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[54] **GILL FOR EXTRACTING OXYGEN FROM OXYGEN BEARING FLUIDS**

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[51] **Int. Cl.**[4] **B01D 53/22**

[52] **U.S. Cl.** **55/158**; 55/159; 55/356; 114/334

[58] **Field of Search** .... 55/16, 158, 159, 356, 55/400; 114/67 R, 67 A, 334

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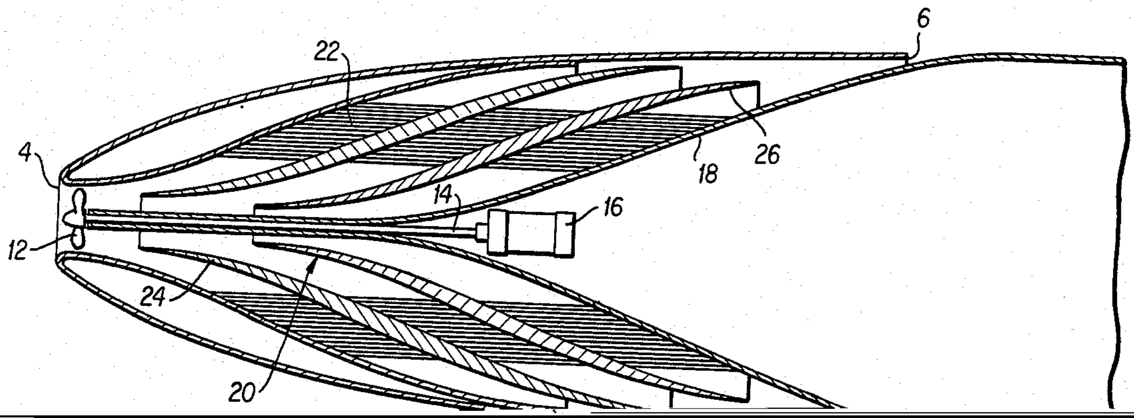
[57] **ABSTRACT**

An apparatus for extracting oxygen from sea water in which a plurality of hollow gill members carry on oxygen extracting heme and are positioned within a diffuser. A flow of oxygen bearing liquid, such as sea water, passes through the diffuser and arpund the gill membranes. The gill membranes are angled with respect to the flow of sea water. The diffuser has a reduced section intake and outlet, and is divided into a number of channels, with the result that the drag force is reduced while maintaining adequate oxygen extraction. Propellers compensate for drag force losses.

9 Claims, 6 Drawing Figures



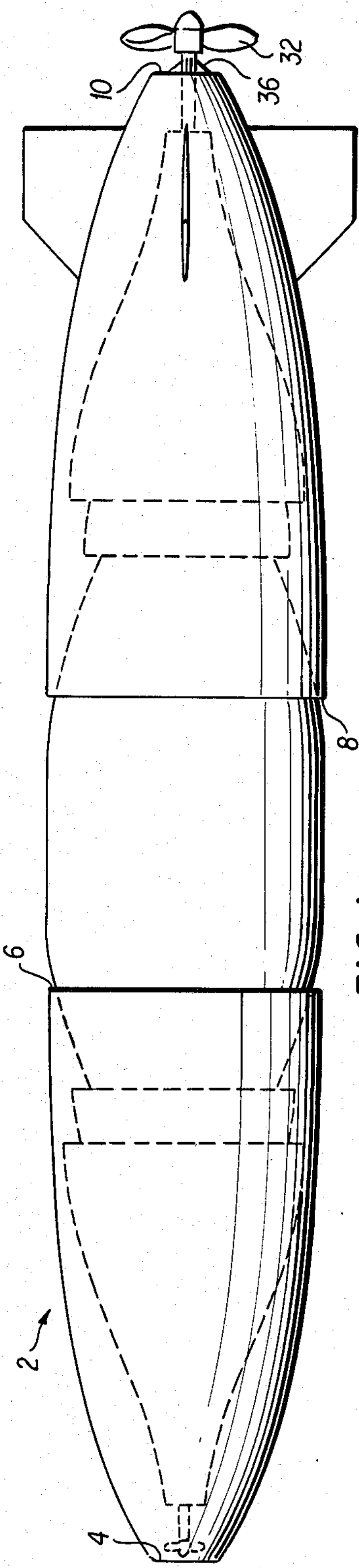
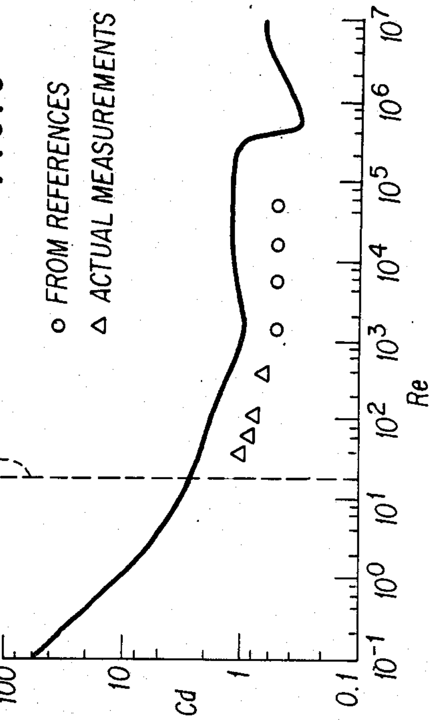


FIG. 1

FIG. 6



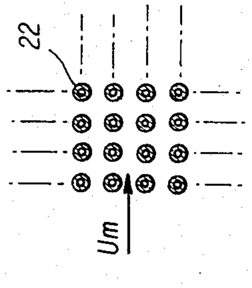


FIG. 5

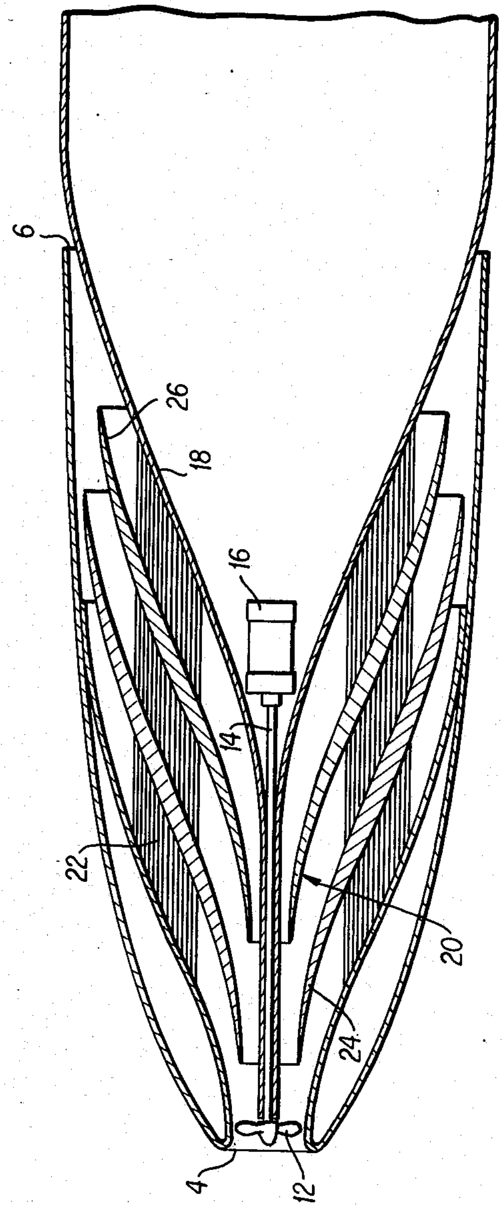


FIG. 2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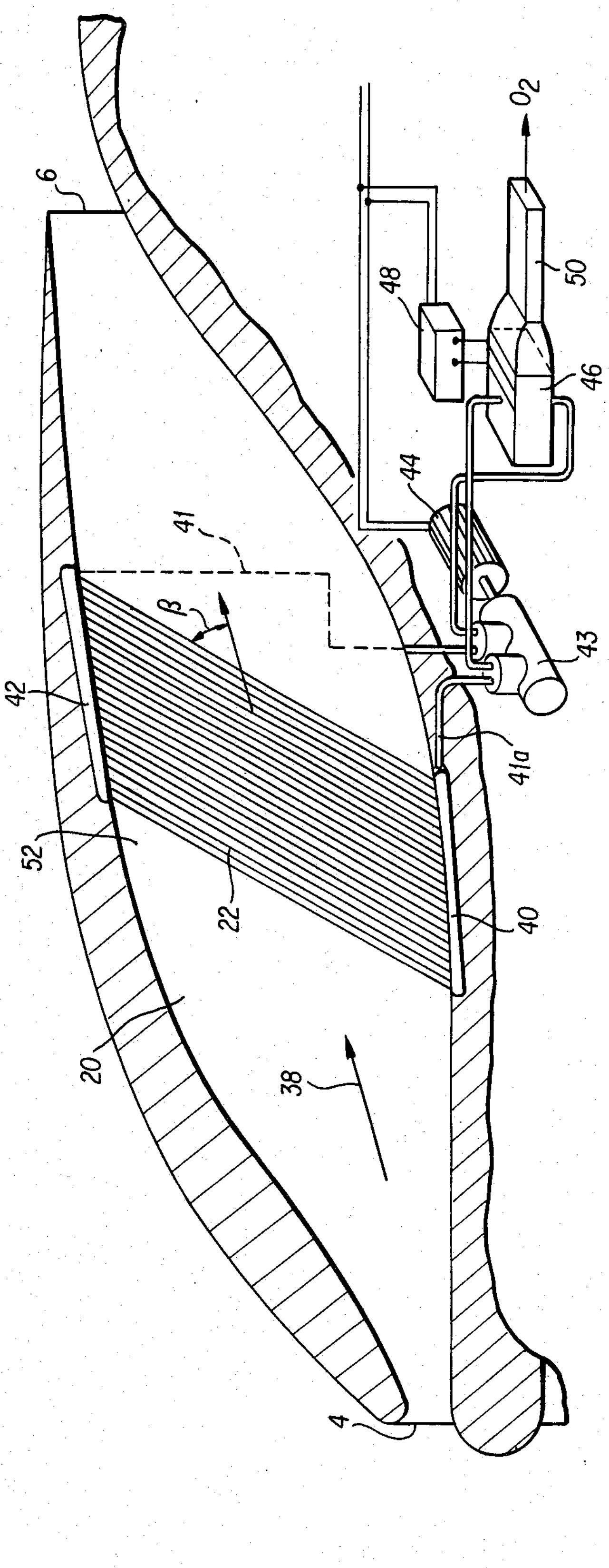

FIG. 4

GILL FOR EXTRACTING OXYGEN FROM OXYGEN BEARING FLUIDS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a gill structure for extracting oxygen from fluids in which oxygen is dissolved.

2. Description of Related Art

Copending U.S. patent application Serial No. 653,850, filed on Sept. 24, 1984, now U.S. Pat. No. 4,602,987 and assigned to the same assignee as the present application, discloses a system and process for the extraction of oxygen from fluids in which oxygen is dissolved. This copending application is hereby incorporated by reference. The copending application discloses a process in which oxygen is extracted from an

velocity reduces the drag induced by the gill structure and increases the residence time of the sea water at the membranes.

The restrictions at the inlet and outlet of the diffuser will result in hydrodynamic resistance and a corresponding pressure drop thereacross. The present invention therefore provides a propelling means such as a propeller at the diffuser inlet or outlet which compensates for the hydrodynamic resistance of the membranes and other diffuser losses.

BRIEF DESCRIPTION OF THE DRAWINGS

Various other objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the following detailed description when considered in connection with the accompanying drawings in which like bow gill. The inlet **8** is annular and lacks a propeller. A main vehicle motor and controller **28**, which may include a spark ignition internal combustion engine which consumes a portion of the oxygen produced by the gill structure, drives a drive shaft **30** and main vehicle propeller **32**. The shaft **30** is surrounded by an annular fairing **34**, and is supported at the outlet **10** by a spyder **36**. The motor and controller may be a well known internal combustion engine and controller therefor, and will not be described in detail.

The gill structure and heme supplying and circulating structure are schematically shown in FIG. **4**, which only shows a single flow channel, and does not illustrate the propeller **12**, for the sake of simplicity. The gill membranes **22** each consist of a hollow cylindrical tube formed of a gas permeable material such as silicone rubber, polytetrafluoroethylene, an alkylcellulose or an acetylcellulose. The gills are arranged in an annular array of non-staggered rows as shown schematically in section in FIG. **5**. The gills all extend radially and are arranged at a uniform angle β with respect to the direction of flow **38** of the water from the intake.

Each end of each gill diaphragm is secured to an annular manifold **40** or **42** in a fluid tight manner, as by bonding using a waterproof resin. Heme or another compound having similar oxygen absorbing and desorbing properties is circulated via lines **41***a* and **41***b* through the manifolds and gills by a pump **43**, which is preferably a double piston pump for purposes of balance. The pump is driven by an electric motor **44**, which may be supplied with electrical power from a [illegible]

extracted oxygen from the water passing through the diffuser **20**, is pumped to an unloading chamber **46** having a power supply **48** and including a membrane **50**, where the oxygen is extracted from the heme, by a process described in detail in the aforementioned copending U.S. patent application Ser. No. 653,850, now U.S. Pat. No. 4,602,987. The oxygen can then be used for various purposes, including for mixing with fuel for

ent for circular cylinder membrane bundles as a function of the Reynolds number, which is in turn is a function of the water velocity U_m. The base line refers to the minimum Reynolds number tested for. The solid line in the graph illustrates values of C_D for a single circular cylinder, the triangles represent actually measured values and the circles represent values derived from Grimson, E. D. "Correlation and Utilization of New Data on Flow Resistance and Heat Transfer for Cross Flow of Gases over Tube Banks," Trans, ASME 59, 583-594 (1937).

Accordingly, it can be appreciated that the gill structure reduces drag force attributable thereto in at least two ways. First, the relatively small diffuser intake area and outlet area result in a substantial reduction in the water velocity past the gill membranes. The resulting lowered Reynolds number results in a reduced value for the drag force which is proportional to the square of the fluid velocity.

A smaller angle β also produces reduced drag. However, as the angle β becomes smaller, the rate of oxygen extraction through the gill membranes is reduced since the gills present a smaller frontal area to the flow of oxygen bearing water. Increasing the number of gills will increase the rate of extraction, but will also increase the drag force. It has been found that an angle $\beta=25°$ provides an optimum balance between these conflicting constraints of reducing drag while maintaining adequate oxygen extraction.

The propeller **12** within the bow gill replaces the [illegible]

propeller **32** provides a similar function for the stern gill structure. The power P_{prop} supplied by the motor to each of the propellers **12** and **32** is based on the following equation

$$P_{prop}=\eta_{prop}(P_{dif}+P_{drag})$$

where η=propellor efficiency

wherein an angle β formed between said flow direction and the longitudinal axes of said gills is less than 90°, whereby the drag force of said apparatus is reduced;

wherein saidmeans for guiding comprise a diffuser conduit having: an intake communicating with said source of liquid and having a first sectional area; a membrane supporting region in which said membranes are positioned, said membrane supporting region having a second sectional area larger than said first sectional area; and an outlet communicating with said source of liquid downstream from said membrane supporting region in said flow direction, said outlet having a third sectional area small than said second section area; and

wherein said means for providing relative movement comprises means in said intake or outlet for propelling liquid within said intake in said flow direction, whereby drag losses are compensated for.

2. The apparatus of claim **1**, wherein β is less than 30°.

3. The apparatus of claim **1**, wherein β is substantially 25°.

4. The apparatus of claim **1**, wherein said membranes are arranged in an annular plurality of rows, all of said rows comprising membranes aligned with one another in said flow direction.

5. The apparatus of claim **1**, wherein said membrane supporting region comprises a plurality of concentric annular membrane supporting regions arranged in parallel and separated by concentric annular fluid flow guide elements, each of said plurality of membrane supporting regions independently communicating with said inlet and said outlet.

6. The apparatus of claim **1**, including means for extracting said oxygen from said heme-like compound.

7. The apparatus of claim **6**, positioned at the upstream end of an underwater vehicle in said flow direction.

8. The apparatus of claim **6** positioned at both the upstream and downstream ends of said underwater vehicle.

9. The apparatus of claim **8**, wherein said vehicle includes vehicle propelling means.

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