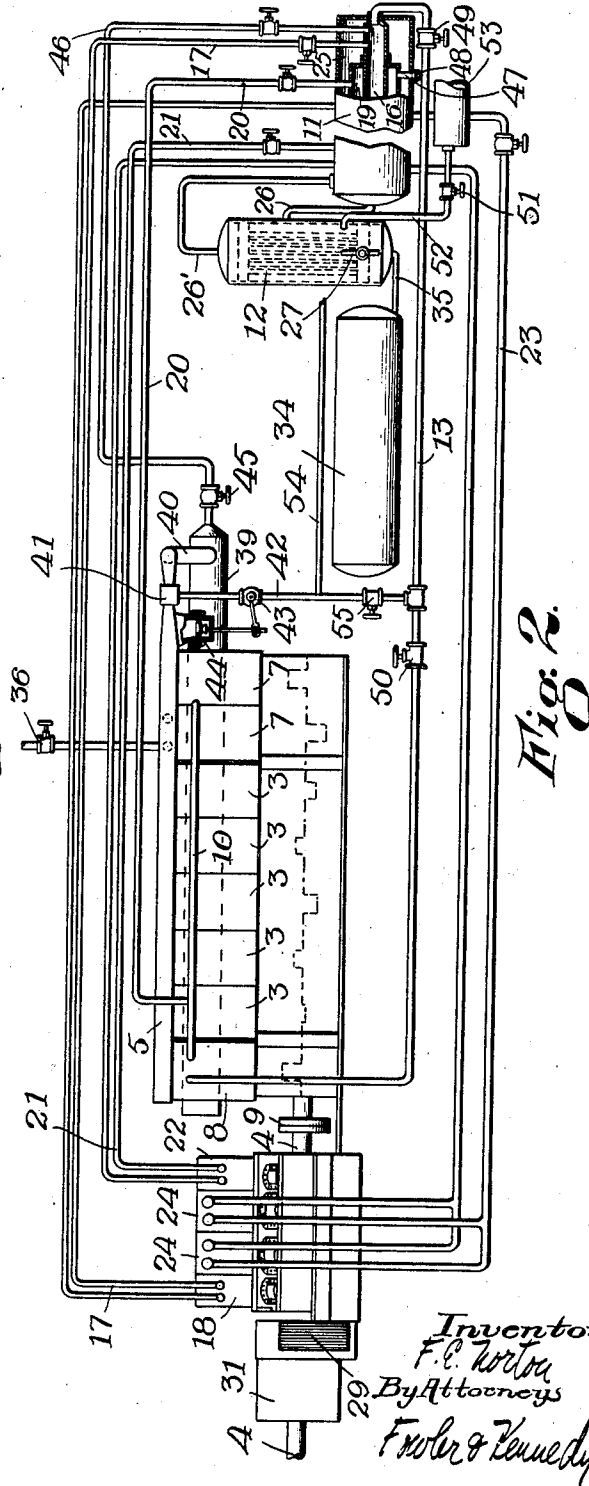
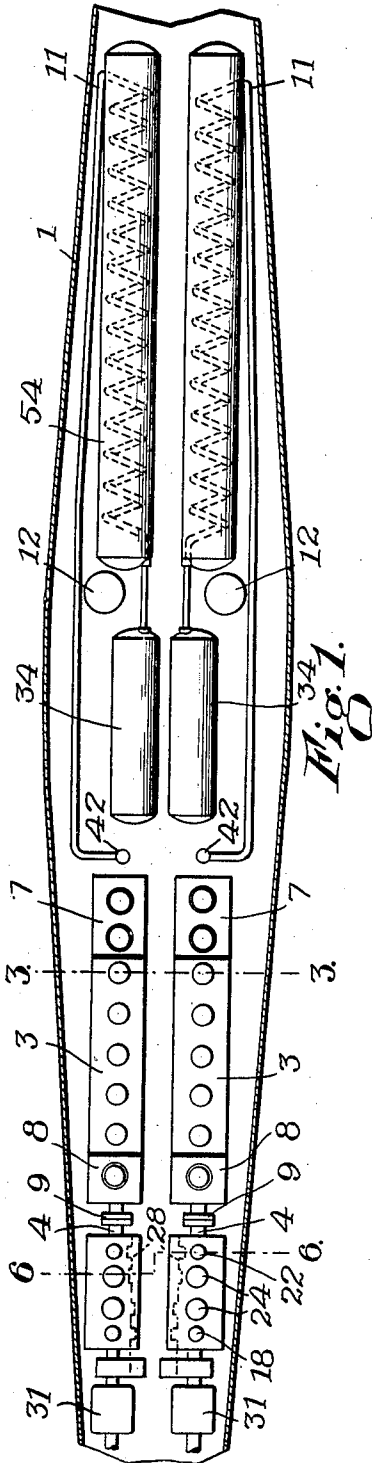


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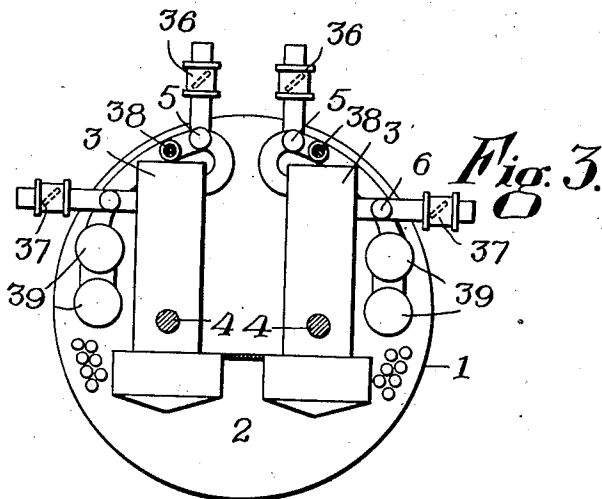
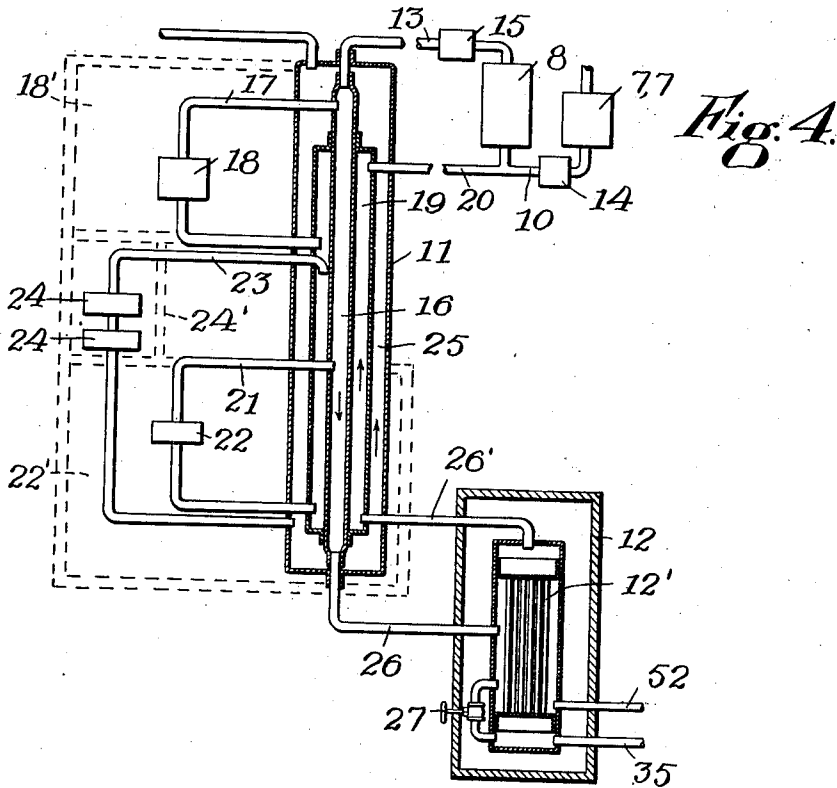
3 SHEETS—SHEET 1.



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 3 SHEETS—SHEET 2.



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 PROPULSION FOR SUBMARINE VESSELS.
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3 SHEETS—SHEET 3.

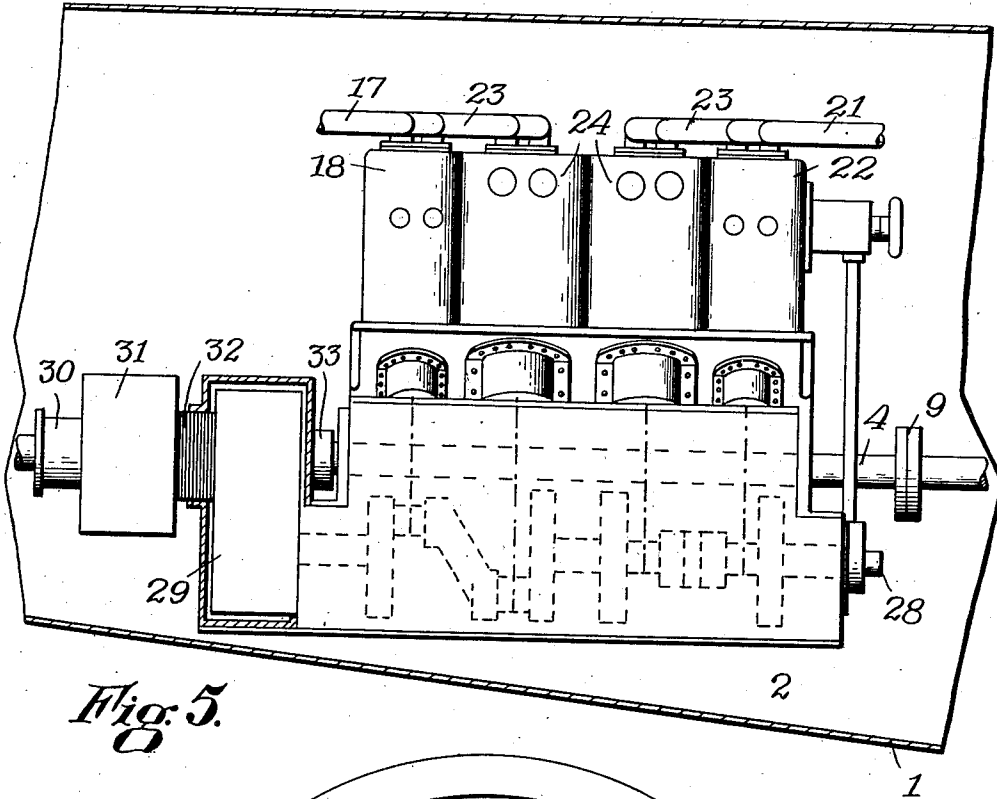


Fig. 5.

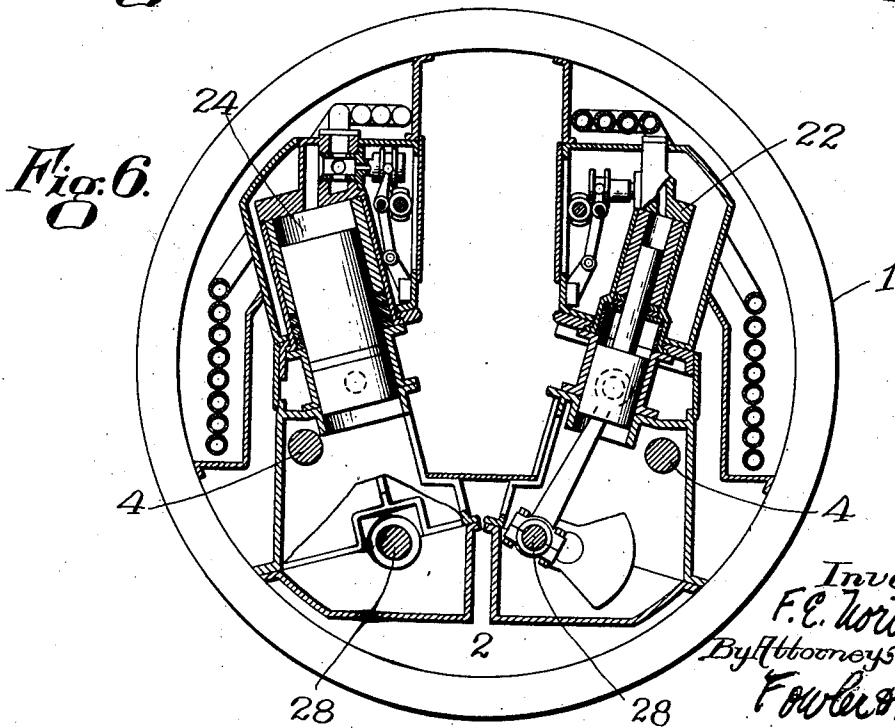


Fig. 6.

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UNITED STATES PATENT OFFICE.

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PROPULSION FOR SUBMARINE VESSELS.

1,380,304.

Specification of Letters Patent.

Patented May 31, 1921.

Application filed October 11, 1917. Serial No. 195,911.

To all whom it may concern:

Be it known that I, FRED E. NORTON, a citizen of the United States, residing at Worcester, in the county of Worcester and Commonwealth of Massachusetts, have invented new and useful Improvements in Propulsion for Submarine Vessels, of which the following, together with the accompanying drawings, is a specification.

10 The present invention relates to improvements in propulsion systems for so-called submarine vessels, adapted to furnish power for the driving of said vessels both above and beneath the surface of the water.

15 The invention resides in an embodiment of wholly new principles for the accomplishment of these ends, with especial regard to the elimination of dangerous and cumbersome electric storage batteries, which are at present almost universally employed for the propulsion of such vessels when submerged.

20 The invention contemplates the utilization of a portion of the power produced by the engines of the vessel, when running unsubmerged, for storing up a supply of liquid oxygen; when the vessel is submerged, this oxygen is vaporized and becomes an element in the motive fluid for the self-same engines, which are thus made available for the under

30 surface propulsion of the vessel. The above and numerous other objects hereinafter pointed out are capable of attainment in the propulsion system which constitutes my invention, together with the novel combination and arrangement of apparatus for carrying the aforesaid new principles into practice. One embodiment of such apparatus is illustrated diagrammatically in the accompanying drawings, where-

40 in—
Figure 1 is a diagrammatic plan view of the power plant of a submarine vessel, according to my invention.

Fig. 2 is a longitudinal elevational view, on an enlarged scale, of the power plant.

Fig. 3 is a transverse sectional view on the line 3—3 of Fig. 1.

Fig. 4 is a diagrammatic view for the purpose of illustrating the operation of the oxygen apparatus.

Fig. 5 is a view in elevation, on an enlarged scale, of the apparatus at the left hand end of Figs. 1 and 2.

Fig. 6 is a sectional view, on an enlarged

scale, taken approximately on the section 55 line 6—6, Fig. 1.

Like reference characters refer to like parts in the different figures.

The hull or shell of the submarine vessel, or that part thereof inclosing the power 60 plant, is indicated generally by the numeral 1, and it will be understood that such shell provides the usual facilities for the storage of oil or hydrocarbon in such suitable spaces thereof as are available beneath and on 65 either side of the power plant, as for instance as herein indicated by the numeral 2, Figs. 3, 5 and 6. For the normal propulsion of the vessel, when running unsubmerged, my invention contemplates twin sets of 70 multi-cylinder Diesel engines 3, 3 of ordinary construction, such as now used in vessels of this class, the same being employed to drive the two propeller shafts 4, 4 to which the twin screws, not shown, of the 75 vessel are attached. These Diesel engines 3, 3, here shown as each consisting of five cylinders, are operated in the usual manner when the vessel is unsubmerged, by the admixture of charges of oil with charges of 80 air compressed by their pistons, said air being taken from the atmosphere through inlet manifolds 5, 5. Since the operation of engines of this class is well known, it is unnecessary in the present instance to show 85 or describe the same in detail, it being clear that the contemplated normal surface propulsion of the vessel is precisely the same as the surface propulsion of any other submarine vessel. The exhaust gases from the 90 Diesel engines 3, 3, in the normal surface operation of the vessel, are discharged to the atmosphere from exhaust manifolds 6, 6, in the usual manner.

As previously pointed out, the vessel here- 95 in shown having twin screws, it will be clear that the power units for the propeller shafts 4, 4 are provided in duplicate, one on each side of the longitudinal center line of the vessel, and for convenience of description 100 hereinafter, only one set of units is enumerated in connection with a single propeller shaft, it being understood that the same are duplicated for the other propeller shaft. Each propeller shaft 4 in addition to its con- 105 nection with the Diesel engines 3 is also connected operatively and permanently to the pistons of a pair of cylinders 7 at the for-

ward end of the Diesel cylinders 3, and also to the piston of a single cylinder 8 at the rear end of the Diesel cylinders 3. The cylinders 7 and 8, when the system is charging, operate as primary and secondary air compressors, as hereinafter described; it will be understood, however, that these cylinders are readily convertible into power cylinders for operation on the Diesel cycle in unison with the cylinders 3, should it be desired at any time, when running on the surface, to increase the normal power and speed of the vessel, at the expense of discontinuing, for the time being, the charging operation. The cylinders 7 and 8 are in all respects the same in construction as the Diesel cylinders 3, being simple compressing cylinders, and therefore a detailed showing of their construction and operation is deemed unnecessary, since it is clear that their valve gear for their operation as compressor cylinders is readily reversible, in the well known manner, to convert them, when desired, into power cylinders.

The normal unsubmerged operation of the vessel, when charging, is as follows:—The Diesel cylinders 3 with oil and air as their motive fluid operate in the usual manner to drive the propeller shaft 4, which has the usual coupling or clutch 9 for operative connection with the engine shaft. The compressor cylinders 7 and 8 are operated from the same source, the former drawing in air from the atmosphere, imparting a primary compression thereto of, say ten atmospheres, and then discharging the same through pipe 10 to compressor 8, where an additional compression is imparted, say to forty atmospheres. The air thus compressed is utilized for the production of a supply of liquid oxygen, and to this end a liquefaction and separation system is incorporated in connection with each set of power producing devices, the same consisting, as herein shown, of a heat interchanger 11, to which the compressed air is led, and a still 12 adapted for the separation of the oxygen from the air which is partially liquefied in the interchanger. A diagrammatic representation of this apparatus, in conjunction with other liquefaction and separation devices, is shown in Fig. 4, wherein the highly compressed air from cylinder 8 is shown as conducted to the warm end of interchanger 11 by a pipe 13. This highly compressed air, subsequent to its several compressions by the cylinders 7 and 8, has undergone cooling to substantially atmospheric temperature, by any suitable means which are ordinarily employed for this purpose, as for instance water coolers, indicated diagrammatically in Fig. 4 at 14 and 15.

The compressed air from pipe 13 enters a suitable portion of the interchanger 11, for convenience here shown as a central

chamber 16. A portion of this air is taken at substantially atmospheric temperature through a pipe 17 and expanded in a cylinder 18, preferably to the degree of primary compression produced by cylinder 7, and here assumed as ten atmospheres. This partially expanded air is returned to another portion of the interchanger 11, for convenience here shown as an intermediate chamber 19, having a connection 20 which returns said air to the inlet of compressor 8, for recompression therein after its cooling effect, below atmospheric temperature, has been absorbed in the interchanger, in the manner common to devices of this class. Another portion of the highly compressed air in chamber 16 is taken therefrom at a lower temperature level in the interchanger through a pipe 21 and expanded in a cylinder 22, being returned to the intermediate chamber 19 at the same pressure as the air from expander 18, viz., the pressure on the inlet side of compressor 8. A portion of the partially compressed air returning through the intermediate chamber 19 is taken through a pipe 23 and expanded in cylinders 24, 24, and then returned at atmospheric pressure to a third part of the interchanger, for convenience here shown as an outer chamber 25. The cooling effect of the several expansions in cylinders 18, 22 and 24 is available by the return of the expanded air through chambers 19 and 25, in countercurrent to the remaining compressed portion in chamber 16, for producing an extremely low temperature at the cold end of the interchanger, sufficient to liquefy in whole or in part the relatively small proportion of the total amount of highly compressed air which reaches said end. A pipe 26 connects chamber 16 with the interior of still 12, where, by expansion through a suitable valve or nozzle 27, rectification takes place, substantially pure liquefied oxygen being collected in the bottom of the still, and the nitrogen of the air being removed through tubes 12' in the form of a gas, because of its more volatile character, and returned by pipe 26' to the intermediate chamber 19, thereby supplementing the cooling effect of the apparatus on the incoming gas in chamber 16.

It will be understood that suitable insulating means, as indicated at 18', 22' and 24', Fig. 4, are employed in connection with the apparatus associated with each of the several expansions above described, to promote the cooling effect in each of the zones of temperature in the interchanger 11. The process of liquefaction and separation, as above described, is a preferred embodiment of my invention; it will be clear, however, that any of the well known processes in this art may be used for the production of liquefied oxygen, in sufficient quantities for the purposes hereinafter set forth.

The high pressure expansion cylinders 18 and 22 of each power unit are preferably disposed at the rear of the Diesel engines, as are also the low pressure expansion cylinders 24, 24, as shown in Figs. 1 and 2. All of said cylinders may be of the usual construction in devices of this class and, preferably, the pistons thereof are connected to a common shaft 28, disposed inwardly of and below the corresponding propeller shaft 4 of the same set of power cylinders. Each shaft 28 carries at its rear end a sprocket wheel, and a sprocket chain 29, as shown in Fig. 5, connects the driving sprocket wheel on said shaft with a driven sprocket wheel which is loosely journaled on a sleeve 30, carried on the propeller shaft 4. The rotor member of a dynamo 31 is secured to the sleeve 30, and a plate or magnetic clutch 32 is adapted to be operated, when desired, to connect sleeve 30 and the loose sprocket wheel thereon, whereby said dynamo will be driven by the power of the expansion engines 18, 22 and 24, thus furnishing a supply of electricity for lighting the interior of the vessel. A jaw or other clutch 33 is provided for connecting the sleeve 30 to rotate in unison with the propeller shaft 4, whereby to operate the dynamo 31 when the vessel is running submerged, it being understood that the power of the expansion engines is applicable for this purpose only when the vessel is above surface, and the oxygen apparatus is charging.

The liquid oxygen formed as above described during a normal operation of the vessel above the surface, is stored in tanks 34, 34, being led thereto by pipes 35, 35 from each of the stills 12, 12. When the vessel is submerged, by any of the well known means provided for this purpose, and not herein shown and described, it is no longer possible to run the Diesel engines 3 in the usual manner, since the supply of air for admixture with the oil must be wholly cut off by closure of a valve 36 in the air intake of inlet manifold 5, or in any other suitable manner. According to the present invention, it is proposed to substitute the artificially produced oxygen in place of the oxygen of the air, for supporting combustion of oil in the Diesel engines when the vessel is running submerged, this oxygen being drawn as a gas or vapor from the supply of liquid oxygen stored in tanks 34. Oxygen, however, if used undiluted with the oil for this purpose, would quickly burn out these engines, and therefore it is proposed to dilute the oxygen with the products of combustion or exhaust gases from said engines, which consist in the main of carbon-dioxid (CO_2). In other words, it is proposed to provide an explosive charge by using the oil in combination with an inert gas (CO_2) enriched with a

suitable quantity of oxygen, the inert gas performing the same function in this connection as the nitrogen of the air, viz., to afford a sufficient volume of gas for absorbing the heat of combustion.

To this end, as the vessel is being submerged, the exhaust manifold 6, which ordinarily discharges to the atmosphere is closed by a valve 37, or by any other well known means, and a normally closed valve 38 is opened, whereupon the exhaust gases from the cylinders 3 are led in any suitable manner through cooling devices 39, 39, of suitable construction, whereby to reduce the temperature of the exhaust to a point where it can be safely enriched with oxygen. From the coolers 39, 39 the exhaust is led by pipes 40, containing the normally closed valves 38, to the inlet manifolds 5, 5, and preferably in the course of its passage thereto is enriched with gaseous oxygen entering a mixing device 41 at the entrance of each inlet manifold. As herein shown, the entrance of gaseous oxygen, under pressure, to said mixing device, takes place through a pipe 42 having therein an automatic valve 43, the operation of which to control the amount of oxygen admitted is made responsive to the pressure in the inlet manifold 5, by a pressure operated diaphragm, or the like, 44 of ordinary construction. The carbon-dioxid thus enriched with oxygen is used in the Diesel engines with substantially the same supply of oil, precisely in the same manner as atmospheric air is used with said oil, for furnishing an explosive charge, thereby making said engines the propelling means for the vessel when submerged, as well as when on the surface. Furthermore, when thus running submerged, the compressor cylinders 7 and 8 which are convertible, as heretofore stated, into power cylinders can, if desired, be operated on charges of carbon-dioxid, oxygen and oil, the same as the regular Diesel engines 3, thereby increasing the power and speed of the vessel when submerged. At this time the expansion engines 18, 22 and 24 are idle, being entirely independent of the propeller shafts 4, 4; the latter, therefore, are operatively connected to the dynamos 31, 31 by the clutches 33, 33 in order to furnish lighting for the vessel.

The gaseous oxygen which is supplied by the pipe 42 is obtained from the liquid oxygen supply in tanks 34, by the closure of valve 27, the oxygen returning through the tubes 12' of the still, and through the pipe 26' to the chamber 19 of the interchanger. The oxygen is reëvaporated in the still 12 and warmed up in the interchanger by passage in countercurrent to the excess gaseous carbon-dioxid which results from the exhaust of the engines. In this connection it will be clearly understood that said

engines, when running with a closed exhaust, are constantly producing a certain quantity of carbon-dioxid over and above that which is returned, as above described, to the inlet manifold, where it is enriched with oxygen and again used in the engines. By the provision of a suitable pressure regulating valve 45 in the exhaust cooler 39, or in any other well known manner, this excess of carbon-dioxid can be directed into a pipe 46, by which it is conducted to the passage 16 of interchanger 11, and thence by pipe 26 to still 12. The normal charging operation of the interchanger and still for the production of liquid oxygen having been discontinued, they are available for securing a progressive interchange of heat between the cold liquid oxygen entering the still and the warm carbon-dioxid entering the warm end of the interchanger.

This interchange of heat is availed of to vaporize and warm up the oxygen, which leaves the warm end of the interchanger by a pipe 47 when a valve 48 therein is opened. The pipe 47 connects with pipe 13, which is closed for this purpose by valves 49 and 50, so that the oxygen is delivered to pipe 42. This interchange of heat liquefies the carbon-dioxid in the still 12, and said liquid passes thence, by the opening of a valve 51 in pipe 52, to a storage tank 53. Or, if desired, the liquid carbon-dioxid can be discharged directly as liquid into the water in which the vessel is submerged, and being in the liquid state, said discharge will not afford a means of detection from the surface of the water. When stored as above described in tanks 53, the liquid carbon-dioxid is available, when the vessel rises to the surface and resumes the charging of liquid oxygen, for furnishing a considerable cooling effect, to assist in the liquefaction of the oxygen, by passing said carbon-dioxid through either or both of the chambers 19 and 25 of the interchanger by any suitable piping, not shown. It will be understood that during the running of the vessel on the closed exhaust, either submerged or on the surface, the various connections from the interchanger which are used in production and storage of liquid oxygen are cut off and rendered inoperative, by suitable valves which need not be specifically referred to; this leaves the interchanger and still available for the vaporization of the stored liquid oxygen and the liquefaction of the carbon-dioxid, as above described.

The operation of the power plant on the closed exhaust circuit as above described enables the engines to produce a greater amount of power, and thus to give the vessel increased speed, when running either submerged or on the surface. This will be clear for the reason that the inlet pressure is greater at all times than atmospheric pres-

sure, the valve 45 being regulable, either by hand or automatically, to maintain any desired pressure, within suitable limits, upon the carbon-dioxid which enters the inlet manifolds 5. In this way the density of the gaseous mixture entering the cylinders is always greater than the density of the air entering the cylinders, when operating on the usual Diesel cycle, and because of this greater density, a greater quantity of oil can be burned in the engines than is possible when atmospheric air is used.

It will also be seen that the present system offers a distinct advantage in that the supply of liquid oxygen is available for running the vessel on the surface, at a higher speed than the usual operation of the Diesel engines could produce, and further, without creating any trace of smoke, so that the vessel is not possible of detection from any distance. Such operation can be carried out by using all of the cylinders 3, 7 and 8, as above described, for producing the highest speed, and under these circumstances the excess carbon-dioxid is liquefied and stored in the manner above described. Or, if desired, such operation can be carried out simultaneously with the charging operation, using the cylinders 7 and 8 as compressors. In this case the excess carbon-dioxid over and above that which is returned to the intakes of cylinders 3, is discharged to the atmosphere as a colorless gas. The charging of liquid oxygen takes place in the usual manner by the liquefaction of the air which is compressed in the cylinders 7 and 8, and the oxygen for enriching the inlet mixture is taken as liquid from the tank 34 and vaporized in a suitable coil 54 of the interchanger, Fig. 1, before being led to the oxygen supply pipe 42, above the valve 55, which is closed for this purpose. The oxygen passing through coil 54 is vaporized by the heat extracted from the incoming compressed air in the interchanger, this action assisting in the cooling of said air, as will be well understood.

With the system of propulsion herein described, the provision of a pure supply of air within the vessel, when submerged, is always insured, and there is no danger of any deficiency in this respect. The air supply for breathing may be readily obtained by vaporizing a small portion of the air which is liquefied in the interchanger 11, and the same may be enriched, if desired, by oxygen, released in suitable quantities from the tanks 34.

The present system, wherein the engines 3 and compressors 7 and 8 are entirely separate and independent from the expansion devices 18, 22 and 24, enables the dynamos 31 to be run by either set of devices as desired, in the manner heretofore described. Said dynamos are preferably provided in

the form of motor-generators, which are operable to create a supply of electricity in storage batteries, not shown. It will thus be seen that the propulsion of the vessel may be effected by the use of engines alone, running either on an open or a closed exhaust, with the propeller shafts 4 entirely free and disconnected from the sleeves 30. Or, if desired, the engines may be used solely for charging liquid oxygen, and the propeller shafts 4 may be run on the power produced by the expansion devices 18, 22 and 24; such operation entails the disconnection of coupling 9 and the connection of the propeller shafts to the shafts 28, by clutches 33. If desired, also, the power of the expansion devices may be added to the power of the engines for driving the propellers. Furthermore, the energy of the storage batteries may also be used for this purpose, either with or without the other power units, as desired.

I claim,

1. The herein described method for the propulsion of a submarine vessel, which consists in making and storing liquid oxygen during the unsubmerged running of the vessel, circulating said oxygen, when the vessel is running submerged, in heat exchanging relation to the exhaust gases from the engines of the vessel, whereby to liquefy said exhaust gases, and employing said liquefied exhaust gases, when the vessel is unsubmerged, to assist in the liquefaction of the oxygen.

2. The herein described method for the propulsion of a submarine vessel, which consists in liquefying oxygen from the air when the vessel is unsubmerged, utilizing said oxygen for liquefying exhaust gases from the engines of the vessel, whereby the

oxygen itself is evaporated, utilizing said evaporated oxygen in conjunction with another portion of said exhaust gases for supporting combustion of hydrocarbon fuel in the engines of the vessel, and utilizing said liquefied exhaust gases for promoting the liquefaction of the oxygen.

3. In a propulsion system for submarine vessels, means operable by the engines of the vessel for compressing atmospheric air and liquefying the oxygen therein, when the vessel is unsubmerged, and means for driving the vessel by the operation of said compressing and liquefying means.

4. In a propulsion system for submarine vessels, means operable by the engines of the vessel for compressing atmospheric air and liquefying the oxygen therein, when the vessel is unsubmerged, and means for driving the vessel by the operation of said compressing and liquefying means or by the operation of said engines.

5. In a propulsion system for submarine vessels, means operable by the engines of the vessel for compressing atmospheric air and liquefying the oxygen therein, when the vessel is unsubmerged, and means for supplying electrical energy by the operation of said compressing and liquefying means.

6. In a propulsion system for submarine vessels, means operable by the engines of the vessel for compressing atmospheric air and liquefying the oxygen therein, when the vessel is unsubmerged, and means for supplying electrical energy by the operation of said compressing and liquefying means or by the operation of said engines.

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