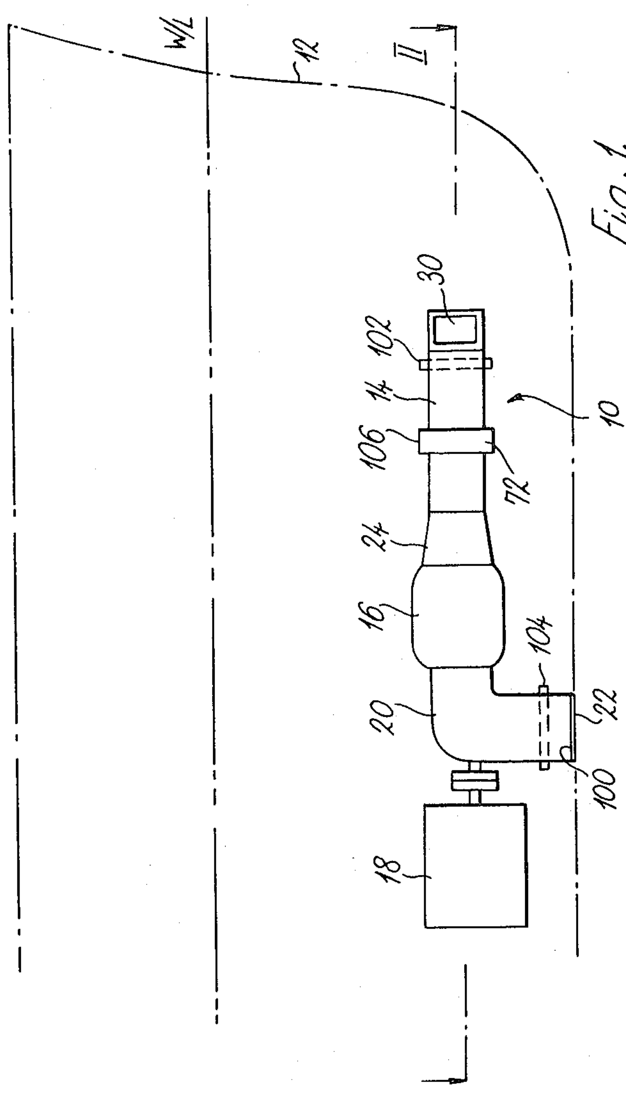


Fig. 1.

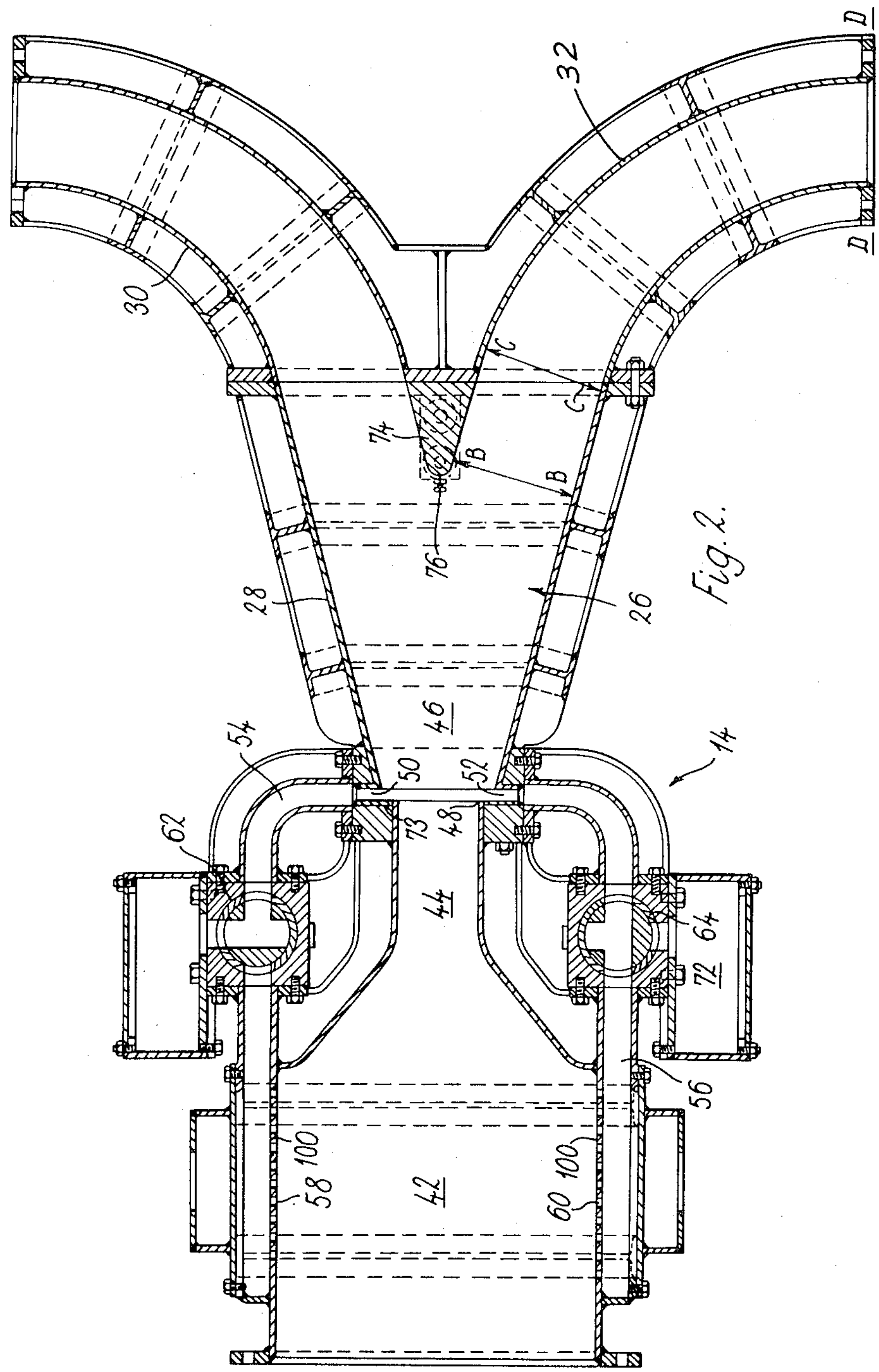

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Fig. 2.

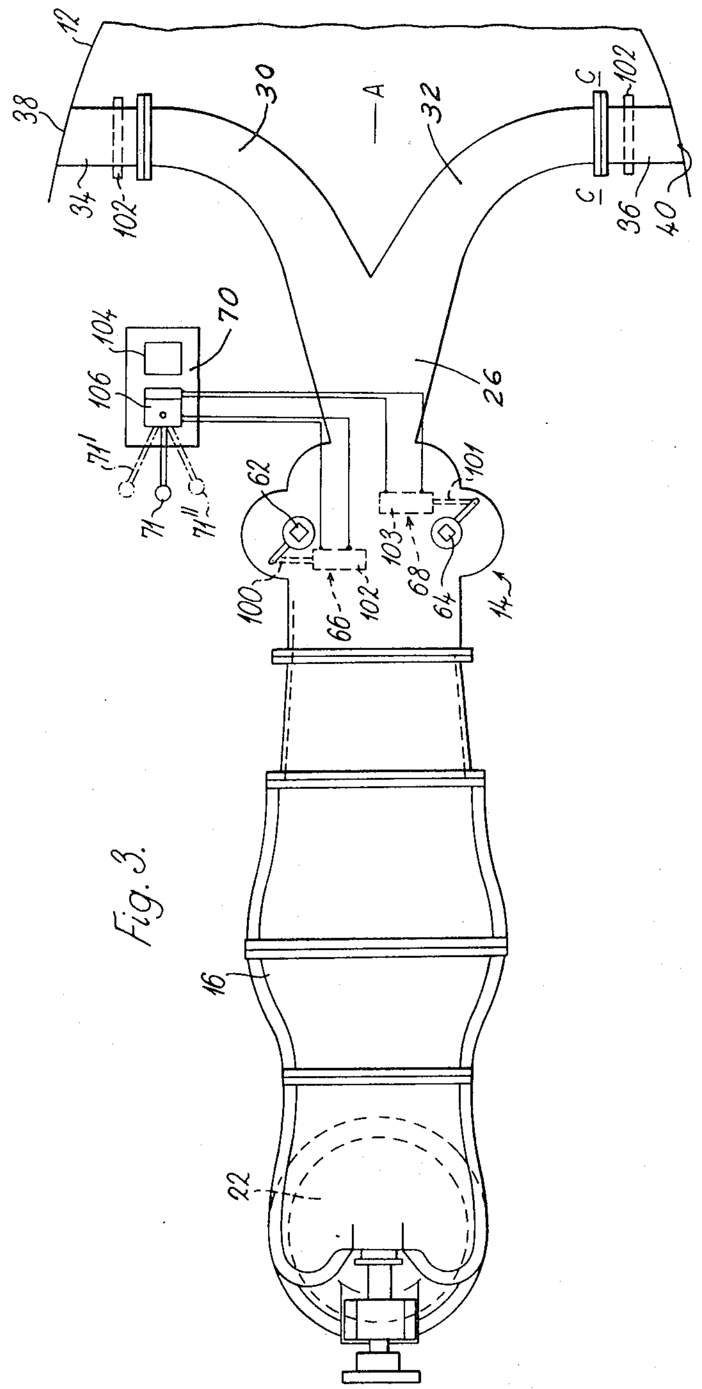
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Fig. 3.

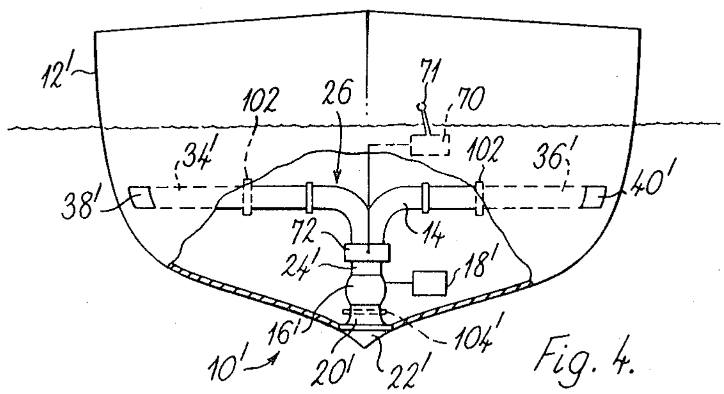
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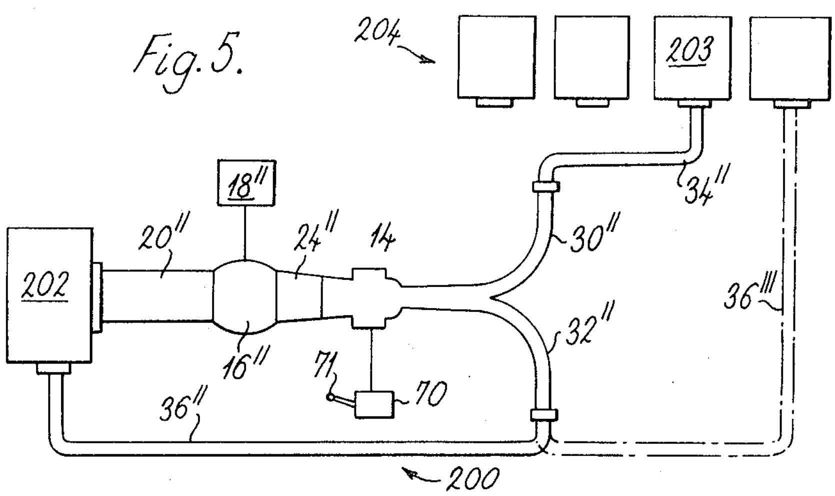
Fig. 4.

Fig. 5.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LATERAL THRUST UNITS

This invention relates to lateral thrust units and in particular, but not exclusively, to the so-called "bow thrusters" for use in marine vessels for docking and slow speed manoeuvring in confined spaces.

Bow thrusters are already known which consist essentially of an open-ended duct passing from side to side of the ship's hull below water level at the front end of the vessel. A propeller mounted in the duct is arranged to pump the liquid in which the vessel floats in at one end of the duct and out at the other. As the bow thruster is located at one end of the vessel, the resulting reaction force on the vessel will cause the vessel to rotate. The sense of rotation will of course depend on the direction of water flow through the duct and a change in flow direction can be achieved either by reversing the motion of the propeller or by using a variable pitch propeller and reversing the pitch.

The principal disadvantage of these known systems is their slow response. Where the constant pitch propeller is used, for example, the propeller cannot be run up to full speed from zero in less than a minute or so if undue strain on the propeller blades and the driving motor is to be avoided, and clearly if it is required to reverse the turning thrust on the vessel then at least double this time will be involved since the propeller will first have to be gradually decelerated to zero before it can be accelerated up to top speed in the opposite direction. The same problem is present with the variable pitch propeller insofar as the pitch of the blades cannot be changed rapidly between various settings if undue strain is not to be imposed on the blades by the inertial water flow through the duct.

A further disadvantage is the inherent expense of such systems involved in the cost of the motor, the drive to the propeller, maintenance, etc.

Bow thrusters have also been proposed which comprise a one or two stage proportional device, designed to give a variable net thrust by proportioning the flow through its two exits whilst maintaining constant propeller speed and direction of rotation. The unit is mounted vertically upwards and driven through a long shaft, passing through the unit, down to a propeller fed from a divided intake in the ship's bottom. The flow discharges through constant area limbs whose final exits are at or near the water surface and bent downwards. The long edge of the rectangular exit is parallel to the horizontal of the ship. In the two-stage version the supply from the propeller is divided four ways; to the power nozzle of the first stage "conrol" amplifier; to the entries of two control chambers for diverting the power nozzle flow; and to the power nozzle of the second stage "main" amplifier. Butterfly control valves in the two control chambers are mounted on a single valve control shaft and are positioned so that shaft rotation simultaneously opens one valve as it closes the other. The effect is to supply opposing control jets of different strength to the control amplifier and this varies the output flows from the control amplifier, which are fed, via vortex chambers, as opposing control flows to apportion the main flow through the second stage main amplifier between its two exits. Zero net thrust is most nearly arrived at by turning the valve control shaft to position the butterfly valves so that ideally, equal conrol signals are obtained for the main amplifier. In the one stage version, the propeller serves only to provide the main flow for the power nozzle and switching is effected by an independently powered controller which provides the control flows at the nozzle outlets.

Both these versions suffer from disadvantages arising directly from their use of a proportional control system and it is an object of the present invention to provide a lateral thrust unit, suitable for use in a bow thruster, which overcomes these disadvantages and those of the side-to-side duct system described earlier.

According to the present invention, a lateral thrust unit which is substantially symmetrical about a centre plane of the unit comprises a main duct for a main flow of fluid and terminating as a nozzle portion, an interaction chamber communicating with the nozzle outlet, two tapering, fluid outlet ducts separated by a nose piece and diverging from the interaction chamber one on one side and one on the opposite side of the centre plane of the unit, control ports (also referred to hereinafter as control slots) in the interaction chamber one on either side of said plane and each with an area of at least 5 percent of the nozzle outlet area, control flow passages leading from the main duct to the control ports, and control flow valve means for separately opening or closing the passages to fluid flow through the passages.

Conveniently the ratio of the smallest area of each of said outlet ducts to the sum of the areas of the nozzle outlet and of either one of the two control ports is less than 1.6.

As will be understood from the following description where the various characteristics of the units are discussed in more detail, a lateral thrust unit in accordance with the present invention can operate as a rapid-switching single-stage bias-control digital bow thruster device whose performance is substantially independent of the loading at its exit ports. The unit is therefore entirely different in design and operation from the load-sensitive, slow-switching, multi-stage or independent-control proportional devices discussed above and these differences lead, in the case of the present invention, to reduced initial cost in terms of materials, to reduced installation costs (the unit of the present invention can be manufactured as a "bolt-on" unit whereas the proportional devices must be incorporated as an integral part of the ship's structure), to conversion possibilities for existing ships (the unit can be bolted on to existing strucures), and to increased reliability and reduced maintenance costs thanks to the simplicity of the design and the absence of complicated ducting and control systems.

In accordance with a preferred feature of the invention the distance between the nozzle outlet and the nearest part of the nose-piece is three to five times the width of the nozzle outlet this latter dimension being measured in a direction perpendicular to said plane.

In a preferred embodiment of the present invention a by-pass conduit connects together the control flow passages, and by-pass valve means are provided for opening or closing the conduit to fluid flow through the conduit.

Conveniently the by-pass valve means and the control flow valve means are arranged to operate in conjunction with one another so that with the by-pass conduit closed, one of the control flow passages is open to the main duct whilst the other is closed and with the by-pass conduit open, both control flow passages are closed to flow from the main duct and the control slots are interconnected through the by-pass conduit. In one such arrangement the main flow valve means and the control flow valve means are both provided by the same 3-way plug valves.

Conveniently the control flow passages are connected with the main duct through openings in the longitudinal walls of the main duct and in one such arrangement filters are included at said openings.

According to a preferred feature of the invention the area of each control port is between 8 percent and 12 percent of the nozzle outlet area.

According to another preferred feature the distance between the nozzle outlet and the nearest part of the nose piece is roughly 3.8 times the width of the nozzle outlet.

Preferably also the ratio of the smallest area of each of the outlet ducts to the sum of the areas of the nozzle outlet and either one of the two control ports is less than 1.10.

The control flow is conveniently introduced at a large angle (i.e., 60° upwards) to the main flow from the nozzle outlet, an angle of 90° being preferred.

A particular application for the unit of the present invention is in its use as a lateral thrust unit in floating vessels e.g. for dynamic positioning of an oil drilling rig or for use in manoeuvring a ship. In this latter case the unit may conveniently be referred to as a "bow thruster" if located at the forward end of the ship. Alternatively or additionally, a unit in accordance with the invention may be fitted at the stern end of the ship. The unit may also be employed in a liquid transfer assembly e.g. for use in a chemical plant, and the term "lateral thrust unit" used throughout the specification includes a unit designed for this latter purpose.

The invention also embraces a vessel incorporating a lateral thrust unit according to the present invention, and in particular a vessel in which the outlet ducts are connected to exit ports one on each side of the vessel by connection pieces, the ratio of the area of each exit port to the sum of the areas of the nozzle outlet and either one of the two control ports is at least less than 1.6 and preferably less than 1.10.

The invention also includes a flow diverting assembly including a unit according to the present invention and means for pumping liquid from a supply of the liquid to the inlet end of the main duct, means whereby at least one of the outlet ducts is adapted to be connected with a container or transfer means for the liquid, means whereby at least the other of the outlet ducts is adapted to be connected with the or a similar container or transfer means or with said supply.

According to another aspect of the invention there is provided a method of operating a unit according to the present invention, the method comprising the steps of providing to one of the control ports a fixed continuous control flow of about twice that needed merely to switch the main flow of fluid from one of the outlet ducts to the other of the outlet ducts. Preferably the method includes the step of providing to one of the control ports a fixed continuous control flow of at least 5 percent of the main flow of liquid through the nozzle outlet and preferably between 6 percent to 10 percent of the main flow of liquid through the nozzle outlet.

In all cases above discussed, the flow of control fluid along the control flow passage is effected by a drop in pressure occuring in operation of the apparatus (when the associated control flow valve is open) between the openings in the wall of the main duct and the control ports at the nozzle outlet.

Three emodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

FIG. 1 is a part-sectional side view of a ship incorporating a thrust assembly including a lateral thrust unit in accordance with the present invention the main duct of the unit being horizontally disposed;

FIG. 2 is a part of a section taken along the line II — II in FIG. 1 and shows the lateral thrust unit in more detail.

FIG. 3 is a plan view of the thrust assembly and shows diagrammatically a control system for use with the lateral thrust unit;

FIG. 4 shows a part-sectional front view of a ship incorporating a thrust assembly including a lateral thrust unit in accordance with a second embodiment of the invention, the main duct of this unit being vertically disposed instead of being horizontally disposed as in the previous embodiment; and

FIG. 5 shows diagrammatically a unit according to the present invention being used as a flow diverter in the liquid transfer assembly of a chemical plant.

Thus referring first to FIGS. 1 to 3, a thrust assembly 10 for a ship 12 includes a lateral thrust unit 14 in accordance with the present invention, a pump 16 for directing the main flow of fluid through unit 14, a drive 18 for the pump, and a curved pipe 20 leading upwardly and forwardly from an inlet port 22 in the bottom of the ship to the section side of pump 16. A transition piece 24 connects the outlet side of the pump with unit 14.

In more detail (FIG. 2), the unit 14 comprises a bifurcated splitter duct 26 of rectangular cross-section. Duct 26 has a root portion 28 dividing into two limbs 30, 32. These are joined by connection pieces 34, 36 (FIG. 3) to exit ports 38, 40 located in the sides of the ship one each side of a vertical centre plane A — A of the assembly. The root portion 28 of the splitter duct is fed from a main duct 42 (FIG. 2) also of rectangular cross-section which terminates in a nozzle portion 44. The root portion 28 also provides an interaction chamber 46 which is separated from the outlet 48 of the nozzle portion 44 by a pair of control slots 50, 52 located one on each side of plane A — A. In the illustrated embodiment, the area of each control slot is 12 percent of the nozzle outlet area and hence well above the permitted minimum of 5 percent stipulated earlier in the specification. Control passages 54, 56 (of rectangular cross-section) lead from the control slots to bleed-off openings 58, 60 formed in the sides of the main duct 42. The vertical dimensions or "height" of the splitter duct, the main duct and the control passages are equal.

The two passages 54, 56 are controlled by respective plug valves 62, 64 which are each movable between a "valve open" position (valve 64, FIG. 2) and a "valve closed" position (valve 62, FIG. 2) by electromagnetic actuators 66, 68 (FIG. 3) forming part of a general control assembly 70. Each electromagnetic actuator comprises a movable plunger 100, 101 in a coil 102, 103. The plungers are spring biassed towards the fully extended position and the coils can be connected across a DC supply 104 by a switching unit 106 controlled by stick 71. With control stick 71 in the position illustrated in FIG. 3, both coils 102, 103 are isolated from the DC supply and the fully extended plungers 100, 101 hold valves 62, 64 in the valve closed position. Movement of stick 71 into position 71' connects coil 102 across the DC supply and plunger 100 is driven into the coil to open valve 62, valve 64 remaining closed. In position 71'', control stick 71 operates switch unit 106 to connect coil 103 across the DC supply in place of coil 102. Thus position 71'' corresponds to the situation illustrated in FIG. 2 where valve 64 is open and valve 62 closed. When in the valve closed position the plug valve concerned will connect the downstream part of its control passage with a low impedance loop or by-pass conduit 72 passing beneath and bridging the nozzle portion of the main duct.

Although the main elements of the assembly 10 have been briefly described above, the invention resides principally in the detailed design of the lateral thrust unit 14 and this aspect is most easily explained in relation to the operation of the thruster assembly.

To operate the assembly, the pump 16 is started to introduce a main flow of liquid from inlet port 22 into the main duct of the lateral thrust unit 14. For a zero thrust condition (stick 71 in the position illustrated) this flow is shared equally between the two splitter duct limbs as will hereinafter be described. However, if it is desired to turn the ship's bows to starboard say, then 10 percent of the main liquid flow is bled off through port 60 by having valve 64 open (stick 71 in position 71''). This liquid passes through control passage 56 for reintroduction as a high velocity (45 feet per second in the illustrated embodiment) control flow (from slot 52) across the main flow of fluid from the nozzle outlet 48. The momentum of this control flow forces the main flow from the nozzle outlet into the limb 30 of the splitter duct. The combined main fluid/control fluid discharge from exit port 38 serves as a power jet which by reaction exerts a side force on the bow of the ship giving rise to a turning moment which will move the ship's bow to starboard. To produce a power jet of maximum effectiveness, the splitter duct must be designed to act as a high energy device in which pressure energy at the inlet end of the duct has been efficiently converted to flow energy by the time it reaches the exit ports. In the illustrated embodiment, the gradual taper of the limbs will provide a favourable pressure gradient throughout the limbs giving a low energy loss and preventing flow separation from the walls of the limbs as the liquid flow changes direction during its travel to the exit ports. If these precautions are taken, the power jet velocity from exit 38 can exceed five-sixths of the main flow velocity from nozzle outlet 48. The internal vertical dimension of the splitter duct is of course constant throughout the length of the duct but to achieve the high power jet velocity the internal horizontal width of the limbs 30, 32 is tapered gradually from a maximum value at the entry portions of the limbs (e.g. at region B — B in FIG. 2) until the bending becomes significant (e.g. at region C — C in FIG. 2), whereafter they taper more rapidly to, at the ends (D — D) of the limbs, about four-fifths this value. It should be borne in mind that the ratio of the area of each exit port to the sum of the areas of the nozzle outlet and a single control port must be below the stipulated maximum value of 1.6. In fact in the illustrated embodiment this ratio is 1.07 and hence within the preferred range (maximum value of 1.10) mentioned earlier in the specification. The internal cross-sectional area of the limbs at D — D is maintained in the parallel-sided extension pieces 34, 38.

In the illustrated embodiment, the height of the main duct, etc. is thirty two inches, the overall axial dimensions of the assembly 10 is some 25 ft. and the length of the ship is between 200 and 300 ft. The pump 16 is driven by a diesel engine 18 and has a working head of 30 ft. In operation as above described, the discharged jet of liquid from exit port 38 will exert a three ton lateral thrust force on the ship's bows. Typically the mass of the vessel is some 3,000 tons.

The assembly described above is essentially unstable in operation in the sense that if, for the sake of argument, the two control ports were both blocked off, the direction of the flow discharge from the nozzle would not lock itself in any particular direction. Instead the flow would be continuously moved at random from one outlet duct to the other, or to the split flow zero thrust position, or to intermediate positions, the smallest change in back pressure at the exit ports or in the outlet ducts themselves being sufficient to move the flow into a different position.

This basically unstable nature of the splitter duct part of the thrust unit is overcome by designing the control slots so that in operation of the unit the fluid flow through each control slot will be about twice that needed merely to switch the main flow from one limb to the other. In terms of geometry of the structure this means that the ratio of the control slot area 50 or 52 to the nozzle area 48 should be at least 5 percent. In the illustrated embodiment this ratio is in fact 12 percent as already mentioned above. The principal advantage of this basic instability is that it encourages rapid switching of the power jet between various positions because boundary layer "lock-on" effects are virtually absent and need not be overcome. One design feature used to deliberately forestall any tendency for "lock-on" to take place, is to ensure that the height of the step (73) in FIG. 2 at the nozzle outlet is kept small relative to the nozzle outlet width. In the embodiment shown the step height is less than 20 percent of the nozzle outlet width. It is important to note that the control flow from the slot 50 or 52 is either zero in the valve closed position or else a fixed continuous proportion of the main flow (10 percent in this embodiment) when the control valve is in the valve open position.

Another important advantage of the control slot geometry of the present invention is that the unit 14 is to all intents and purposes unsensitive to back pressure effects in limbs 30 and 32. The exit ports 38, 40 can be located well below the surface of the water in which the ship floats (9 to 10 feet below in this embodiment). The successful operation of the unit is therefore unaffected by anything short of freak wave conditions in the surface. For example, it would require one exit port to break the surface whilst the other was submerged to a depth of 10 feet to switch the discharge momentarily from one exit port to the other against the stabilising action of the control flow.

The exit ports, which are of course rectangular in cross-section, are arranged with their longer edges "vertical," i.e., roughly parallel with the frame of the ship, and their shorter edges "horizontal," i.e., roughly in the direction of the ship's forward motion, in order to cause the minimum structural interference and to minimise drag forces on the ship. In the illustrated embodiment the horizontal dimension of the exit port is

0.8 ft. and its "depth" (vertical dimension) is 32 inches.

The ratio of the depth of the nozzle outlet 48 to its width (a ratio of 4 in this case) is called the "aspect ratio" of the nozzle outlet. Although the exact value of this ratio is not critical, too small a value is avoided in case this should lead to pressure leakage across the bottom and/or top walls of the nozzle portion. Generally speaking an aspect ratio in excess of three is probably most suitable although too large a ratio might lead to fabrication difficulties.

Another important feature of unit 14 is the very short "splitter distance," i.e., the distance between the nozzle outlet 48 and the closest part (76 in FIG. 2) of the nose piece 74 separating the two limbs 30, 32. The splitter distance should preferably be between three times and five times (3.8 times in the illustrated embodiment) the width of the nozzle outlet, the nozzle outlet width being measured in a direction perpendicular to the plane A — A.

The most significant advantage of having a short splitter distance is that the power jet can be switched very rapidly, as will be hereinafter described, from one exit port to the other, or to the split flow (zero thrust) situation. In the illustrated embodiment the full thrust reversal of 3 tons can be effected in less than 1¼ seconds. To minimise the effect of geometry changes due to erosion in operation of the unit, the nose piece 74 is made of especially hard material e.g. a "stellite" and is replaceable. A definition of "stellite" is available from Chambers Technical Dictionary.

It will be clear from the foregoing description that the power jet discharge can be switched from the port exit 38 to the starboard exit 40 by closing the valve 64 and opening the valve 62 to reverse the direction of control flow at the nozzle outlet 48 (by moving stick 71 to position 71'). As previously explained, the unit 14 is inherently unstable unless a large bias flow can be provided to maintain a power jet discharge exclusively in either of the two splitter duct limbs so no inertia effects are called into play when the main flow is switched from one position to another. Thus beginning with the situation illustrated in FIG. 2, as soon as valve 64 is closed the main flow of fluid will immediately move towards the split flow position (in which the main flow is equally divided between the two limbs of the splitter duct). If valve 62 has been opened as valve 64 is closed, then the fluid flow moves onwards to the starboard discharge limb 32 under the influence of the control jet from slot 50. If full advantage is to be taken of the rapid switching characteristic inherent in the detailed design of unit 14, then obviously the valves 62, 64 should be of a fast acting type and for this reason electromagnetically controlled plug valves are generally preferred and are used in this embodiment. The control circuit for these valves has already been described with reference to FIG. 3. As will be clear from FIG. 2 of the drawings, each valve plug has a T-shaped passage so that in the valve-closed position the valve connects the downstream part of its control passage with a by-pass conduit 72 passing beneath and bridging the nozzle portion of the main flow duct. In the valve-closed position, the upstream part of the control passage is isolated from the by-pass conduit by the non-apertured portion of the plug. The operation of the two valves to share the jet flow discharge between the port and starboard exit ports or to divert the flow to one of these exit ports to the exclusion of the other has already been described above. In the split flow case (zero thrust condition), shutting both the conrol valves automatically interconnects via conduit 72, bhe downstream parts of the control passages, and the control slots they feed. If the flow from nozzle outlet 48 tends to vary from this split flow position, in favour of the starboard discharge limb 32 for example, then the low pressure induced at the starboard control slot 52 induces sufficient flow through the by-pass conduit from the higher pressure region in the vicinity of the port control slot 50 to provide a pulse of control fluid which moves the jet from nozzle outlet 48 back to its initial split flow position in which the flow is equally divided between the two limbs of the splitter duct. Thus in this way the by-pass conduit 72 continuously stabilises the main flow in the split flow position — provided of course that both valve 62 and valve 64 are maintained closed.

In the assembly of FIGS. 1 to 3, the main flow duct 42 of unit 14 is mounted substantially horizontally in the hull of the vessel 12. In accordance with other embodiments of the invention, this duct can be mounted vertically or in an inclined position. An embodiment of the invention is shown in FIG. 4 in which the main duct is mounted vertically. The details of the structure and operation of this embodiment are so nearly identical to those described in relation to FIGS. 1 to 3 that they need not be given here. Briefly therefore, with reference to FIG. 4, the assembly (10') for a ship 12' comprises the lateral thrust unit 14' of FIGS. 1 to 3 mounted vertically, a pump 16' for diverting the main flow of fluid through unit 14, a drive 18' for the pump, and a straight pipe 20' leading upwardly from an inlet port 22' in the bottom of the ship 12' to the suction side of pump 16'. A transition piece 24' connects the outlet side of the pump with unit 14. The bifurcated splitter duct 26 leads through constant cross-section connection pieces 34', 36' to exit ports 38', 40' similar in shape and position to exit ports 38, 40 earlier described. Numeral 70 indicates the control panel of FIG. 3.

Further details of the two embodiments will be clear from the drawings. For example ports 22, 58, 60 are all provided with filter grids identified in the drawings by the common reference numeral 100. These grids prevent ingress of particulate matter into the assembly. Sliding gate valves may also be provided if desired e.g. in extension pieces 34, 36 (as indicated at 102) and in pipe 20 (as indicated at 104) to shut off the unit 14 from exit ports 38, 40 and inlet port 22. This makes it possible to carry out routine inspection checks on the unit at sea. In addition, top covers 106 are fitted which can be removed so that the plug valves may be withdrawn.

It is an advantage of the unit 14 that lateral thrust force on the vessel 12 can be rapidly cut off (without having to run down the pump) by closing valve 62 or 64 as the case may be, and interconnecting the control slots through conduit 72. Full thrust is then nevertheless quickly available when called for for the reasons explained earlier in the specification and because low pressure regions formed on either side of the nozzle outlet when the unit is operating in the split flow zero thrust condition assist in the rapid build up of control fluid flow from which ever control slot has been brought into operation. The drive 18 for pump 16 may be of any suitable sort but a constant speed drive would appear adequate in most cases using the 3 position controller 70, 71. A variable speed drive, with or without the conduit 72 could be fitted if preferred.

In a variation, the conduit 72 is omitted from the illustrated embodiments and to achieve a no thrust condition the valves 62, 64 are continuously moved between their open and closed positions by actuators 66, 68 to switch the main flow of fluid rapidly and continuously between the two exit ports 38, 40. Conveniently in this case the pump is provided with a variable speed drive and during the no thrust operation it is driven at minimum speed.

It will be appreciated that by using a continuous bias flow from the control slots to deflect the remaining flow of liquid, the lateral thrust unit of the present invention gives stable diversion despite its short splitter distance. The unit has a high momentum recovery, between the nozzle outlet and the exit ports 38, 40 and has very rapid switching properties. Typically as above mentioned a 3 ton diverter will switch in between one or two seconds at maximum thrust. A 50 ton unit should switch in 5 to 10 seconds.

As already mentioned, the apparatus also compares very favourably with known bow thrusters from the point of view of manufacturing costs. Maintenance costs are also vastly less. Total costs can be reduced further by having as the pump for moving the fluid through the main flow duct one already required in the ship for some other purpose e.g. pumping ballast liquid. As in the illustrated embodiments it is envisaged that the bow thruster will usually be manufactured as a complete "bolt on" unit and it can of course be made in a variety of sizes for use with existing marine pumps.

It will naturally be understood that a second lateral thrust unit according to the present invention may be fitted at the stern end of the ship. This can be operated in conjunction with the bow thruster version of the present invention either to increase the turning moment exerted on the ship by the bow thruster or alternatively to oppose that moment by producing a parallel and roughly equal force on the stern portion of the ship acting in the same direction as that at the forward end. This latter situation will result in a transverse displacement of the ship without substantial rotational movement.

A third possibility is of course to operate the stern apparatus alone.

Although the invention has been described in relation to lateral thrust assemblies and units for use in ships, oil rigs and the like, a third embodiment of the invention will now be described with reference to FIG. 5 in which the unit 14 of FIGS. 1 to 3 is used as a flow diverter in a liquid transfer assembly 200. Thus in the embodiment of FIG. 5, liquid from a storage tank 202 is fed to one tank 203 of a number of auxiliary tanks 204 through a pipe 20'', pump 16'' (with drive 18''), transition piece 24'', one limb 30'' of unit 14, and flexible connection piece 34'' which is connected with an inlet port to tank 203. Numeral 70 indicates the control panel of FIG. 3 but simplified in this instance if desired, to exclude the split flow zero thrust control position. Immediately tank 203 is full, unit 14 is switched from panel 70 to redirect flow from tank 202 back to the tank via limb 32'' and connection piece 36''. Connection piece 34'' is then connected up to the next of tanks 204, the flow switched to limb 30'' and the above described filling process repeated. The most important advantage of unit 14 in this use, as compared with conventional systems, is its extremely rapid response which enables flow to be switched from tank 203 (or any other tank) the instant this tank is full. With previous systems there is nearly always some significant inertial effect and either liquid is spilt or the flow diverter must be switched before the auxiliary tank is properly full to allow space for liquid delivered after switching. Obviously the use illustrated in FIG. 5 is not confined to chemical plants — it could for example be used for any parallel set of circumstances e.g. for filling tanks in an oil tanker.

In an alternate mode of operation connection piece 36'' is connected to the next of auxiliary tanks 204 (as indicated at position 36''') whilst tank 203 is filling instead of being used as a permanent connection back to tank 202. In this way the auxiliary tanks can be filled in rapid succession (using limbs 30'' and 32'' alternately), connection piece 36'' (or 34'' as the case may be) only being connected back to tank 202 when the last of the tanks 204 is being filled.

I claim:

1. A lateral thrust unit substantially symmetrical about a centre plane of the unit,
a main duct for a main flow of fluid,
a nozzle portion in which the main duct terminates,
an interaction chamber communicating with the nozzle outlet,
two curved tapering, fluid outlet ducts diverging from the interaction chamber one on one side and one on the opposite side of the centre plane of the unit,
a nose piece separating the two outlet ducts,
surfaces defining control ports in the interaction chamber one on either side of said plane and each with an area of at least 5 percent of the nozzle outlet area,
control flow passages leading from the main duct to the control ports, and
independently operable control flow valve means for separately opening or closing the control flow passages to fluid flow through the passages.

2. A unit as claimed in claim 1, in which the area of each control port is between 8 percent to 12 percent of the nozzle outlet area.

3. A flow diverting assembly including a unit as claimed in claim 1, means for pumping liquid from a supply of the liquid to the inlet end of the main duct, means whereby one of the outlet ducts is adapted to be connected with a container or transfer means for the liquid, and means whereby the other of the outlet ducts is adapted to be connected with the or a similar container or transfer means or with said supply.

4. A unit as claimed in claim 1 in which the ratio of the smallest area of each of said outlet ducts to the sum of the areas of the nozzle outlet and of each of the two control ports is less than 1.6.

5. A unit as claimed in claim 4, in which the ratio of the smallest area of each of the outlet ducts to the sum of the areas of the nozzle outlet and either one of the two control ports is less than 1.10.

6. A unit as claimed in claim 1, in which the distance between the nozzle outlet and the nearest part of the nose piece is three to five times the width of the nozzle outlet.

7. A unit as claimed in claim 6, in which the distance between the nozzle outlet and the nearest part of the

nose piece is roughly 3.8 times the width of the nozzle outlet.

8. A unit as claimed in claim **1**, including a by-pass conduit connecting together the control flow passages, and by-pass valve means for opening or closing the conduit to fluid flow through the conduit.

9. A unit as claimed in claim **8**, in which the by-pass valve means and the control flow valve means are arranged to operate in conjunction with one another so that with the by-pass conduit closed one of the control flow passages is open to the main duct whilst the other is closed, and with the by-pass conduit open both control flow passages are closed to flow from the main duct and the control ports are interconnected through the by-pass conduit.

10. A unit as claimed in claim **9**, including **3**-way plug valves which provide both the main flow valve means and the control flow valve means.

11. A unit as claimed in claim **1**, in which the control flow passages are connected with the main duct through openings in the longitudinal walls of the main duct.

12. A unit as claimed in claim **11**, including filters at said openings.

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