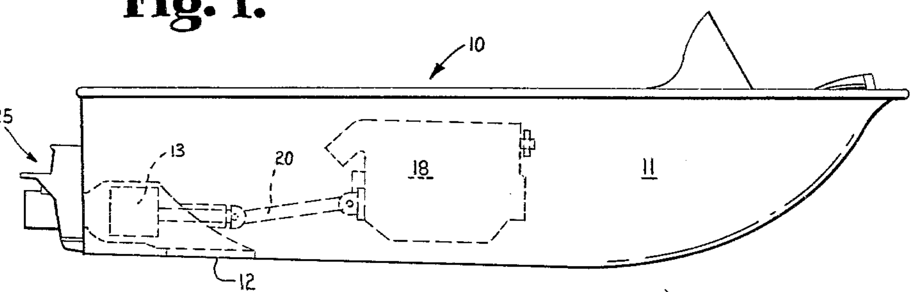
Nov. 2, 1965 R. L. COCHRAN 3,214,903

JET BOAT NOZZLE

Filed March 14, 1963

Fig. 1.



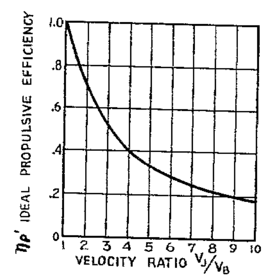


Fig. 4.

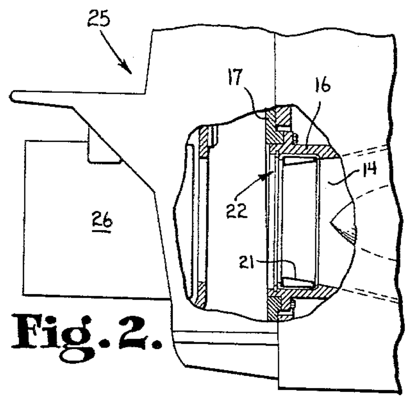
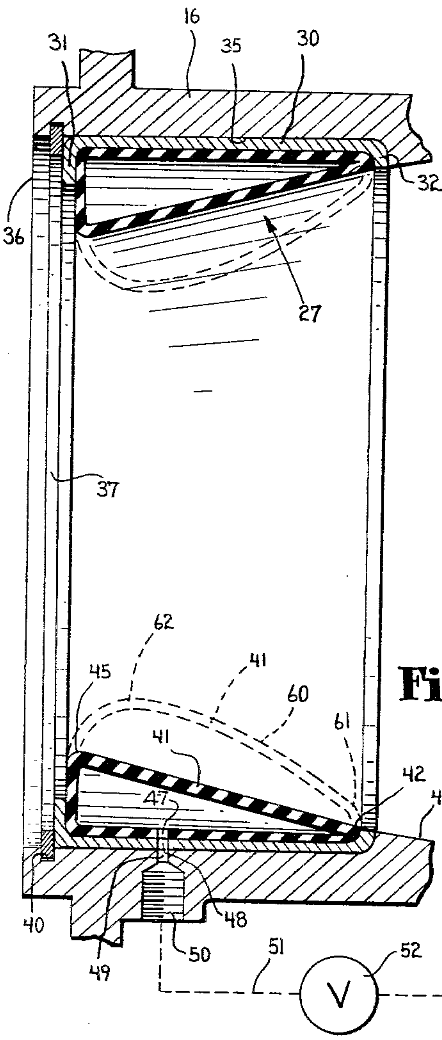


Fig. 2.



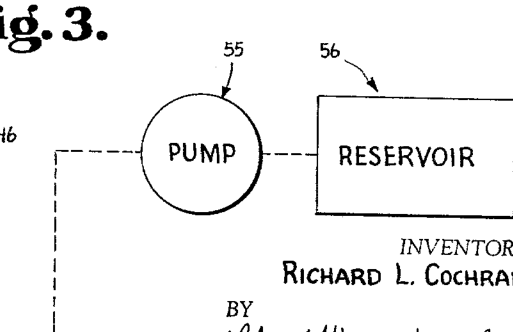


Fig. 3.

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JET BOAT NOZZLE

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The present invention relates to jet propelled watercraft.

One form of jet propelled boat incorporates an engine operatively connected to a pump located within a conduit extending through the boat from an intake opening at the bottom of the boat to an exhaust at the rear of the boat. Water is drawn into the conduit through the intake opening and is exhausted in a jet stream from the rear of the boat causing the boat to move. It has been found that the relative velocity of the jet stream as compared to the velocity of the boat has a controlling effect on the propulsive efficiency of the boat.

Consequently, one object of the invention is to provide a jet boat nozzle arrangement which can be operated to propel the boat at relatively high propulsive efficiency.

A further object of the present invention is to provide an engine-powered jet-watercraft nozzle arrangement which can be controlled to cause the jet craft to operate at a relatively high miles per gallon of fuel.

Still another object of the invention is to provide an improved control system and nozzle arrangement for a jet-craft.

Related objects and advantages will become apparent as the description proceeds.

One embodiment of the present invention includes a control system for a jet-craft comprising a conduit mounted on the craft and extending and opening rearwardly thereof, means for pumping water through the conduit to exhaust from said opening. Mounted within the opening is an annular inflatable flexible tube to which is connected a compressed-air-providing means. The size of the tube and the size of the opening are controlled by inflating or deflating the tube so as to control the velocity of the jet as it leaves the conduit and to thereby maintain the velocity of the jet at a desired value relatively close to the velocity of the boat.

The full nature of the invention will be understood from the accompanying drawings and the following description and claim.

FIG. 1 is a side elevation of a jet boat incorporating the novel control system of the present invention.

FIG. 2 is an enlarged side elevation of the rear portion of the jet boat of FIG. 1 with a portion broken away to show internal details of a nozzle arrangement forming a part of the present arrangement.

FIG. 3 is an enlarged axial section through the opening or exhaust of the pump conduit showing details of the nozzle arrangement of the present invention, said FIG. 3 also including a schematic flow diagram showing means for controlling compressed air supplied to the nozzle arrangement.

FIG. 4 is a graph showing the relationship of ideal propulsion efficiency to the velocity ratio, i.e. the jet velocity over the boat velocity.

Referring now more particularly to the drawings, there is illustrated a jet boat **10** having a hull **11**, the hull being provided with an intake opening **12** communicating between the bottom of the boat and a pump **13**. The pump **13** has a passage therethrough communicating between the intake **12** and a passage **14** through a tailpipe **16** secured to the rear or transom **17** of the boat. The pump **13** is driven by a conventional marine engine **18** by means of a shaft **20** and functions to pump water from intake

12 to and out of the rear of the boat. The water is constricted into a stream by the converging surface **21** of a nozzle arrangement **22** mounted within the exit end of the tailpipe **16**.

The jet, after being formed by the nozzle arrangement **22**, passes through a housing **25** secured to the rear of the boat and passes between a pair of deflectors **26** pivotally mounted on the housing. Since the housing **25** and deflectors **26** form no part of the present invention, they will not be further described herein. For further details regarding the suitable housing **25** and deflectors **26**, reference is made to the copending application of James W. Reynolds et al., Serial No. 236,292, entitled Jet Boat Steering Deflectors and assigned to the same assignee as the present application.

In order to move the boat **10**, it is necessary that the pump **13** changes a certain mass of water per second from one velocity to another velocity. Thus, the propulsive force or thrust developed is equal to the mass rate of flow through the system times the velocity change across the system. Or:

$$T = m\Delta v$$

where:

T=thrust in pounds
m=mass of water in slugs/second
Δv=change in velocity of the water from its entry into the boat to its exit out of the boat.

The direction of the thrust is determined by Newton's third law which holds that "for every action, there is an equal and opposite reaction."

The propulsive horsepower produced by the thrust may be expressed as follows:

$$\text{H.P. output} = \frac{T V_B}{550}$$

where:

T=thrust in pounds
V_B=velocity of the boat in ft. per second

The overall system propulsive efficiency may be expressed as follows:

$$\eta_p = \frac{\text{H.P. output}}{\text{H.P. input}} = \frac{T V_B}{(550)}\ \text{H.P. input}$$

The system efficiency may be expressed as the product of the ideal propulsive efficiency and the mechanical efficiency. Thus:

$$\eta_p = (\eta_p')(\eta_m)$$

η_p', the ideal propulsive efficiency represents the maximum efficiency possible in any propulsive system. As set forth above, in order to produce a thrust, there must be a change in velocity of the water pumped. It is also true, however, that the velocity change of the water pumped represents a loss of kinetic energy to the system. If the change in velocity is great, the loss of kinetic energy is even greater and in fact, is magnified as the square of the change in velocity because of the fact that kinetic energy is proportional to the square of the velocity times the mass involved.

When used for hydraulic jets, the ideal propulsive efficiency may be written:

$$\eta_p' = \frac{2}{1 + \frac{V_J = \text{velocity of the jet}}{V_B = \text{velocity of the boat}}}$$

This relation has been plotted graphically in FIG. 4.

Consequently, it is desirable that the boat be operated as far to the left on this graph as possible. For example, a velocity ratio of 1.5 to 1.7 provides a good balance between reducing loss of kinetic energy and high thrust. As can be read from FIG. 4, the propulsive efficiency for such a velocity ratio is approximately 75%.

Assume now that the boat **10** is moving at a given velocity which produces the desired velocity ratio of 1.5 to 1.7 and which produces the desired propulsive efficiency of 75%. Assume further that the boat now takes on a heavy load which appreciably reduces the boat velocity. As a result, the velocity ratio increases and causes the propulsive efficiency to be substantially reduced. The nozzle arrangement **22** is used to bring the jet velocity down to a figure which produces the desired velocity of 1.5 to 1.7. Thus, the jet velocity is decreased by increasing the size of the orifice **21** through the nozzle arrangement **22**. As a result, a greater mass of water is pumped through the nozzle arrangement but this greater mass of water leaves the boat in a jet having a lower velocity. In the situation that the boat **10** is carrying a heavy load which is removed from the boat, the orifice size of the nozzle arrangement **22** is reduced in order to bring the jet velocity up to a sufficiently high value so that the boat can operate at a high speed. In order to operate the boat at a high speed, thrust must be provided and this thrust is, of course, dependent upon the change in velocity of the water as produced by the pump.

The nozzle arrangement **22** includes an annular inflatable flexible tube **27** of triangular cross-section which is received within and bonded to a receptacle **30**. The receptacle has a generally cylindrical shape with inwardly projecting flanges **31** and **32** at the opposite ends thereof. Preferably, the outer wall of the tube **27** is bonded to the receptacle **31** whereby a certain amount of desired rigidity is provided in the mounting of the tube. The receptacle **30** is received within a recess **35** which extends into the tailpipe **16** of the conduit from the rear **36** thereof. The receptacle **30** is retained in position by a snap ring **37** which is received in a peripheral recess **40** opening into the recess **35** of the tailpipe.

It should be pointed out that the inflatable tube **27** has an inner wall **41** which tapers smoothly from a larger inside diameter at its forward end **42** to a smaller inside diameter at its rearward end **45** adjacent the exit of the tailpipe. The third side or wall of the tube is located at the rearward end of the receptacle **30** adjacent the exist of the tailpipe. Thus, the wall **41** forms an extension of the converging inside surface **46** of the tailpipe and defines an orifice which forms the jet stream.

The tailpipe **16**, receptacle **30** and tube **27** have aligned apertures **47**, **48** and **49** therethrough which form a passage for conducting or removing compressed air from the tube **27**. The tailpipe **16** has a threaded counterbore **50** which can receive a suitable air conduit indicated schematically by the dotted line **51**. This conduit is controlled by a valve **52** and leads to compressed-air-supplying means including the pump **55** and a reservoir **56** which are mounted in suitable locations in the boat **10**.

The compressed-air-supplying means can also include a pressure control (not shown) for operating the pump when the pressure in the reservoir falls below a given value and shutting off the pump when the pressure in the reservoir rises above a given value. The valve **52** is of conventional type and can be moved to a position wherein the passage **49** and pump communicate or a position wherein the passage **49** communicates with atmosphere or a position wherein the passage **49** is closed off and the air contents of the tube **27** are maintained constant.

By means of the valve, pump and reservoir, the tube **27** can be inflated to various positions, one of which is illustrated in dotted lines in FIG. 3. It will be noted that when the tube **27** is inflated, a smoothly curved shape **60** results, this shape having a larger inside forward diameter in the area **61** as compared to the smaller inside rearward diameter in the area **62**. When water is being forced through the tailpipe **16**, the pressure of the water may deform the tube **27** so that it does not bulge uniformly across the inner wall **41** as illustrated in FIG. 3. In such a situation, the tube **27** will deform but will still maintain a smooth shape which does not appreciably interfere with the flow of the water. Even so, the smooth shape defined will be an orifice of smaller diameter than that produced when the compressed air is removed from the tube. Obviously, the size of the orifice can be varied through an infinite number of sizes two of which are represented by the solid and dotted lines of FIG. 3.

From the above description, it will be obvious that the present invention provides an improved control system and nozzle arrangement for a jet-craft. It will also be obvious that because of the fact that efficiency can be maintained at a uniformly high value by means of the present nozzle arrangement, the miles per gallon of the jet-craft can also be maintained at a high value. It should also be evident from the above description that the control system of the present invention makes possible propelling of a jet boat at a relatively high propulsive efficiency.

It should be understood that even though the means for inflating the tube **27** has been described as compressed-air-supplying, various other types of inflation means can be used. For example, it may be preferable to use hydraulic fluid, water or some type of liquid in view of its incompressibility. Also, other gases or fluids besides air might be used.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiment has been shown and described and that all changes and modifications that come within the spirit of the invention and the scope of the claim are also desired to be protected.

The invention claimed is:

A control system for jet-propelled watercraft comprising a tailpipe mounted on the craft extending rearwardly thereof and defining a rear opening; means for pumping water through said tailpipe to exhaust from said opening; said tailpipe having an inside surface converging inwardly toward said opening; a generally cylindrical recess extending into said tailpipe from the rear thereof; a generally cylindrical receptacle received within said recess and having radially-inwardly-projecting flanges at opposite ends thereof; an annular inflatable flexible tube received within said receptacle, said tube having a triangular cross-section and having an inner wall, an outer wall, and a third wall; said outer wall being bonded to said receptacle; said inner wall tapering inwardly toward said rear opening in said tailpipe to form an extension of the inward converging surface of said tailpipe; the third wall of said flexible tube being adjacent said rear opening; a snap-ring engaging said tailpipe and retaining said receptacle in said recess; said tailpipe, receptacle, and tube having an aligned passage therethrough; and means connected to said passage for providing compressed air to said tube; whereby the size of the passage through said tailpipe for movement of water can be decreased for operation of the craft at increased speeds by inflating the flexible tube, the inflated tube being expanded to a greater thickness near said rear opening of said tailpipe and providing a smoothly curved shape which does not appreciably interfere with the flow of water through the tailpipe.

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