C. DEL PROPOSTO.

PROPULSION OF SUBMARINE BOATS.

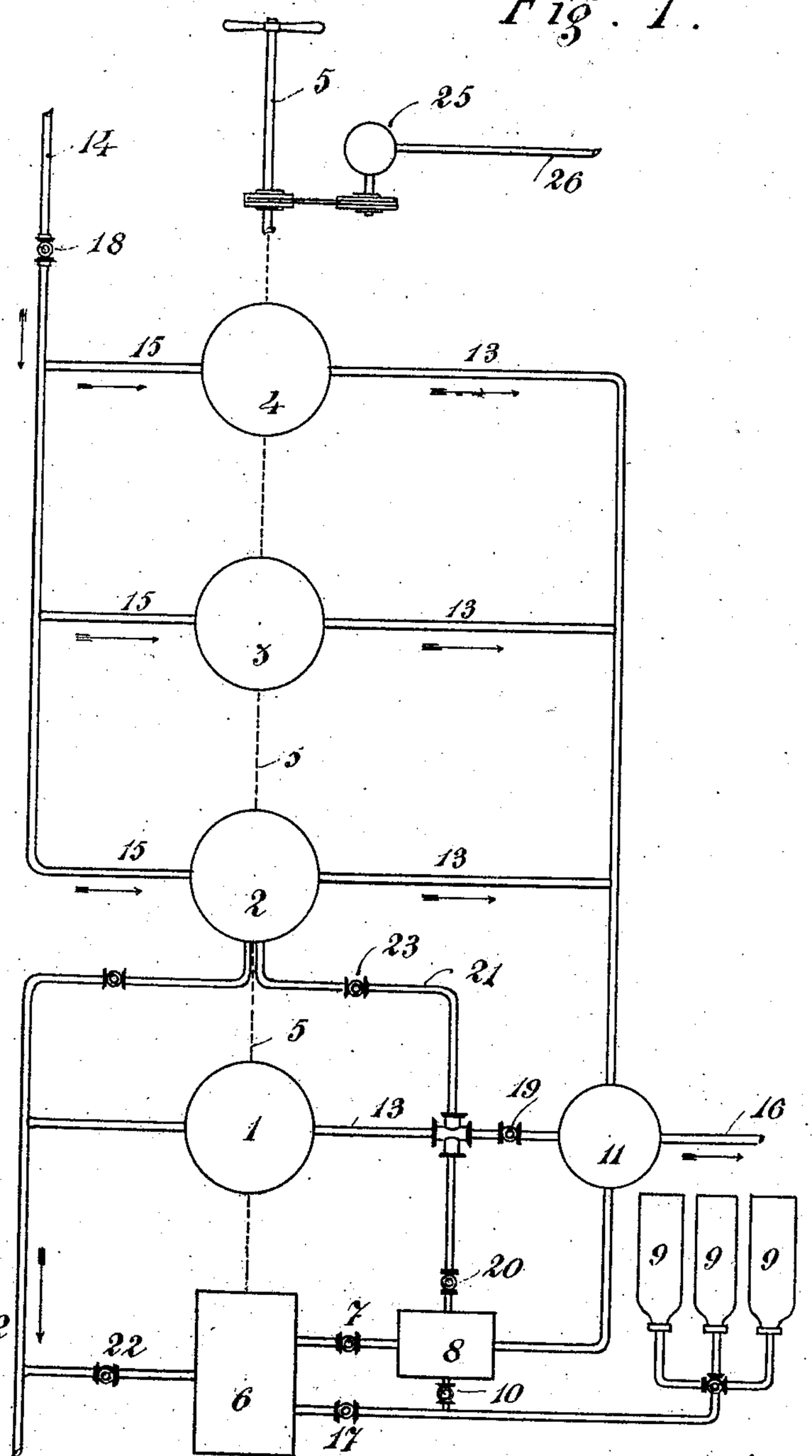
APPLICATION FILED OCT. 5, 1907.

944,776.

Patented Dec. 28, 1909.

2 SHEETS—SHEET 1.

Fig. 1.



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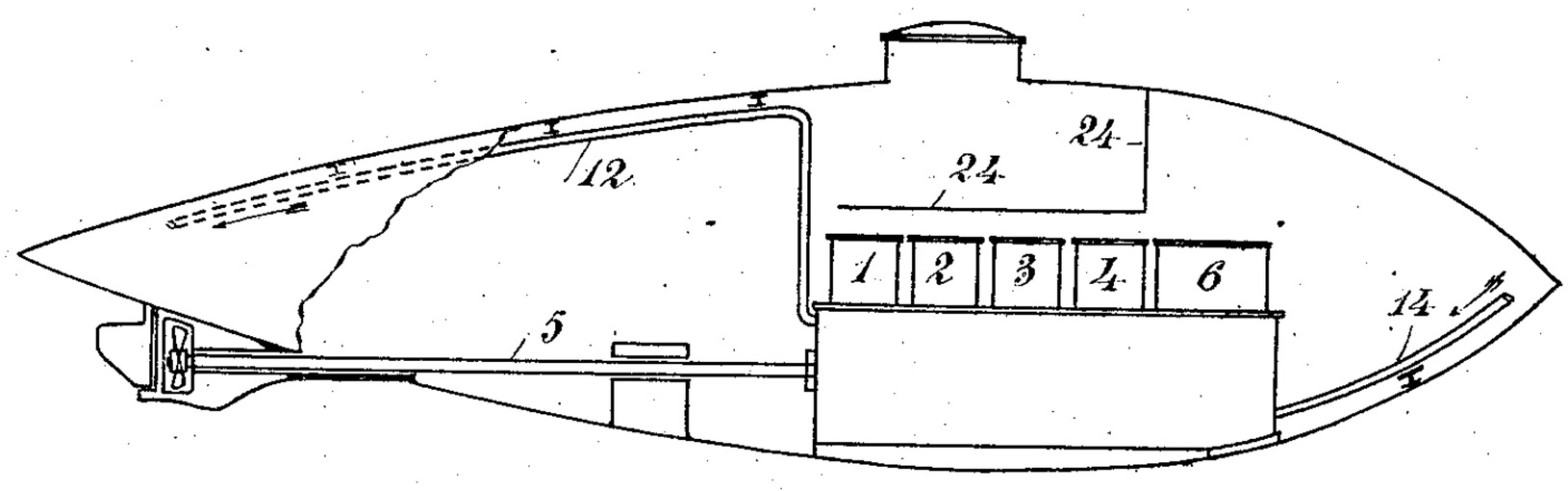
2 SHEETS—SHEET 2.

Fig. 2



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UNITED STATES PATENT OFFICE.

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PROPULSION OF SUBMARINE BOATS.

944,776. Specification of Letters Patent. Patented Dec. 28, 1909.

Application filed October 5, 1907. Serial No. 396,358.

To all whom it may concern:

Be it known that I, CESIDIO DEL PROPOSTO, a subject of the King of Italy, residing at Rome, Italy, have invented certain new and useful Improvements in Propulsion of Submarine Boats; and I do hereby declare the following to be a full, clear, and exact description of the same.

This invention has for its object to improve the means of production of energy for the propulsion of submergible or submarine boats of every kind, propelled under water by compressed air (without batteries of electric accumulators) and to increase their radius of action under water while maintaining on board an energetic ventilation and a comfortable temperature. For the propulsion of submarine boats of this type while under water, the compressed air, has been until today utilized in one of the two following manners: (1) The compressed air stored up in suitable reservoirs, is used to feed a compressed air-motor which drives the propeller shafts and then discharges outside the boat. (2) The compressed air is utilized merely to support the combustion in the cylinders of an internal combustion engine. In the former case is utilized the mechanical energy stored up in the compressed air, in the latter case energy is produced by burning in the cylinders of the motor the oxygen contained in the compressed air.

By adopting the system hereinafter set out the same compressed air can be utilized successively in the two ways mentioned above, and consequently, increases considerably the total work which can be produced by means of a given quantity of air at a certain pressure and, therefore, all other conditions being equal, it increases in the same rate the radius of action of the boat under water.

On the annexed drawing, Figure 1 shows schematically by way of example the arrangement of the different parts of the motive apparatus, and Fig. 2 a longitudinal section of a submarine boat according to the present invention.

In said drawing, —1—2—3—4— represent the four cylinders of an explosion engine by means of which the boat while navigating at the surface is propelled and air is stored up through a compressor —6— driven by the propeller shaft —5— into suitable reservoirs —9—.

Each cylinder of an explosion engine of a convenient type (Diesel for instance) can be made to act as a compressor of air at a certain pressure depending on the construction of the motor. Then the compression of the air in the reservoirs can be performed (when the boat is navigating at the surface) by arranging one or more cylinders of the polycylindrical motor, either the cylinder —1— or —1— and —2— for instance each as an air compressor, while the other cylinders —3— and —4— continue to work as usual, and further to drive a subsidiary compressor —6— which brings the compressed air coming out from the cylinder —1— and —2—, of the motor to the normal pressure of the reservoirs; thus the compression will be made in two successive steps and in two distinct engines. The air compressed in the cylinders —1—, —2— reaches the compressor —6— through the pipes —13— and —21— respectively. By such arrangement the power and also the weight and encumbrance of the independent compressor can be reduced considerably.

During the navigation under water the energy for the propulsion of the boat will be supplied both by a compressed air motor and by the internal combustion motor, which, under water is kept running just as in the open air. The air escaping from the compressed air motor, is discharged into the inside of the boat, circulates through same and ventilates it and then is aspired by the internal combustion motor, and discharged, as combustion gases outside the boat. A separate engine may be employed as a compressed air motor; but in order to diminish the weight and encumbrance of the machinery on board, it is better to use, for this purpose, either the same compressor —6— used for storing the compressed air during the surface navigation (provided that its construction allows it to be reversed) or one or more cylinders for instance the cylinder —1— or —1— and —2— of the internal combustion motor, (which in this case, should be polycylindrical) and this can always be done in such motors which are started normally by means of compressed air. In the first case the compressed air coming from the reservoirs —9— is directly immited in the cylinders of the compressor —6—. The exhaust valve —22— allows the air escaping from the compressor to discharge in the pipe —12—. In the latter

case, therefore, during the navigation under water, the cylinders of the internal combustion motor work partly in the usual way, and partly as compressed air motors, so that the compressed air which is brought to a suitable pressure by means of a reducing valve —10—, passing through the subsidiary reservoir —8—, reaches first the cylinder —1— which acts as a compressed air motor or the cylinders —1— and —2— when the valve —23— is open, is then discharged through the tube —12— in the inside of the boat and is aspired by the other cylinders of the internal combustion motor through the tube —14— by means of the pipes —15—, and discharged outside the boat at —16— through the pipes —13—and the exhaust box —11—.

From the foregoing it appears clearly that in the aforesaid system the same air is utilized firstly to produce energy in the compressed air motor, by its expansive force, and then, after having ventilated the boat, it is utilized in combination with an appropriate fuel to feed an internal combustion engine and thus is enabled to develop a second time thermal energy for the propulsion. This system therefore reduces considerably the total consumption of air per H. P. transmitted to the propeller shafts. With the same object in view, viz. to reduce the consumption of air for each H. P. developed it is advisable to use on board a compressed air motor which may be fed at the highest possible initial pressure, because, as is well known, the consumption of air per effective H. P. in compressed air motors diminishes when the admission pressure increases. It is also advisable to select for this purpose an internal combustion engine in which the consumption of air per effective H. P. be the smallest possible; therefore it is also to be preferred a motor with a high final pressure (Diesel type for instance) and the average pressure of which (average given by the diagram of the indicator) be the highest possible. Such a motor possesses the advantage not only of consuming the smallest possible quantity of air, but also of being less influenced by the counter pressure in the discharge phase, which counter pressure, in a submerged boat, depends upon the depth of the immersion and tends to diminish the power which the motor can develop. It is also known that the air consumption of a compressed air motor can be reduced by heating previously the compressed air to a convenient temperature; it is known as well that said consumption can be still reduced considerably if the compressed air is previously saturated with steam at the temperature of admission. Moreover the result of these two operations is to increase the temperature of the air at the escape and thus to prevent the formation of ice in the cylinders of the compressed air motor; therefore it is convenient to adopt both in the submarine boats of the aforesaid system.

In the compressed air engines working in the open air, the heat necessary for the preliminary heating and for the saturation of the compressed air is obtained by the combustion of an appropriate fuel but this must be avoided as much as possible on board of submarine boats because the combustion of the fuel results finally in an additional consumption of air. It is possible to reduce or even to avoid completely any air consumption for this purpose: (1) by utilizing as much as possible in performing said operations the heat still contained in the escape gas of the internal combustion motor; (2) by increasing if necessary, the heat contained in said gases, by burning in their midst a convenient fuel; and this is always possible because the gases escaping from the internal combustion engine contain unavoidably a considerable percentage of unburned free oxygen, which, under suitable conditions can support the combustion of a certain quantity of fuel. Practically the heating and the saturation of the compressed air will be performed by circulating the compressed air within a closed vessel —11— in the ordinary apparatus provided therefor, with the exception however that said apparatus have to be heated in the manner mentioned above, that is in the exhaust box by means of the exhaust gases escaping through the pipes —13— from the cylinders —2—3—4—.

By employing the above mentioned process for the utilization of the compressed air, coming out from the reservoir —9— and reaching the cylinders —1— and —2— through —10—8—11—15—13—21— together with the heating and saturation by heat of the exhaust gases, in the exhaust box —11—, it is possible to reduce the consumption of air per effective H. P. developed on the propeller shaft down to limits heretofore unknown. And in fact, all other conditions being equal, the weight of the machinery on board becomes much less than the weight of the machinery for submarine boats propelled under water by a battery of electrical accumulators, or even by compressed air utilized in the manner now generally in use.

The total efficiency of the compressed air utilized as a motive power is reduced: (1) by the losses of energy in the compressor, (2) by the losses of energy in the compressed air motor, and also by the fact that the pressure in the reservoirs is generally higher than the allowable initial pressure in the compressed air motor, so that the use of a reducing valve —10— is necessary, while the preliminary heating and saturation of the compressed air by means of the exhaust gases of the explosion engine is an excellent method of utilization of the heat stored

in said gases and tends to enhance the total efficiency mentioned above. By conveniently regulating the work of the various parts of the whole plant it is possible to increase the total efficiency of the compressed air used in this way almost up to unity.

In the foregoing the fuel consumption has never been considered, because, during the navigation under water it is very small in comparison with the consumption of air and because the difficulty of storing the necessary fuel is beyond comparison less than that of storing the compressed air.

The barometrical pressure in a submarine boat of the type considered must remain almost constant, during the navigation under water and not much different from the ordinary atmospheric pressure and independent from the depth of immersion of the boat. This condition is evidently required by the welfare of the crew and also for the satisfactory working of the explosion engine, because the air pressure in the machinery room is an important factor in the working of the engines and it contributes in determining the pressure developed in the cylinders, and influences the combustion as well as the extreme temperatures of the cycle; therefore considerable variations of pressure in the interior of the boat are not admissible. The barometric pressure inside the boat under water will remain stationary provided that the quantity of exhaust air escaping from all the compressed air engines (on board, besides the compressed air motor which produces the energy for the propulsion, there may be other compressed air engines for various services, the exhaust of which is discharged also inside the boats) be equal to the quantity of air aspirated by the explosion engine, and expelled, together with the combustion gases, outside the boat. The indications of a barometer permit therefore to ascertain whether the aforesaid correspondence is maintained and show how to eventually regulate the pressure.

Should the pressure begin to differ from the normal one, as the quantity of air absorbed by the internal combustion motor cannot be easily modified, then, in order to reëstablish the balance and to maintain the pressure stationary, the best way is to modify, automatically or by hand, following the indications of the barometer, the quantity of air admitted into the compressed air motor —1— which supplies partly the energy for the propulsion.

The temperature in a submarine boat of the type described during the navigation under water tends to increase because of the heat radiating from the internal combustion motor and at the same time it tends to diminish because the exhaust air of the compressed air engines although having been previously heated is cold; there is therefore a certain compensation. Within certain limits and by the application of the means generally known it is possible to diminish the radiating heat of the motor and also the temperature of the exhaust air of the compressed air engines; but the best protection against the elevation of the temperature is afforded by the ventilation, which is very energetic in the boats of the type described because the whole air, which is directly or indirectly used as motive power is utilized in it.

A serious inconvenience in the submarine boats driven under water by an internal combustion motor is the bad smell produced by the emanations of the fuel (mineral oil, benzin etc.) reaching in the interior of the boat through insufficiently tight joints of the pipes or due to leakages in various parts of the engine; to prevent the spreading of said emanations into the part of the boat occupied by the crew the following arrangement is adopted. The exhaust air of all the compressed air engines —1— is discharged inside the boat at the end —12— thereof usually occupied by the crew, while the aspiration of the internal combustion motor —1—2—3— takes place at the opposite end —14— of the boat, so that the whole inside of the boat is constantly swept by a draft of air. In any point whatever of the boat the speed of said air current is in inverse ratio of the free cross section afforded to its passage; therefore by means of suitable partitions —24— it will be possible to increase considerably the speed of the air current where it will be necessary and arrange said partitions for instance in such manner, that in proximity of the engines the current be strong enough to carry off to the other end of the boat any emanation where the foul air is absorbed by the aspiration of the internal combustion motor.

To keep the boat at a constant depth during the navigation under water, the weight of the boat must remain unaltered; therefore in the boat the weight of the exhaust gases of the internal combustion motor discharged outside must be substituted by an equivalent weight of water; and as the weight of the exhaust gases (at least for certain types of internal combustion motors) is almost in proportion of the number of turns of the motor, because the quantity of air absorbed at each piston's stroke is almost unvaried; and the weight of the fuel burned can be neglected in comparison with the weight of air necessary for the combustion, so the loss of weight, suffered by the boat in consequence of the expulsion of the exhaust gases, can be compensated by providing a water pump 25 of convenient capacity and actuated by the motor for instance conveniently connecting same

with the propeller shaft, which pump introduces water from the exterior through the pipe 26 when the motor is running. The weight of the exhaust gases at each turn of the shaft being a known quantity by a given motor, it follows that it will be an easy task to determine the size and the speed of the water pump which will keep the load of the boat unvaried.

In submarine boats for military services, it is desirable that the discharge of the exhaust gases of the internal combustion motor be suppressed when the boat gets very near the enemy because the bubbling caused at the surface of the water by the said exhaust gases may help in detecting the presence of the boat. To avoid such inconvenience, the propulsion in said case is made as follows: When the boat is very near the enemy, her engines are run exclusively as compressed air motors, the exhaust air of which is discharged, as before, into the inside of the boat. Under these conditions the barometrical pressure in the boat will increase slowly up until the maximum which the men of the crew and the resistance of the hull are able to support. It is easy to figure out, that before such limit is reached, a sufficient length of time will elapse to allow the boat to get away to a distance, where the bubbling can be no more noticed. Then the engine is again run, exclusively as an internal combustion motor in the same manner as when the boat is at the surface of the water until the barometrical pressure in the inside of the boat lowers anew to the normal atmospheric pressure; at this point the normal propulsion by the compressed air motor and the explosion engine will be resumed. It should be remarked however that, as the internal combustion motor could not work, properly where the external air pressure is sensibly superior to the atmospheric pressure, on the air inlet pipe must be provided an automatic reducing valve, —18— which brings the air pressure down to the value convenient for the normal working of the motor. In passing it should be remarked that by such a process the air is utilized twice as in the former case, but the two steps of the cycle are successive instead of being simultaneous. Therefore by adopting the system above described, the discharge of the exhaust gases outside of the boat can be suppressed during a limited time, and of this possibility the boat will take advantage whenever the bubbling of the water at the surface becomes dangerous.

In submarine boats for military service, the reduction to a minimum of the time required by the boat to pass from surface navigation to the submerged position is a very important feature. The immersion is obtained by filling with water ballast tanks, it is important therefore, to perform this operation as quickly as possible and this can be done by producing a vacuum in the ballast tanks, for this purpose an air pump may be used, but the best means is to so arrange some of the cylinders of the internal combustion motor as to enable them to act as air pumps, for instance the same cylinder —1— which according to the various circumstances acts as an internal combustion motor, as a compressor, as a compressed air motor, and as an air pump.

Claims:

1. In a submarine boat, an engine having a plurality of cylinders, an air compressor driven by said engine and a storage reservoir wherein the compressed air is stored: one of the cylinders of the engine adapted to act as an air compressor, to effect a first step in the compression of the air while the boat navigates at the surface, air connections from said compressor cylinder to the first-mentioned compressor to complete the air compression, connections from said reservoir to said compressor, said air compressor operated by the remaining cylinders of the engine working in the usual way.

2. In a submarine boat, the combination of a polycylindric explosion motor for propelling the boat, an air compressor for serving at will as an air motor to assist in propelling, a reservoir for compressed air, connections between said compressor and reservoir, and connections between the latter and a plurality of cylinders of the motor, whereby the latter is adapted at will to operate as an air motor to assist in the propulsion.

3. In a submarine boat, the combination of a polycylindric explosion motor for propelling the boat, an air compressor driven by said motor, a compressed air reservoir connected with said compressor, means whereby several cylinders of the explosion motor are enabled to act as a compressed air motor at will to assist in the propulsion, and a reducing valve inserted between the aforesaid air reservoir and cylinders.

4. In a submarine boat, an engine for propelling the boat, an air compressor which, at will, acts also as a compressed air reservoir, means for admitting compressed air from the reservoir into the air compressor while acting as a compressed air motor, exhaust connections from said compressed air motor to the interior of the boat, and feed connections from the interior of the boat to the engine, to supply air to the latter.

5. In a submarine boat, the combination of a polycylindric motor for propelling the boat, an air compressor driven thereby, a compressed air reservoir connected therewith, means whereby the air compressor and a plurality of cylinders of the explosive motor are enabled to act, at will, as a com-

pressed air motor to assist in the propulsion of the boat, connections for allowing the compressed air of the reservoirs to reach directly into the cylinders of the air compressor when acting as a compressed air motor, connections from said cylinders of the engine with the air compressor for allowing the exhaust air of same, when acting as a compressed air motor, to pass into the cylinders of the engine acting also as compressed air motors, means for discharging the exhaust air of the latter in the interior of the boat, and means feeding into the remaining cylinders of the explosion motor, air taken from the interior of the boat.

6. In a submarine boat, the combination of a combustion engine for propelling the same, a compressed air motor to assist in propelling the boat and having an exhaust valve, a compressed air reservoir and connections for feeding compressed air to cylinders of said motor, a closed vessel for receiving and circulating compressed air coming from the reservoir before reaching the cylinders aforesaid of the compressed air motor, and connections between the exhaust valve of the engine and said closed vessel for allowing the exhaust gases of the engine to heat the air which is circulated in the closed vessel.

7. In a submarine boat, the combination of a polycylindric engine for propelling the boat, an air compressor, driven by said engine, a compressed air reservoir connected therewith and wherein the compressed air is stored, a plurality of the cylinders of the thermic engine adapted to act, at will, as air compressors to effect a first step in the compression of the air, connection from the air reservoir to the air compressor whereby the latter is enabled to act, at will, as compressed air motor to assist in propulsion of the boat, suitable connections between those cylinders of the engine where the first step of the compression of the air is effected and the air compressor where the compression of air is completed, and a closed vessel for receiving the exhaust gases of the engine in order to heat the compressed air coming from the reservoir before reaching the air compressor when acting as a compressed air motor.

8. In a submarine boat, the combination of a polycylindric engine for propelling the boat, an air compressor driven thereby, a storage reservoir for compressed air, a number of cylinders of the thermic engine adapted to act, at will, as air compressors to effect a first step of the compression, and a compressed air motor to assist in the propulsion of the boat, a reducing valve inserted between the air reservoir and the mentioned cylinders of the engine, and a heating apparatus for receiving the exhaust gases of the cylinders acting as explosion engine, and a conduit connecting the storage reservoir, with the cylinders acting as compressed air motors and passing through the heating apparatus, whereby the exhaust gases are utilized for heating the air which circulates in said conduit.

9. In a submarine boat, a motor for driving said boat, means for causing said motor to also drive a compressor, when the boat is near the surface of the water, a suitable reservoir for storing said compressed air, a compressed air motor to assist in propelling the boat under water, connection from the reservoir to said compressed air motor for supplying compressed air to the latter, an exhaust valve provided on said compressed air motor and through which air is discharged into the interior of the boat, and inlet valves on the engine and which, when the boat is under water admit the air from the interior of the boat for supporting combustion in the cylinders of the engine.

10. In a submarine boat, a compressed air motor and a combustion engine having a plurality of cylinders, a conduit for discharging the exhaust air of the cylinders which act as compressed air motors at one end of the boat, another conduit from the inlet valve of the engine to the other end of the boat, for supplying air to the engine, and partitions provided in convenient places in the interior of the boat and reducing, at said places, the clear section, to increase the speed of the air current which goes from one end of the boat to the other.

In testimony whereof, I have signed my name to this specification in the presence of two subscribing witnesses.

CESIDIO DEL PROPOSTO.

Witnesses:
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H. A. JOHNSON.