

March 5, 1968

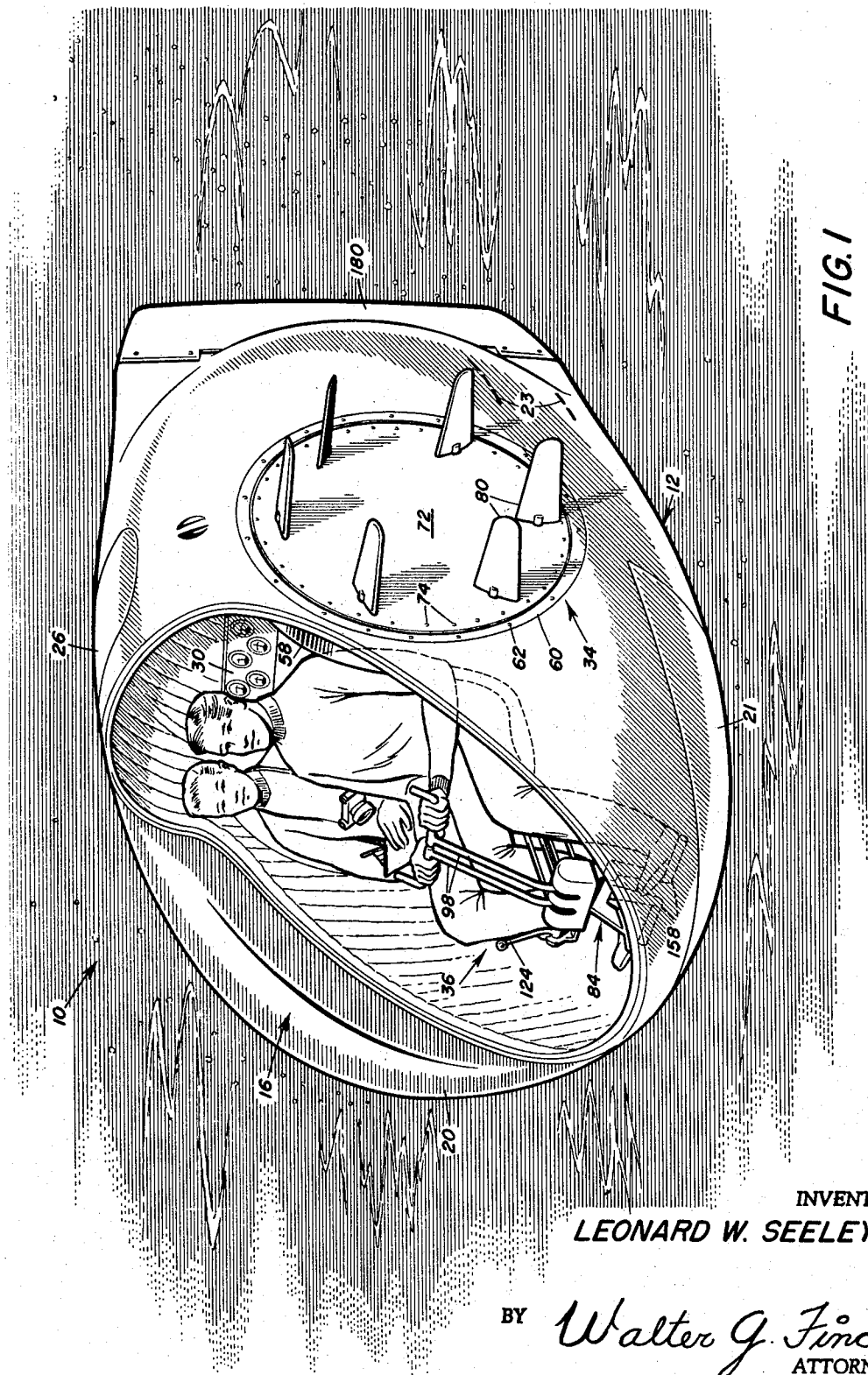
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3,371,635

SUBMERSIBLE VESSEL

Filed Sept. 7, 1966

6 Sheets-Sheet 1



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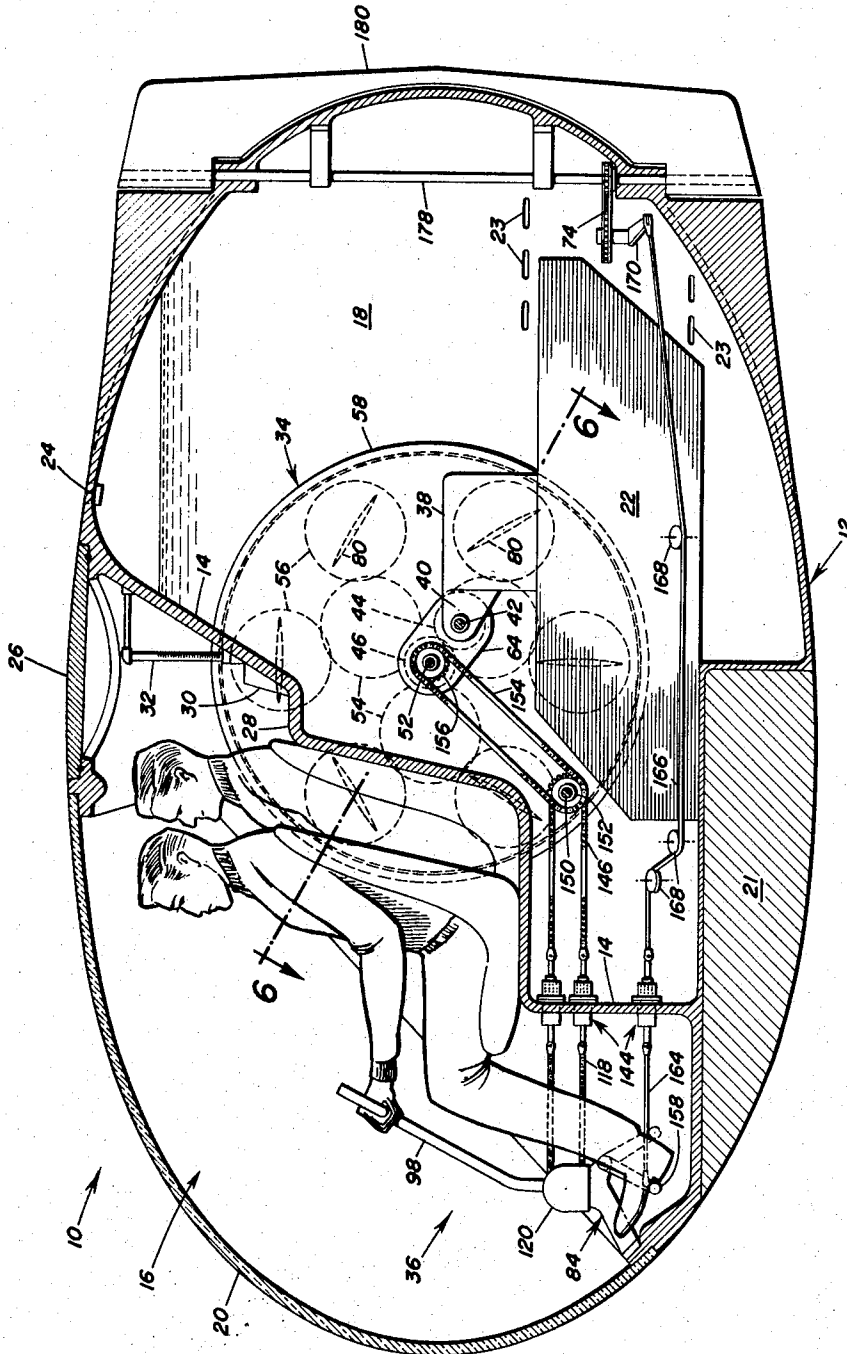
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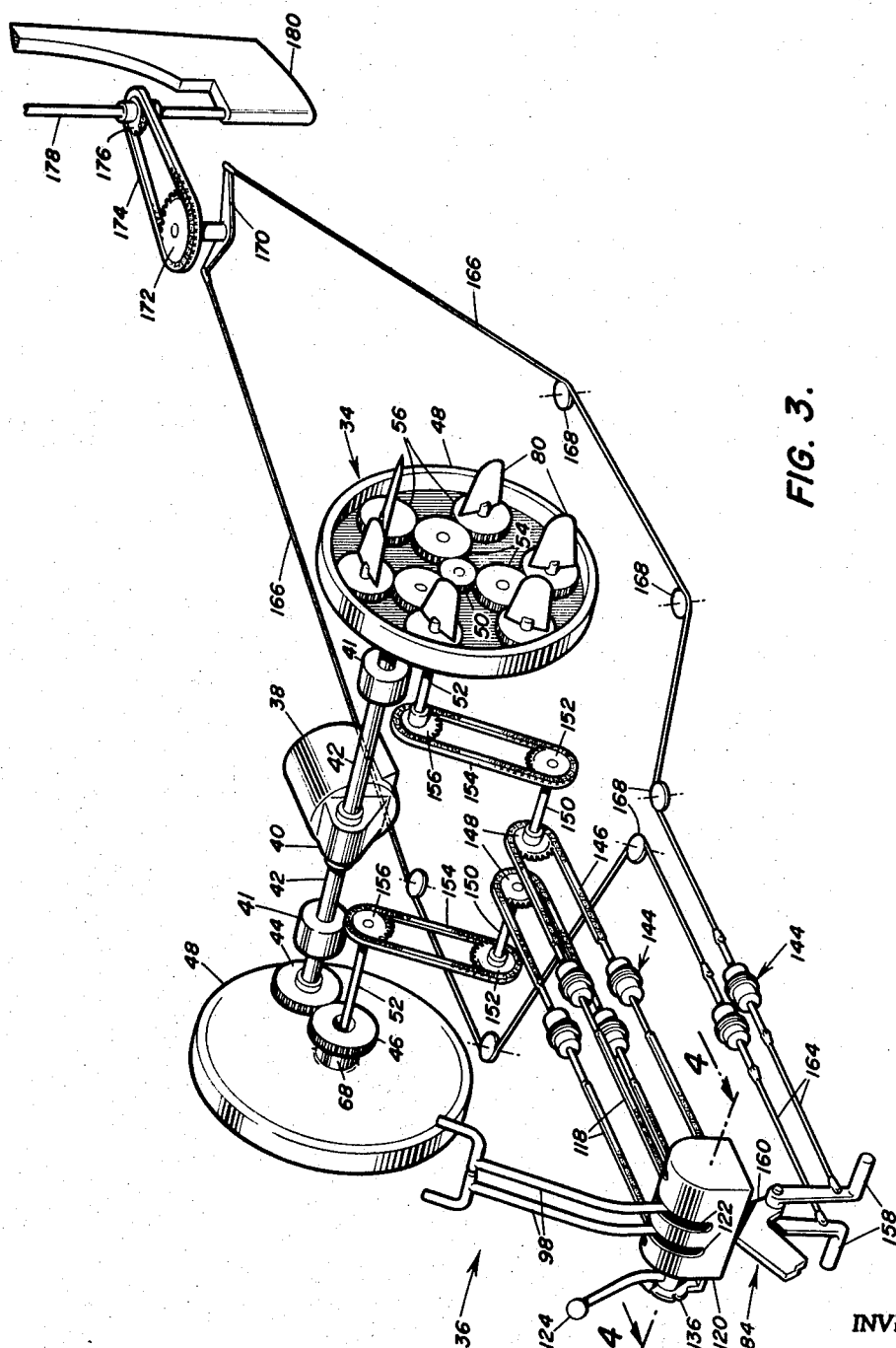


FIG. 3.

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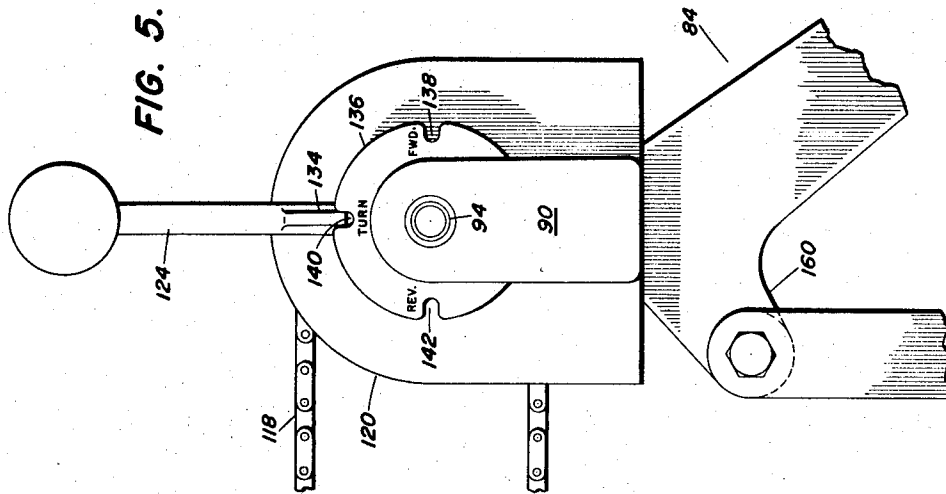
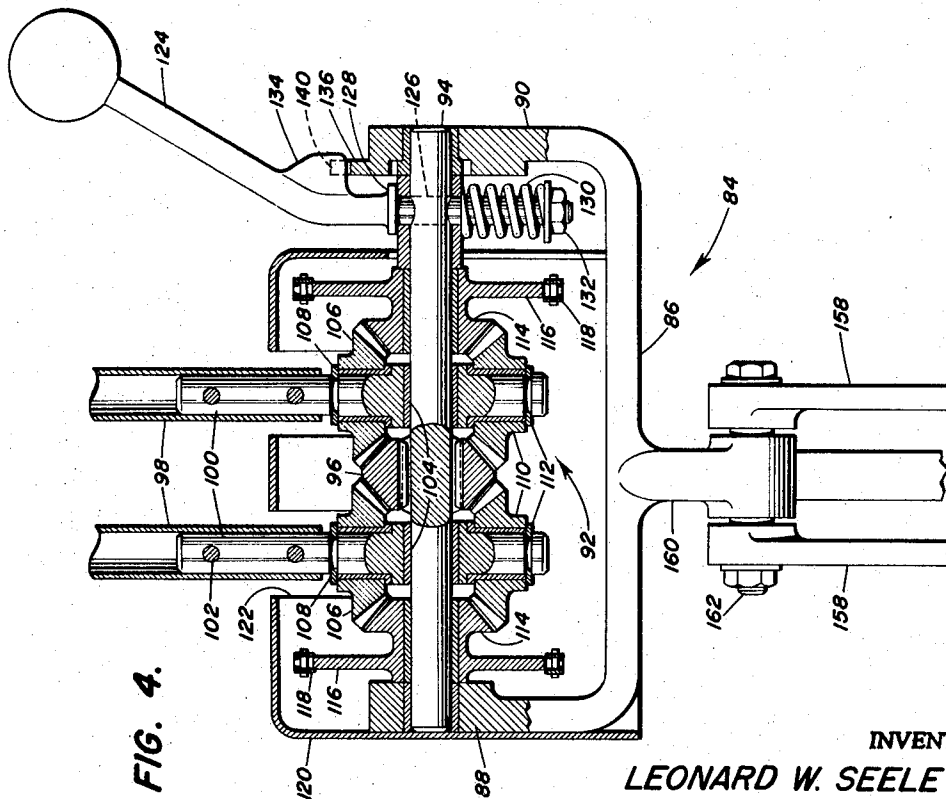
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6 Sheets-Sheet 4



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FIG. 6.

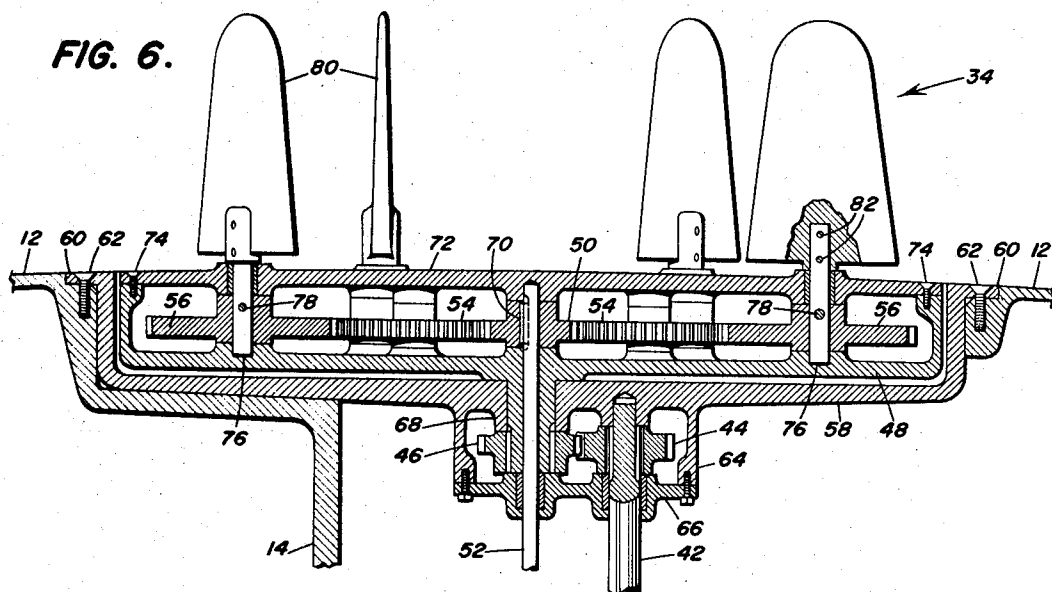
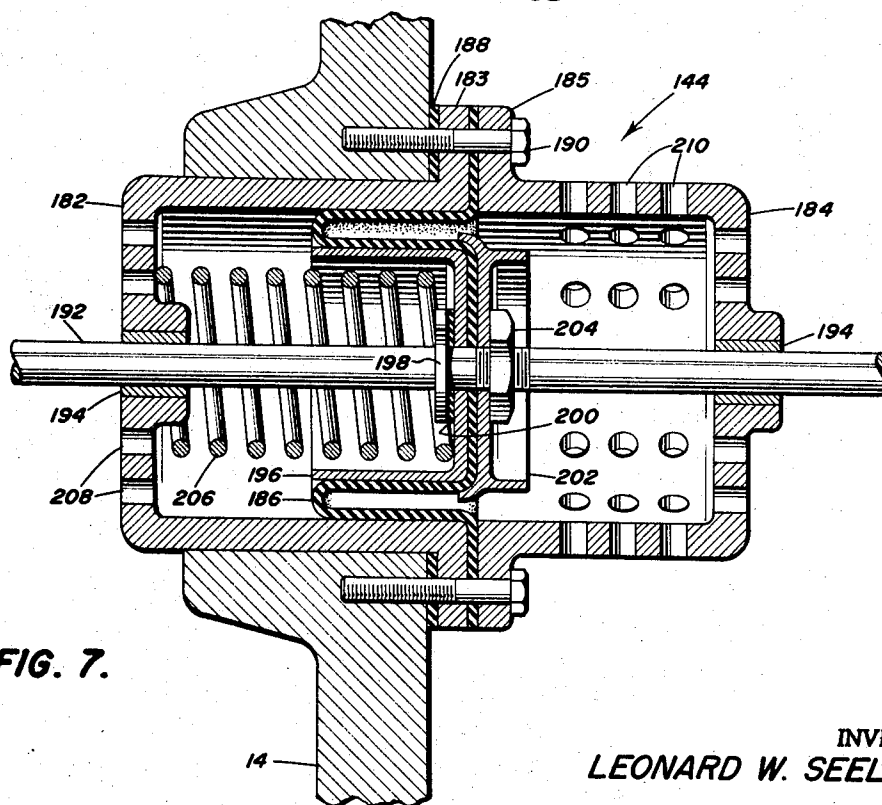


FIG. 7.

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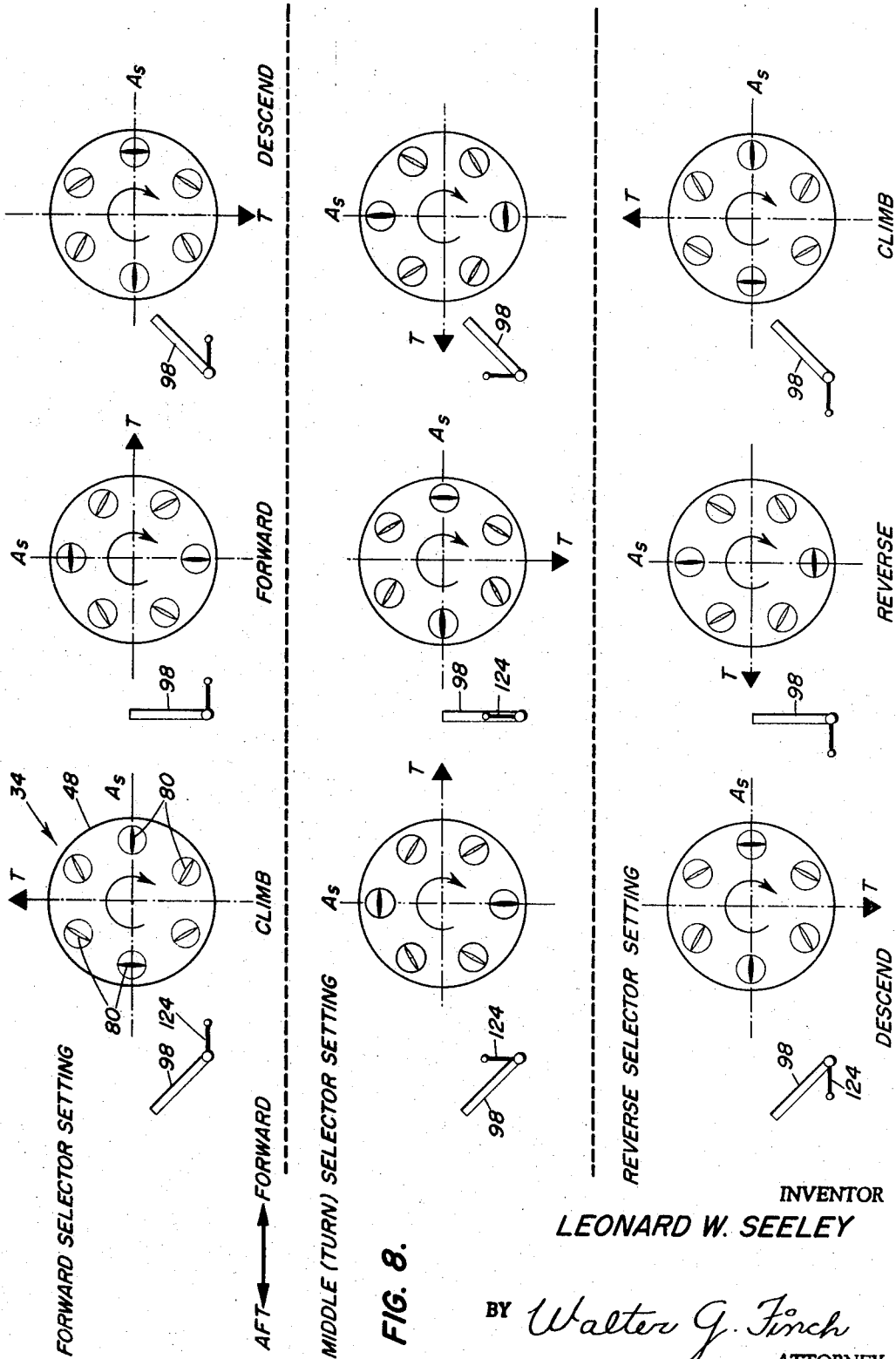
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3,371,635

SUBMERSIBLE VESSEL

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Filed Sept. 7, 1966, Ser. No. 577,644

16 Claims. (Cl. 114-16)

This invention relates generally to submarine vessels, and more particularly it pertains to an undersea sport and utility boat or submersible.

There exists at the present time no generally available machine comparable to the automobile, light aircraft, or pleasure boat for underwater travel. It is generally accepted that in the future man will enter the sea in ever increasing number for the purposes of sport, adventure, exploration, mining, military necessity, commercial transport, and the harvesting of fish and sea crops and a wide variety of underwater craft will be developed specifically for such purposes.

In the interim, the submersible described herein provides two major design advances and various new and novel features to the small submersible design art.

One of the objects of this invention, therefore, is to provide a hydrodynamically efficient submarine hull shape of the near ellipsoid type as seen in nature in the sun fish and perch for example.

Another object of this invention is to provide a small submersible arrangement in which the packaging emphasis is on a comfortable seated position for the occupants without need for drag-producing superstructure, turrets and the like.

Still another object of this invention is to provide a one or two man submarine which will use propulsive energy at a lower rate for increased endurance and range.

Another object of this invention is to provide a mid-hull twin cycloidal propeller system having novel control means for excellent maneuvering characteristics for an underwater machine.

Improved stability around the vertical turning axis and roll axis without addition of drag-producing auxiliary surfaces is featured in what would otherwise by a yaw unstable body configuration.

Yet another object of this invention is to provide a pressure bulkhead positioned at an angular attitude whereby improved stability and ballasting is obtained in a submersible.

To provide a control system for a submarine having flooded mechanism which operates entirely by linear movement through water-tight couplers, is still another object of this invention.

Another object of this invention is to provide a control pedestal whereby cycloidal propeller systems can be efficiently and conveniently controlled.

Other objects and attendant advantages of this invention will become more readily apparent and understood from the following detailed specification and accompanying drawings in which:

FIG. 1 is a perspective view of a submersible incorporating features of this invention;

FIG. 2 is a vertical section, fore-and-aft, of the submersible of FIG. 1;

FIG. 3 is a schematic depiction of the control and propulsion system for the submersible with parts shown in perspective relationship;

FIG. 4 is an approximately full sized vertical section view taken on line 4-4 of FIG. 3 showing details of the novel control pedestal;

FIG. 5 is an end view thereof;

FIG. 6 is a cross section of the cycloidal propulsion system taken on line 6-6 of FIG. 2;

FIG. 7 is an enlarged cross-section showing the details of a control line coupler; and

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FIG. 8 is a series of diagrams illustrating the relationship of the control stick and lever settings on the positioning of the cycloidal propeller blades and the resulting response of the submersible.

Referring now to the details of the invention as shown in FIGS. 1 and 2, reference numeral 10 indicates generally a submersible embodying features of this invention. The hull structure 12 is of ellipsoidal shape in elevation having a major transverse axis arranged vertically. In plan, however it is preferably tapered to a tear-drop stern. It will be noted that the occupants are positioned in a comfortable seated position as opposed to other existing cigar-shaped craft that require the occupants to be prone or that head and shoulders be accommodated by viewing turrets which break the hydrodynamic smoothness of the hull.

Further, in addition to providing minimum hull displacement volume, the ellipsoid can be shown to have less surface area than prolate spheroids of the same volume and width. As viscous drag (skin friction) accounts for the largest part of the total hydrodynamic drag of submersibles, a reduction thereof can be demonstrated for ellipsoidal hulls. Propulsive energy is thus considerably reduced.

Interiorly, hull structure 12 is divided by a pressure bulkhead 14 into a cockpit area 16 and an area 18 for power, air ballast and environmental systems, as best seen in FIGS. 1 and 2.

It will be noted that this bulkhead 14 is disposed at an angular attitude generally and demonstrates a seat-shaped contour in side view starting at a point on the deck near the bow of the submersible 10 and terminating back of the centerline at the overhead. The occupants, shown seated on this bulkhead 14, are relatively displaced fore-and-aft somewhat to better provide for hip room. Further, by the angular attitude of bulkhead 14 the volume hence buoyancy of compartment 16 is reduced minimizing the requirement for lead ballast.

A large canopy 20 of transparent material such as specially treated glass forms a large portion of the forward portion of the hull 12 and a jettisonable lead ballast 21 completes the forward contour thereof below the occupants.

The heavy power batteries are housed in a flooded battery case 22 somewhat aft of the centerline and low in the area 18. Near the bottom of area 18, several vents 23 open to the exterior are provided by which it can be pumped out by pressurized air or flooded by sea water. For this purpose, an air bleed valve 24, shown in FIG. 2, is mounted through the hull 12 near the highest point. A water level sight gauge 32 located in area 16 is used for monitoring the flooding process.

A top-located hatch 26 gives access to area 16, through the use of an entry step 28 formed in the bulkhead 14. The rear of this entry step 26 is also utilized as a shelf for an instrument panel 30.

A cycloidal propeller propulsion system 34, indicated generally, is provided and it utilizes certain principles of U.S. Patent No. 1,432,700 issued to F. K. Kirsten and which is adapted for undersea use by the control system 36 to be described.

A motor 38 is provided which is of the immersion type. It is controlled with electrical circuitry of suitable type for operation from the battery in case 22. This motor 38 has a gear reduction head 40 and has free wheeling clutches 41 in each of oppositely extending drive shafts 42 as best shown in FIG. 3. At the end of each shaft 42, there is secured a gear 44 and these mesh with gears 46 each splined to a hub 68 of a drum shaped spider 48, one on the port side and one on the starboard side.

A sun or control gear 50 is centered within the spider 48 and it is keyed to a control shaft 52 which extends through the gear 46 and a hub 68 as shown in FIGS. 3

and 6. Idler gear 54 mesh with gear 50 and also meshes with planetary blade gears 56.

This planetary system of gears within spider 48 is recessed into the hull 12 by means of a housing well 58. A suitably gasketed flange 60 and screws 62 assure a pressure tight seal of housing well 58 to hull 12.

Integral with this housing well 58 is a housing 64 for the gears 44 and 46, previously mentioned. A cover and bearing plate 66 also provides water tight journaling for the shafts 42 and 52. A key 70 secures shaft 52 to the control gear 50.

A cover and bearing plate 72 is secured on the outside of spider 48 by means of screws 74. This plate 72 fairs into the ellipsoidal shape of hull 12 and also journals protruding shafts 76.

Propeller blades 80 are secured by pins 82 to the outer end of shafts 76 and extend outwardly at right angles to the surface of the hull 12 with no other support. These shafts 76 are secured by pins 78 for rotation with the planetary blade gears 56.

Control for this mechanism is provided by a control pedestal 84 in cockpit area 16, as shown in FIG. 3. The control pedestal 84 consists of a U-shaped frame 86 as best shown in FIG. 4. The frame 86 is provided with two vertical arms 88 and 90 which embrace a siamese differential system 92 on a shaft 94.

A double-faced bevel gear 96 is splined to shaft 94 intermediate the ends thereof. A pair of control sticks 98 extending down between the knees of the pilot and are attached to stub shafts 100 by bolts 102. The stub shafts 100 are apertured to receive bushings 104 and thereby mounted for oscillation about shaft 94.

Upper bevel gears 106 are mounted for rotation on each stub shaft 100 by means of snap rings 108. Lower bevel gears 110 are similarly mounted on stub shafts 100 by snap rings 112. All four bevel gears 106 and 110 mesh with the double-faced bevel gear 96 and each pair 106, 110 further mesh with a side gear 114 of bevel type.

Sprockets 116 are formed integrally on both of the side gears 114 and each sprocket is provided with a block chain 118 extending sidewardly through slots (not shown) in a cover 120. Similar slots 122 allow the control sticks 88 to pass through the cover 120 with $\pm 45^\circ$ of freedom of movement.

As shown in FIGS. 4 and 5, on the outside of cover 120 there is mounted a selector lever 124 in an aperture 126 of shaft 94. This selector lever 124 is normally urged downwardly with its flange 128 against shaft 94 by means of a spring 130, and a retaining nut and washer 132. This causes a tongue 134, integral with the selector lever 124, to bear against a selector quadrant 136, which is part of arm 90. A quadrant 136 is provided which has three detent notches separated by 90° ; a forward (FWD.) detent notch 138, a turn detent notch 140 at the top, and a reverse (REV.) detent notch 142. The movement of selector lever 124 is thus seen to rotate shaft 94 to three preselected positions and likewise translating the double faced bevel gear 96.

With reference now to FIGS. 2 and 3, it will be noted the movement of chains 118 is transmitted as a push/pull action through the pressure bulkhead 14 by means of control link couplers 144. In area 18, these couplers 144 move chains 146 which pass around sprockets 148 having shafts 150.

Outermost sprockets 152 on the ends of shafts 150 carry this motion upwardly by means of endless block chains 154 to sprockets 156 on the inner ends of the control shafts 52 of the port and starboard cycloid propeller propulsion systems 34.

The control pedestal 84 is provided with a depending bracket 160 on which a pair of foot pedals 158 are hinged on a bolt 162 as best shown in FIG. 4. Cables 164 extend aft from these foot pedals 158 connecting through a pair of control link couplers 144 in the pressure bulkhead 14 to cables 166 therebeyond. Pulleys 168 reeve the

cables 166 around the sides of area 18 to a tiller crank 170 near the stern of the submerisble 10. A sprocket 172 on this tiller crank 170 carries an endless block chain 174 which passes around another sprocket 176 on a vertical shaft 178.

The shaft 178 is journaled top and bottom through the hull 12 and externally carries a rudder 180, a movable end of the tear drop body configuration.

Details of the control link couplers 144 are illustrated in FIG. 7. These couplers 144 must be capable of withstanding large pressure differentials and use is here made of a commercially available rolling diaphragm known as "Bellofram." The coupler 144 consists of a cuplike form and casing 182 having a flange 183 and a similar aft casing 184 having a flange 185.

The rolling diaphragm 186 is clamped at its edges between the flanges 183 and 185 by through-bolts 190 which also mount the assembly to the bulkhead 14 on a watertight gasket 188. A coupler rod 192 slidable on bushings 194 extends through both casings 182 and 184, and diaphragm 186 and carries a piston 196 back and forth therein. A nut 204 and a flange 198 both on the coupler rod 192 clamp a gasket 200 against the piston 196, and diaphragm 186 between the piston 196 and a piston cap 202.

The piston 196 is deeply cup-shaped while the piston cap 202 is only slightly so. The diaphragm 186 is forced into a re-entrant shape thereby and is caused to "roll" with translation of the control rod 192 and it maintains a continuous seal.

The forward casing 182 is vented to the cockpit area 16 by means of apertures 208, the aft casing 184 to the floodable area 18 by apertures 210. The pressure differential is substantial and while it is partially absorbed by a spring 206, still the journals of shafts 150 must be fairly strong to take this tension on the chains 146, for example.

The operation of the control system will now be described in conjunction with FIGS. 3, 4, and the diagrams of FIG. 8.

The differential system 92 drives the sun or control gears 50 of the port and starboard cycloidal systems 36 by the port and starboard chain sprockets 116 in the same direction and through precisely the same angle in a ratio of one-to-one. With the selector lever 124 detented in any of the three positions (forward, reverse, or turn), motion of the control sticks 98 will drive their respective sprockets 116 in the same direction but through twice the angle because of the differential gears 106, 110. Therefore to rotate the sun or control gears 50 $\pm 90^\circ$, the control sticks 98 must be capable of being moved $\pm 45^\circ$. With the control sticks 98 held fixed by the left hand of the pilot, moving the selector lever 124 from "forward" position to "reverse" position will rotate the chain sprockets 116, 180° in the opposite direction, thus reversing the sun or control gears 50 at their respective cycloidal propulsion systems 36 and thus the thrust direction of propeller blades 80.

Normally turning of the submersible 10 is accomplished by operating the rudder 180 with the foot pedals 158 but at zero forward speed turns about a vertical axis can be accomplished by moving the selector lever 124 to the "turn" position and deflecting the control sticks 98 in opposite directions.

Actually, the propeller blades 80 may be employed for turning at any speed. To turn to starboard, for example, the selector lever 124 would be positioned in turn detent notch 140, and the starboard control stick 98 would be advanced to its limit and the port control stick 98 pulled back to its limit. The thrust of the port propeller blades 80 would then be forward and the starboard ones backward.

Obviously many modifications and variations of the present invention are possible in light of the above teachings. It is therefore, to be understood that within the

scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A submersible vessel, comprising, hull structure defining an ellipsoidal shape having its major transverse axis arranged vertically, pressure bulkhead means dividing said hull structure into a cockpit area and a flooded area for power, air ballast and environmental systems, a mid-hull twin cycloidal propeller propulsion system mounted on the starboard and port sides of said vessel for propulsion thereof, and means for controlling the operation of said propulsion system so as to control the maneuvering characteristics of said submersible vessel.

2. A submersible vessel as recited in claim 1, wherein said hull structure is of the near oblate spheroid shape.

3. A submersible vessel as recited in claim 1, wherein said control means includes mechanism for changing the speed as well as the direction of movement of said submersible vessel.

4. A submersible vessel as recited in claim 1, wherein said pressure bulkhead is positioned at an angular attitude whereby improved stability and ballasting of said submersible vessel is obtained.

5. A submersible vessel as recited in claim 1, and additionally rudder mechanism for controlling the direction of movement of said submersible vessel.

6. A submersible vessel as recited in claim 1, wherein said pressure bulkhead is disposed at an angular attitude generally and conforms to a seat-shaped contour in side elevation starting at a point on the deck of said vessel near the bow thereof and terminating back of the centerline at the overhead of said vessel.

7. A submersible vessel as recited in claim 1, and additionally a canopy of transparent material forming a large portion of the forward portion of said hull structure.

8. A submersible vessel as recited in claim 7, wherein said transparent material consists of specially treated glass.

9. A submersible vessel as recited in claim 1, and addi-

tionally jettisonable ballast means completing the forward underneath contour of said vessel.

10. A submersible vessel as recited in claim 1, and additionally flooded power means positioned in said flooded area for furnishing power for said propulsion system.

11. A submersible vessel as recited in claim 10, and means for flooding the flooded area of said submersible vessel.

12. A submersible vessel as recited in claim 1, and hatch means to obtain access to said cockpit area.

13. A submersible vessel as recited in claim 1, wherein said control means includes a control pedestal positioned in said cockpit area, and mechanism for coupling said control pedestal to said mid-hull twin cycloidal propeller system.

14. A submersible vessel as recited in claim 13, and additionally means including an independent rudder system mechanically coupled to said control pedestal for independently controlling the direction of movement of said submersible vessel.

15. A submersible vessel as recited in claim 1, wherein a plurality of propeller blades are provided for said mid-hull twin cycloidal propeller propulsion systems.

16. A submersible vessel as recited in claim 13, wherein said control pedestal includes independent and movable control members for the port and starboard sides for controlling the direction of said vessel.

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