Aug. 9, 1932.

A. R. NEFF

1,870,263

SUBMARINE

Filed March 18, 1930

5 Sheets-Sheet 1

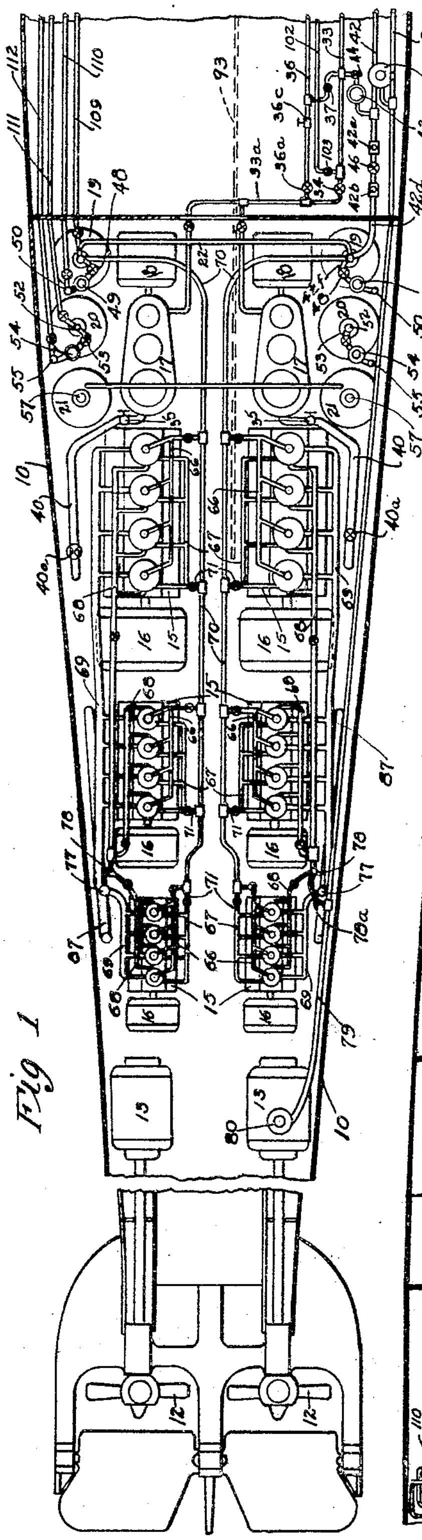

Fig 1

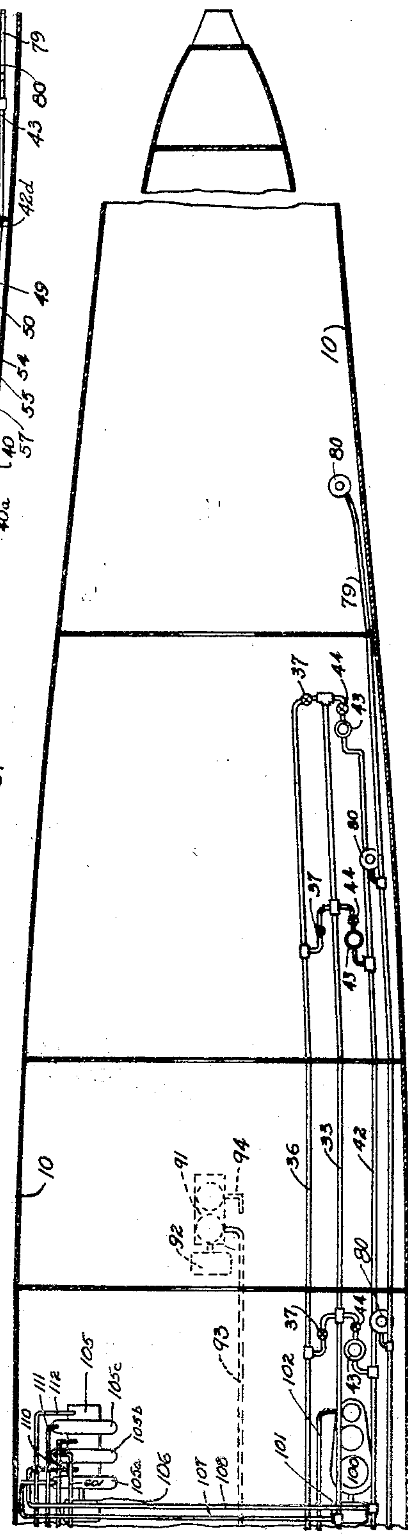

Fig.1a

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Aug. 9, 1932. A. R. NEFF 1,870,263

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Filed March 18, 1930 5 Sheets-Sheet 2

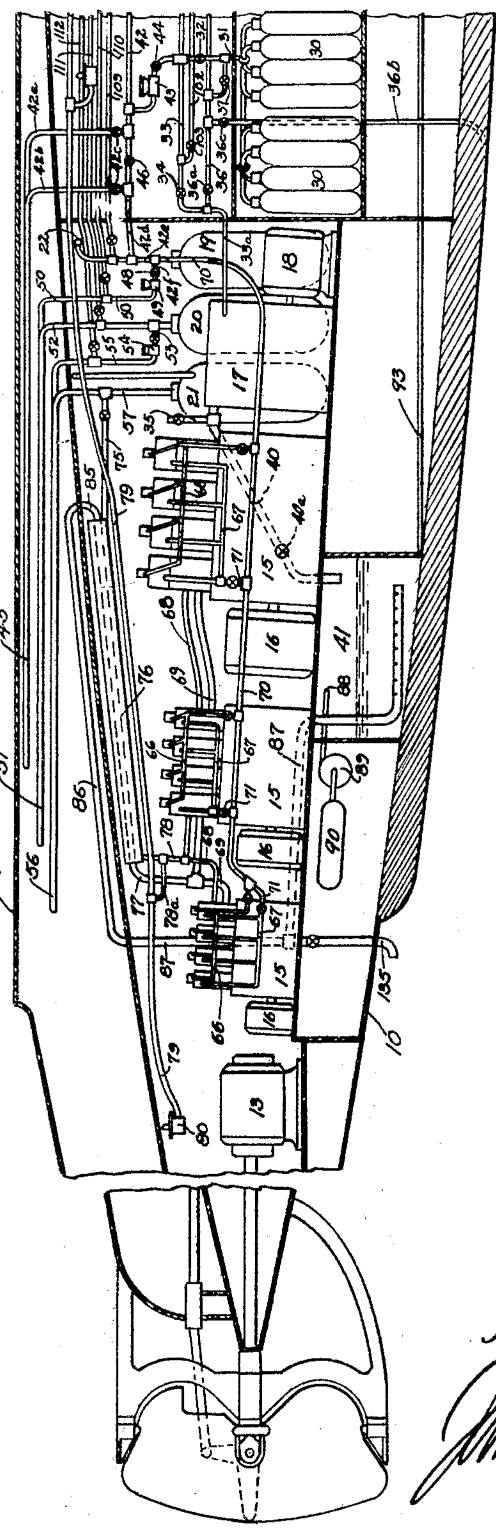

Fig. 2.

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Filed March 18, 1930 5 Sheets-Sheet 3

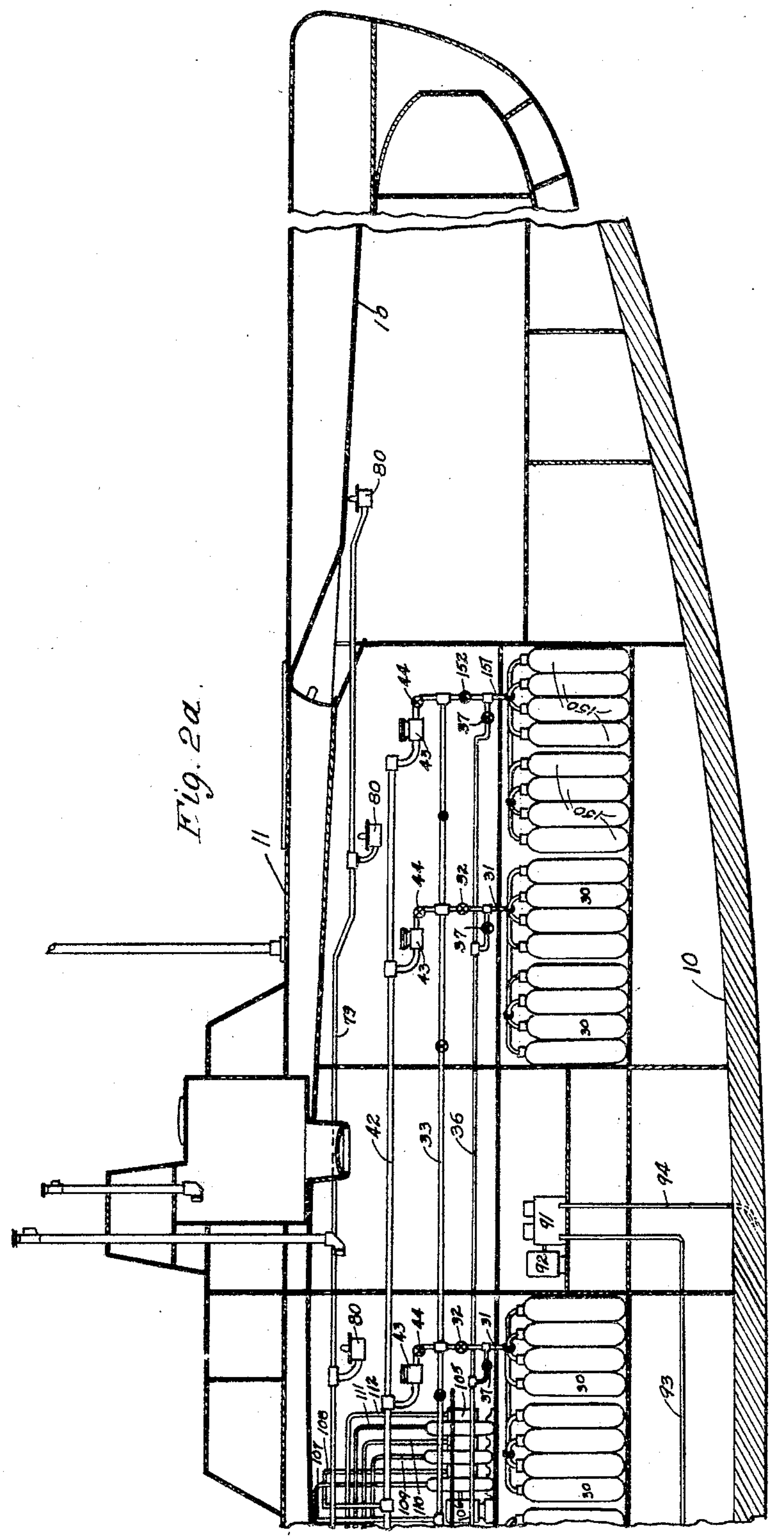

Fig. 2a

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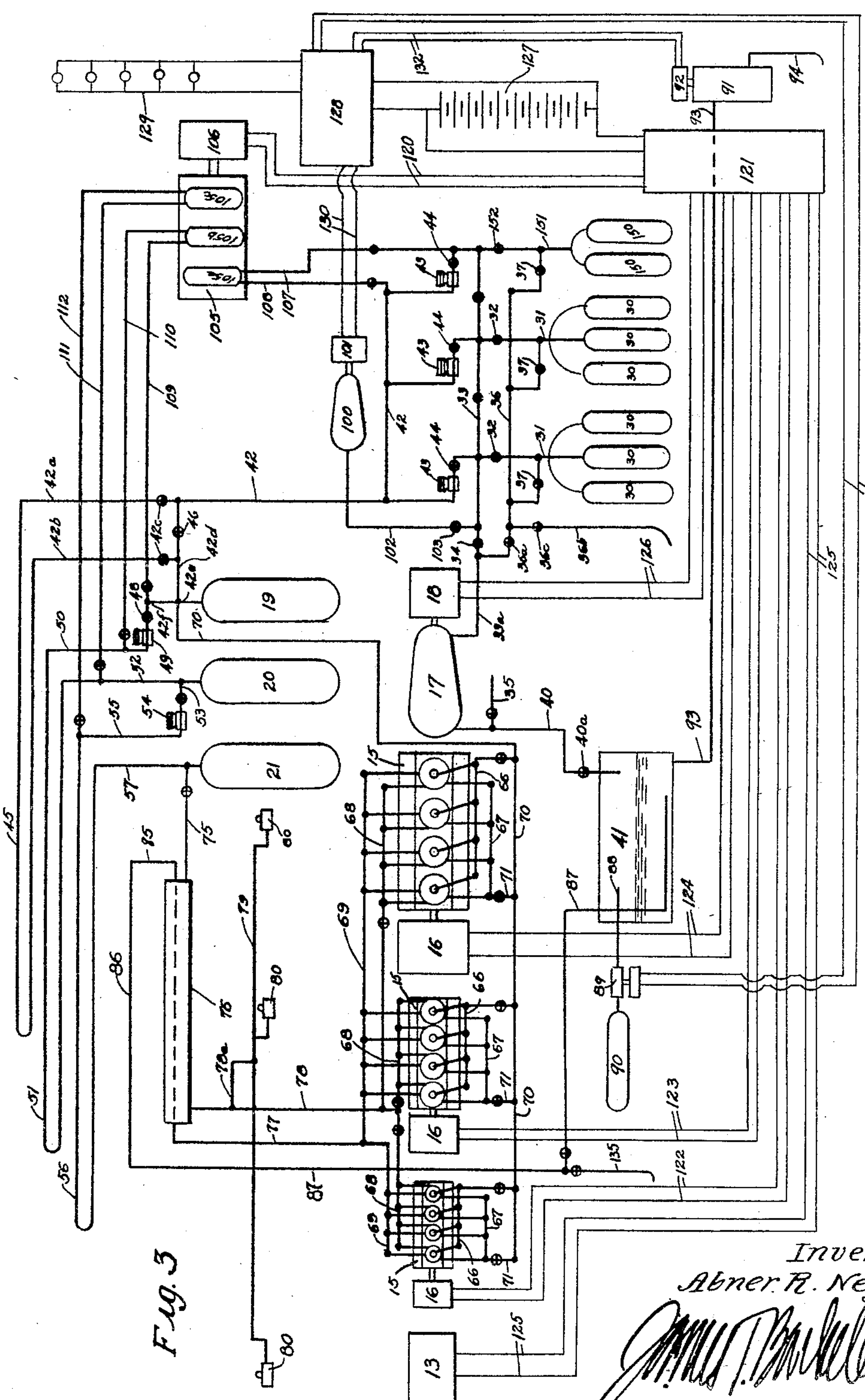

Fig. 3

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SUBMARINE

Filed March 18, 1930 5 Sheets-Sheet 5

Fig. 4.

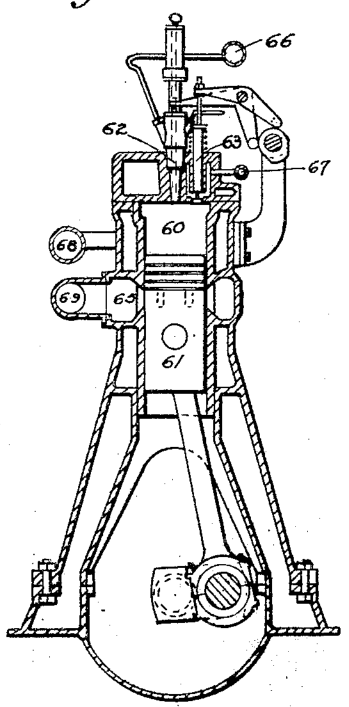
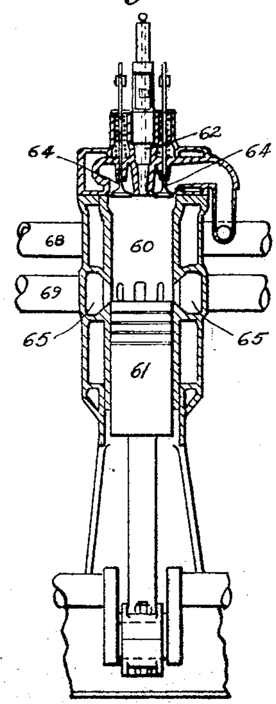


Fig. 5.



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UNITED STATES PATENT OFFICE

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SUBMARINE

Application filed March 13, 1930. Serial No. 436,705.

This invention relates to submarines, and, in some of its characteristic features, although not necessarily limited wholly thereto, relates to submarines of the general type disclosed in the patent issued to John M. Cage, 1,126,-616, on January 25, 1916, and also of the type set out in Patent No. 1,172,992 granted to me February 22nd, 1916, as the assignee of Allen Hoar. In the submarine of said Cage patent, propulsion, both on the surface and submerged, is by means of combustion engines, dispensing with the storage battery drive now generally in use for under-water propulsion. It is provided in that patent that air for the combustion engines be stored and carried at high pressure in flasks; the engines taking their air from the interior atmosphere of the submarine, which interior atmosphere is supplied from atmospheric air while running at the surface and from the storage while running submerged. The exhaust gases, in the Cage patent, are compressed and expelled overboard by an exhaust compressor operated by the engine.

In the Hoar patent the propulsion is by combustion engines, both at the surface and submerged, as in the Cage submarine. In the Hoar system, however, the exhaust gases, after being cooled and somewhat condensed, are compressed and expelled overboard by using the energy of expansion of the stored air.

In the submarine in accordance with my present invention I utilize both these prior ideas and, among other things, my present invention provides improvements upon those former systems. The present invention, however, contains other improvements in submarines, as will be set out later. Generally speaking, the object of the present invention may be briefly summarized under the following heads:

(1) To improve the efficiency and range of action of submarines which are driven exclusively by combustion engines;

(2) To improve the flexibility of operation and control of such a submarine;

(3) To provide such a system of operation that the submarine can either travel or lie under water for comparatively long periods without betraying its presence by any expulsion of foul or exhaust gases; and

(4) To provide for the accomplishment of all these and other things in a unified and co-ordinated system of such nature as to allow flexibility of utilization of energy.

Many other objects and corresponding accomplishments will be apparent from a consideration of the following detailed description. The system about to be described utilizes that system of propulsion now commonly known as "electric"—the system in which the final propulsion motors are driven directly from generators operated by prime movers, without any intervening electric storage. In adapting this electric drive to a submarine, and particularly for purposes of increased flexibility in operation, and for efficient use of the limited interior space, I divide the engine-generator sets into several sets of different sizes, any or all of which may be used for driving the propulsion motors.

Such division leads both to efficieny and flexibility of operation. For instance it enables very slow speed propulsion of a submarine without the usual very low engine efficiency. It also makes for better propelling efficiency as the propellers are designed for operation only by the propulsion motors, instead of being designed as a compromise for efficiency between operation by propulsion engines and propulsion motors. And at the same time, this division of the power plant into units of different sizes enables the units to be located with high space-using efficiency in the tapering hull of the boat.

In thus utilizing combustion engines exclusively for propulsion power, the present system provides for efficient air storage and for efficient use of the stored air and also of its energy of compression; and also for efficient use of the heat of combustion which otherwise would go to waste from combustion engines. The air is initially compressed to storage by compressor units driven by the combustion engines. On coming out of storage the air is reduced in pressure by stages and is heated by heat exchange with sea water or heat exchange with the engines, at each stage of expansion. The maximum amount of energy of compression is thus kept in the stored air. The air pressure at the several stages may very conveniently be used for Diesel engine operation, such engines being the preferred type of prime mover selected for submarines. Utilizing thus the several stages of air pressure, the necessity of compressor units on the engines themselves is eliminated. In other words, a single compressor unit or compressor plant serves for all purposes in a complete unified submarine system.

To utilize the energy of compression of the air, I prefer to provide an air pressure motor such as an air pressure turbine which drives an electric generator which in turn delivers its output into the common electrical system which feeds not only the final propulsion motors but also all other electrically operated appurtenances of the boat, such, for instance, as the lighting system and the small pumps necessary for ventilation when the submarine is at rest. Thus, by making such arrangement for utilizing the energy of compression, that energy is utilized under any and all circumstances of the submarine.

With this general idea of the system in mind, the invention as a whole, and many other objects and accomplishments, will be best understood from the following detailed description wherein I set forth, in more or less specific details, the preferred and illustrative form of the invention, reference for this purpose being had to the accompanying drawings, in which:

Fig. 1—1*a* is a more or less diagrammatic plan of a submarine equipped with my system; the complete figure being divided into two parts for convenience of illustration;

Fig. 2—2*a* is a similar section elevation;

Fig. 3 is a diagram illustrating the interrelations and interconnections of the various elements in my system. In this diagram piping interconnections are shown in heavy lines and electrical interconnections in light lines; and

Figs. 4 and 5 are vertical sections of a typical Diesel engine unit as may be used in my system.

As the description proceeds it will be noted at various points and as regards various features of the described system, that the invention is not necessarily limited to the particulars described. It may, however, be noted at the outset that the system is not at all necessarily limited to the use of Diesel engines, except in some particulars wherein the system is especially adapted to Diesel engine operation. On the other hand, broadly speaking, any type of combustion prime mover may be utilized.

In the drawings a typical hull is indicated at 10 and a typical super-structure at 11. The hull is divided into several various compartments and, in general, will contain all those compartments, tanks, etc., usual or desirable in a submarine. Such things need no particular description here. The propellers 12 are directly coupled with and driven by the propulsion motors 13, which motors may conveniently be located in the stern of the hull close to the propellers, or, if the propellers be arranged forwardly in the hull, then the motors will in that case be arranged in the forward part of the hull close to the propellers.

In the stern portion of the hull I place the several engine generator units, each of which comprises a Diesel engine 15 and a generator 16. In the present instance, I have shown three such units at each side, with the larger units of each set forward and the small units aft; so as to utilize to fullest advantage the space within the tapering hull. Just forward of the engine units are shown two compressor units 17, each of which may be of any suitable number of stages; and each driven by a motor 18. Alongside these compressor units the air expansion flasks or reservoirs 19, 20, 21, may be situated. These are shown as three in number as I show the air as being expanded in three stages. Of course any suitable number of stages may be used for air expansion; I merely indicated here three as being typical and suitable.

The propulsion motors, engine generator sets and compressor units, so far described, as well as the air expansion flasks, are arranged in duplicate sets for purpose of symmetry and utilization of space. But an explanation of operation of a single set suffices for both, and so only a single set is shown in the diagram of Figure 3. To combine the two oppositely arranged sets of expansion flasks into a single operating unit, the two flasks 19 may be cross connected by the pipe shown at 22 in Figures 1 and 2.

In any suitable location in the hull, the several banks of air storage flasks may be located. For instance, these flasks are shown at 30 in Figures 2 and 2*a*; and they are shown as interconnected in groups or banks, each bank being connected by a pipe 31, controlled by valve 32, with the high pressure air line 33. This high pressure air line has a branch 33*a* leading to the high pressure outlet of compressor 17, and is controlled by a valve 34. Through this connection air may be compressed at suitable high pressure (say 3000 or more pounds per square inch) into the flasks. The compressor units take the air for this purpose from the interior atmosphere of the submarine, the valve controlled inlet of the compressor being shown at 35 in Figures 2 and 3.

It will be noted that the high pressure air line 33 is so connected to the several banks of air flasks that any one or more of the banks may be put into communication with the high pressure line either for compressing air into the flasks or for releasing air from any selected set of flasks. Paralleling the high pressure air line 33 is a high pressure exhaust gas line 36; and a valve controlled connection is made at 37 between this high pressure exhaust gas line 36 and each of the connections 31 to the several banks of flasks; and thereby this high pressure exhaust gas line may be put into communication with any selected one or more of the banks of flasks. This high pressure exhaust gas line, controlled by a valve 36*a* connects into the high pressure air line extension 33*a*; so that, by proper manipulation of the high pressure air control valve 34 and the high pressure exhaust control valve 36*a*, compressor 17 may be connected so as to compress air or exhaust gas into either the high pressure air line 33 or the high pressure exhaust line 36. The high pressure exhaust line 36 has a branch 36*b*, controlled by a valve 36*c*, leading overboard. And the inlet of compressor 17 not only comprises the atmospheric valve 35 but also a connection pipe 40, controlled by valve 40*a*, and which communicates with the exhaust tank 41 for the purpose of taking up the condensed residue of exhaust gases when it is desired to compress them into any of the air flasks.

Paralleling the high pressure air line 33 is a first reduction air line 42, which line is in communication with high pressure line 33 through communications which include reducing valves 43 and shut-off valves 44. There may be one such reducing valve communication from the high pressure to the first reduction line for each bank of air flasks. The reducing valves will reduce the pressure typically from the high pressure to a first stage pressure of say 800 pounds per square inch.

The first stage air line 42 has branches 42*a* and 42*b*, controlled by valves 42*c*, leading to an outboard coil 45 in which the expanded air is heated by heat exchange with sea water, the outboard coil being located exterior of the hull and within the super-structure. A valve 46 is located in the air line 42 and between the branches 42*a* and 42*b* so that, by proper manipulation of the valve 46 and the valves 42*c*, air may be passed through the outboard coil, or not, as desired.

After passing the outboard coil 45, the first stage air line extends on, as at 42*d* and has a connection at 42*e* with the first reduction tank 19 which acts as a reservoir for the first stage air. Then this first stage air line 42 also has a connection 42*f*, controlled by the valve 48, to a reducing valve 49. From the reducing valve a connection 50 leads to an outboard heating coil 51, and from this coil 51 a connection 52 leads to the second stage tank 20.

From the connection 52 a valve controlled branch 53 leads to the reducing valve 54 which has connection at 55 with the third outboard heating coil 56; and from this third coil a connection 57 leads to the third stage air tank 21.

The pressure in the second stage tank 20 may typically be 200 pounds per square inch and the pressure in the third stage tank 21 may be typically about 5 pounds per square inch. The air in each of these three stage tanks and their interconnected pipe systems will have been at least to some extent warmed by heat exchange with sea water; so that the energy of compression at each stage is kept as high as possible or practicable.

As I have indicated before, the several stages of expansion may preferably be selected so as to suit the operation of a Diesel engine, and to do away with the necessity of having special compressor units on the engine. Though this system is particularly adapted to and is described with a 2 cycle engine, it will be appreciated that it may be adapted, by making minor changes, to a 4 cycle engine, as well as any type of combustion engine, and still be within the spirit of my invention.

For instance in Figures 4 and 5 I show a unit of a Diesel engine wherein the cylinder is shown at 60, the piston at 61, the injector valve at 62, the starting valve at 63, the scavenge valves at 64 and the exhaust at 65. The injection air manifold is indicated at 66, the starting air manifold at 67, the scavenge air manifold at 68 and the exhaust manifold at 69; and the piping connections are correspondingly indicated in the diagram of Figure 3. The fuel injection air will be operated at the first stage pressure of say 800 pounds; and so a branch line 70 leads from the first stage line at 42*e* to feed air at that pressure to the injector system of the several engine cylinders. Air at this same pressure is used for starting operations, and so branch connections are indicated in the diagram of Figure 3 at 71 to communicate air from the fuel injection air line 70.

Air from the third stage at approximately 5 pounds pressure is used to feed the engine scavenge. For this purpose the air is led from the pipe line 57 through pipe 75 and then through a heat exchanger 76 through which the exhaust from the several engines is passed by exhaust communicating pipes 77 as indicated in Fig. 2. And the low pressure air, leaving the heat exchanger via line 78 communicates with the scavenge air manifolds 68 of each engine. Also in communication with this low pressure air line 78 at 78*a* is a line 79 which leads to reducing valves 80 to discharge air into the interior of the hull to keep up the proper atmospheric pressure there.

The exhaust gases, after leaving the heat exchanger 76 by way of pipe 85, first pass through the outboard cooling coil 86 which acts as an exhaust condenser to cool and condense the exhaust gases as far as is practicable by cooling with sea water. As a result of this condensation a considerable amount of liquid (mostly water) is produced, and the exhaust gas residue is also reduced in volume. The condensed and contracted exhaust then passes by pipe 87 into the exhaust tank 41, where the pipe leads under the level of the liquid which may be maintained in the tank, so that the gases are washed. Also to wash the gases and carry down any suspended liquids or solids, a spray may be introduced into the tank at 88. A small motor operated spray pump is shown at 89 which takes its liquid from a small tank 90. The tank may contain water or any other liquid, or any chemical which by reaction with the exhaust gases tends to condense or liquefy them. The accumulated liquid in the exhaust tank may be pumped out by the bilge pump 91 operated by a motor 92, a piping connection from the tank to the pump being shown at 93, and a line leading overboard from the pump at 94.

Under ordinary running conditions the exhaust gas residue is taken from the exhaust tank 41 through the line 40 to compressor 17, and is forced out at the requisite high pressure from the compressor through the high pressure exhaust line 36 through exhaust line 36*b* overboard. If at any time it is desired not to pass any exhaust gases overboard, for purposes of concealment, the valves 36*c* in exhaust line 36*b* may be closed and the exhaust then compressed into the high pressure exhaust line 36 and, by proper manipulation of the valves 37 compressed at high pressure into any selected bank or banks of the air flasks which at that time do not contain air. It will be readily understood that, in order to provide for storage of exhaust at any time during the submarine operation, at least one bank of the air flasks must be at all times empty of the air and ready to take the exhaust. To take additional exhaust storage while running submerged, other banks of air flasks will be emptied of their contained air fast enough to be ready to take exhaust storage as banks are filled up with exhaust.

When the wide range of rates at which the compressor 17 will handle exhaust gases is considered, the importance of being able to operate the compressor over a wide range of speed independently of the engine speed becomes apparent, especially since the maximum speed required will undoubtedly be greater than the speed at which fresh air is compressed and this variable speed of compressor operation not only has reference to compressing exhaust, but also to forcing it directly overboard as elsewhere explained. In such case exhaust condensation may be partially or wholly disregarded and the compressors operated at high speed to expel the gases.

When it is subsequently desired to release the stored exhaust gases, that can readily be done by simply connecting the proper air flask banks with the high pressure exhaust line 36, and connecting that line with the exhaust line 36*b*, when the exhaust will be expelled overboard under the pressure of storage in the flasks. The relatively small residue of exhaust left in the flasks at the low final pressure may be cleaned out by subsequently pumping air into the flasks and then discharging. The flasks are thus cleaned for subsequent reception of their compressed air charge.

Interior ventilation of the submarine is, of course, effected by the compressor 17 when air is being compressed into the air flasks; because the compressor takes its air from the submarine interior. The compressor, however, is only operated to compress air when the vessel is on the surface and atmospheric air is entering. It is, however, used to compress exhaust, at least at certain times, when the boat is submerged; and during those periods the compressor 17 may be used for drawing foul air from the interior and compressing it along with the exhaust gases by somewhat opening the air intake 35 of the compressor so that a proportion of air from the interior will be taken in for compression along with the exhaust from tank 41. This is true also whenever the compressor 17 is compressing exhaust gases overboard. So that, whenever the vessel is running submerged, and the exhaust gases are being compressed either into the flasks or overboard, the compressor 17 may be used to draw off interior air and thus cause ventilation.

At times when the vessel is at rest submerged, and the engines are not being operated and it is thus not desirable to operate the air compressor or compressors 17, ventilation may be effected by a smaller compressor 100 operated by a motor 101. This compressor has its intake from the submarine interior and compresses through a high pressure line 102, controlled by valve 103 to the high pressure air line 33, and thus to the flasks. Seeing that compressor 17 and compressor 100 need not at any time be operated simultaneously, the high pressure air line and its distribution system to the flask banks may thus be utilized to compress and store the foul air from the compressor 100 in any selected bank or banks; to be subsequently released just as exhaust may be released. Or, if so desired, this compressed foul air may be subsequently released back through the high pressure air line and through the reduction systems, to be used, along with other air, in the engines and thus go into the engine exhaust which is ultimately stored or pumped overboard. The thorough ventilation of the submarine interior is thus provided at all times.

Just as the compressed foul air may be fed back to the engines, so compressed exhaust may be selectively fed back to the engines with a proportionate amount of pure air, or with a proportioned amount of oxygen which may be supplied from a special oxygen storage 150 which is shown connected into high pressure line 33 by pipe 151 controlled by valve 152. In average Diesel engine operation the oxygen content of the air is not completely consumed; and re-use of such once used air, either mixed with other air or oxygen, makes it possible in emergencies to maintain engine operation longer than can be otherwise.

In order to utilize the expansion energy of the stored air or other pressure stored gases, I may employ a turbine 105 which may preferably comprise three steps 105*a*, 105*b* and 105*c* (as many steps as there are in reduction of air pressure), and this turbine may conveniently drive a generator 106 which is connected into the general electrical system of the submarine. It is preferred to utilize a turbine of multiple stages in order that as nearly as possible the full expansive energy of the air or gases may be utilized. Thus the first turbine stage 105*a* may be connected by a line 107 to the high pressure air line 33, and its exhaust may go by line 108 to the first stage air line 42. Similarly the second turbine stage 105*b* will be connected by lines 109 and 110 between the first stage air line 42 (through the lines 22) and the second stage connection 50; and the third turbine stage 105*c* be connected by lines 111 and 112 between the second stage air line 52 and the third stage connection 55.

Suitable valvular arrangements are included whereby the air in its several stages of expansion may be passed in any proportion desired either through the turbine stages or through the several stage reducing valves; and in each case the exhaust connections of the turbine stages are made so that the expanded exhaust gases will pass through the several outboard heater coils 45, 51 and 56; so that, so far as the expansion of the air is concerned, the turbine stages perform exactly the same functions as are performed by the pressure reducing valves.

The turbine operated generator 106 has its output line 120 connected into the main electrical system so that this generator output may be flexibly utilized for any power purpose. For instance, in the diagram of Figure 3 the switchboard represented at 121 takes the output of all the generators 16, through their output lines 122, 123 and 124, and the output of generator 106 through its output line 120; and from this switchboard run the feed lines 125 to propulsion motor 13, and 126 to compressor motor 18. Also from the switchboard a small storage battery 127 may be fed; and another switchboard 128 is illustrated as being fed from the storage battery lines, which last mentioned switchboard controls the smaller electrically operated elements and those which may want to be operated at times when none of the generators are necessarily in operation. This, for instance, includes the lighting circuits 129, the compressor motor 101 which is fed by line 130, the spray pump motor 89 which is fed by line 131 and the bilge pump motor 92 which is fed by line 132. The storage battery for these purposes need not be very large—in fact it may be quite small as compared with the storage battery size necessary for storage battery propulsion of a submarine.

When the submarine is being propelled, one or more of the prime mover engines is, of course, being operated, with the propulsion motors directly energized from the generator or generators then in operation. For normal propulsion on the surface the engines simply exhaust overboard, either by operation of compressor 17 to raise the low pressure required for that purpose, or by direct exhaust overboard. For direct exhaust overboard a valve controlled branch 135 may lead from exhaust line 87. Accordingly, while running on the surface none of the auxiliary machinery need be operated unless it is desired to charge the air flasks, when compressor 17 will be operated.

Normally all of the air flasks will be preferably kept charged with air in readiness for submergence, excepting a single bank of flasks. If the boat is submerged and there is no immediate necessity for concealment, the engine exhaust is simply forced overboard by operation of compressors 17. Air from the flasks is released for interior ventilation and for engine operation; and foul air from the interior may be removed also by compressors 17 as long as the propulsion engines are operated.

Then if it becomes necessary to conceal the exhaust, that may be compressed at high pressure into any empty flask bank and, as has been before indicated, such storage of exhaust may continue as long as the vessel is capable of running submerged, because there are always air flasks available for exhaust storage as they are emptied of their air charge for engine operation.

In case the vessel is at rest submerged, then ventilation compressor 100 is utilized as hereinbefore described to remove foul air and compress either overboard or into empty air flasks, replenishing air being released from the air flasks.

Whenever, in any of these operations air is released from the high pressure storage, the air pressure turbine 105 may, of course, be operated. When the submarine is being propelled in submergence, the turbine operated generator 106 adds a considerable amount of electrical energy for propulsion purposes, or for compression of exhaust, or for any of the various other purposes for which power is required. Such utilization of the pressure energy is thus very flexible and is not confined to any one particular purpose. For instance, although thus the compression energy may be utilized for exhaust compression, it is not necessarily utilized for that purpose but may be utilized for propulsion or for any other power purpose. And one particularly advantageous result flowing from this flexibility of power use is in this; that even when the submarine is at rest submerged, and only a small amount of stored air is being released for ventilation, the corresponding small amount of energy, utilized through turbine 105 and generator 106 will be sufficient to supply a large proportion of the power required by compression motor 101 even if the foul air is being stored in flasks at high pressure. By compressing the foul air overboard, or by storing it in the flasks at something less than the high pressure of original air storage, the turbine generator set 105, 106 may be made to supply substantially all the power necessary for lighting and small power purposes and for the compressor motor 101; so that in such manner the submarine may lie concealed as long as its stored air will suffice for ventilation.

I claim:

1. In a submarine, the combination of a hull and a propeller therefor, a propulsion power plant including a combustion engine, air storage units, a compressor, intake means for the compressor whereby it may take either air or engine exhaust for compression, and a piping system connecting with the air storage units and whereby the compressor may compress either air or exhaust into any selected storage unit.

2. In a submarine, the combination of a hull and a propeller therefor, a propulsion power plant including a combustion engine, air storage units, a compressor, intake means for the compressor whereby it may take either air or engine exhaust for compression, and a piping system connecting with the air storage units and whereby stored air may be released from any selected storage unit for feeding the combustion engine.

3. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a combustion engine, a compressor adapted to take either air or engine exhaust for compression, air storage units, a piping system selectively connectible with any of the air storage units and with the compressor, an air discharge piping system leading from the selective piping system to the combustion engine and to the hull interior, and a second compressor adapted to compress air from the hull interior into the selective piping system and thereby into any selected storage unit.

4. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a combustion engine, means for cooling and condensing the exhaust from said engine, and means for compressing and storing said exhaust under pressure.

5. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a combustion engine, means for cooling and condensing the exhaust from the said engine, a compressor having intake arrangements to take either air or the condensed exhaust for compression, air storage units, a selective piping system capable of being selectively connected with any of the air storage units and with the compressor, whereby either air or condensed exhaust may be compressed or stored in any selected storage unit, and means for feeding air to the combustion engine from the selective piping system.

6. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a combustion engine, means for cooling and condensing the engine exhaust by heat exchange with sea water, and means for compressing and storing the condensed engine exhaust under pressure.

7. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a combustion engine, means for cooling and condensing the engine exhaust by heat exchange with sea water, a compressor, a plurality of air storage units, a selective piping system selectively connectible with any of the storage units and with the compressor, whereby condensed exhaust may be stored under pressure in any selected storage unit, and means for feeding air from the selective piping system to the combustion engine.

8. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a combustion engine, a compressor energized from the combustion engine and having an intake adapted selectively to take either air from the hull interior or the engine exhaust, pressure storage means, and means connecting the compression side of said compressor either to the exterior of the submarine or to pressure storage means.

9. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a combustion engine, a compressor energized from the combustion engine and having an intake adapted selectively to take either air from the hull interior or the engine exhaust, pressure storage means, the second compressor energized from the combustion engine and having its intake from the hull interior, and means whereby the compression side of both said compressors

may be selectively directed overboard or to the pressure storage means.

10. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a Diesel type internal combustion engine utilizing air at two different pressures for its operation, air storage means, a compressor energized from the engine and adapted to compress air into the storage means, and means for discharging air from the storage at reduced pressures and feeding the air at such reduced pressures to the engine.

11. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a Diesel type internal combustion engine utilizing air at two different pressures, a plurality of air storage units, a selective piping system selectively connectible with the storage units, a compressor adapted selectively to take air or engine exhaust and compress into the selective piping system, and means for discharging air and exhaust from the piping system at reduced pressures and feeding the air at such reduced pressures to the engine.

12. In a submarine, the combination of a hull and a propeller therefor, a propulsion plant including a Diesel type internal combustion engine utilizing air at two different pressures, a plurality of air storage units, a selective piping system selectively connectible with the storage units, a compressor adapted selectively to take air or engine exhaust and compress into the selective piping system, and means for discharging air and exhaust from the piping system at reduced pressures and feeding the air at such reduced pressures to the engine, and oxygen storage selectively connectible with the selective piping system.

In witness that I claim the foregoing I have hereunto subscribed my name this 17th day of February 1930.

ABNER R. NEFF.