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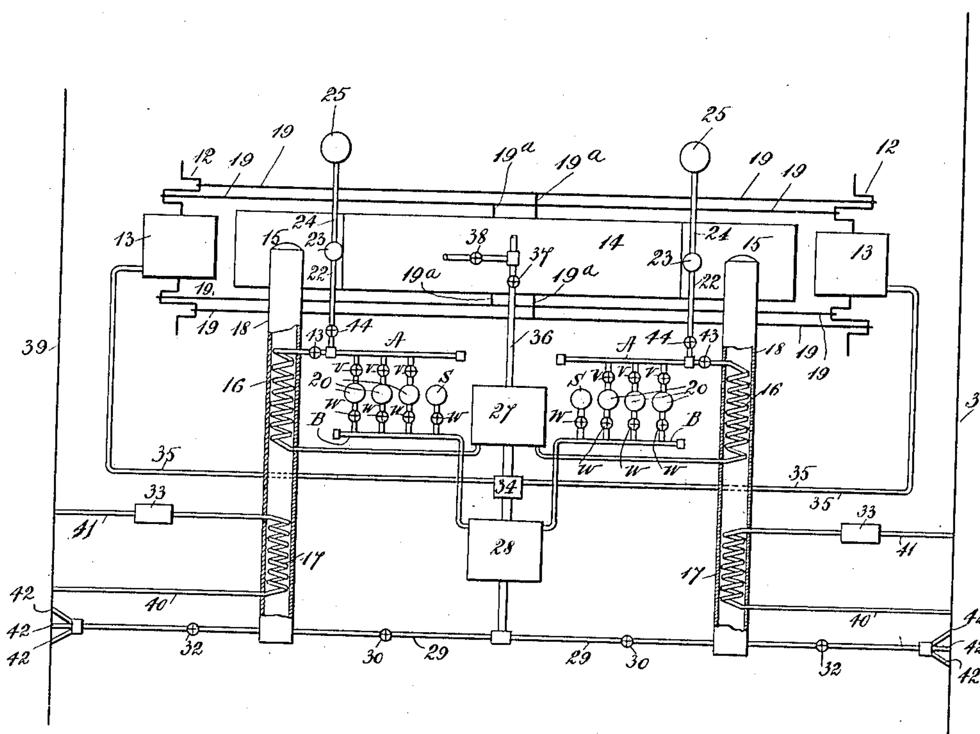
APPARATUS FOR SUBMARINES.

APPLICATION FILED NOV. 30, 1917.

1,291,458. Patented Jan. 14, 1919.



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UNITED STATES PATENT OFFICE.

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APPARATUS FOR SUBMARINES.

1,291,458. Specification of Letters Patent. Patented Jan. 14, 1919.

Application filed November 30, 1917. Serial No. 204,564.

To all whom it may concern:

Be it known that I, REGINALD A. FESSENDEN, of Brookline, in the county of Norfolk and State of Massachusetts, a citizen of the United States, have invented a new and useful Improvement in Apparatus for Submarine and other Anaeroergic Operations, of which the following is a specification.

The invention has for its object an increased efficiency of operation of submarine, torpedoes and other apparatus, primarily for military but also for commercial purposes, for example to enable submarine merchant vessels to operate between the north shore of Russia and the North Sea and in Hudson Bay and from Japan and Alaska to Europe, or for railway operation through long tunnels.

The accompanying drawing illustrates, partly diagrammatically, suitable methods and apparatus for carrying out the invention.

In the figure is shown diagrammatically an engine preferably of the Fessenden or external piston sleeve type, shown in United States Patent No. 1,132,465. The crank shafts 12, 12 are driven by connecting rods 19, 19, etc., which are connected to the pistons of said engine by connections 19^a, 19^a, etc. Dynamos 13, 13 are mounted to be operated by means of the crank shafts 12, 12 and furnish power for operating the propellers of the submarine by applicant's electric-drive method, well known in the art and a description of which as applied to the U. S. collier "*Jupiter*," will be found in the "*Journal of the American Society of Naval Engineers*" for August, 1912.

14 is the admission receiver, 15, 15 the exhaust receivers and 18, 18 the exhaust pipes.

In operation air or oxygen or a mixture of air and oxygen is stored in the air bottles 20, 20. Two sets of bottles are shown, one set to feed each one of the engines, and the operation of each set is identical. A is a pipe which connects the bottles 20 with the pipe 22 by means of the valve 44 and with the coils 16 by means of the valve 43. Valves *v* connect each bottle with the pipe A and preferably the bottles are emptied one at a time and after each bottle is emptied its valve *v* is closed and the valve *v* of a full bottle is opened. These bottles 20 are also used when emptied to receive and store the exhaust gases. For this purpose a pipe B is provided which is also connected with the bottles 20, 20 by valves *w*, *w*. The pipe B connects with the exhaust compressor 28 and it is best made to have the same volume as one of the bottles 20, which are all of the same capacity. Thus the valves *w* being closed, the pipe B can easily hold the exhaust gases resulting from the use of the contents of one of the bottles 20. When a bottle 20 is emptied the valve *v* of the said bottle is closed and the valve *w* being opened, the contents of the pipe B fills the said bottle, after which the valve *w* is closed, and the pipe B then becomes an exhaust gas receiver again until the next bottle 20 is empty. If the pipe B has not sufficient capacity an extra bottle S is attached thereto by a valve *w*, which is kept open while the first bottle 20 is being exhausted so that the exhaust gases are compressed in the bottle S until the first bottle 20 is exhausted or until the bottle S is filled, when the valve *w* of the bottle S is closed and the valve *w* of the exhausted bottle is opened, its valve *v* being first closed. In the operation of the engine the two sets of bottles are used simultaneously. On opening the valves 44, 44 this air passes through the pipes 22, 22 to the spray injectors 23, 23, and sprays the oil passing from the tanks 25, 25 through the pipes 24, 24 into the engine cylinders, in the well known way.

If desired, high pressure steam may be used instead of the air for injecting the oil, and this may be generated by the heat of the exhaust.

On opening the valves 43, 43, the compressed air passes through the heating coils 16, 16 where the air is heated by the exhaust gases, and thence into the air turbine 27, where it helps to drive the compressor 28, and thence through the pipe 36 and valve 37 into the admission receiver of the engine, and thence into the engine cylinders in the well known way, where it is compressed, burns the injected oil, expands and then passes out of the exhaust ports into the exhaust receivers 15, 15, and thence through the pipes 18, 18 where after heating the air in the coils 16, 16 it is itself cooled by the sea water circulating in the coils 17, 17. Thence after this cooling, it passes by the pipes 29 through the valves 30, 30 into the compressor 28 (its volume being now only approximately 97% of the original volume, owing to the fact that exhaust gases occupy less volume than the original air) and is recompressed and passes into the pipe B and bottles 20, 20 as above described.

The cooling water for the coils 17, 17 is derived from the pipes 41, 41, passing through the sides 39, 39 of the vessel, and is circulated by the pumps 33, 33, and passes out again through the pipes 40, 40.

The power furnished by the air turbine 27 is not sufficient to compress the exhaust gases, and the balance needed is furnished by the electric motor 34 driven by the dynamos 13, 13 through the leads 35, 35, etc.

This method is used when it is desired to run below the surface without showing any part projecting above the water surface, or leaving any air bubble track or oil track.

When it is unnecessary to run without air bubble track, the valves 30, 30 are closed and the valves 32, 32 opened. The engine then exhausts overboard through the fine copper pipes 42, 42, etc., passing through the side of the vessel. In this case 34 acts as a generator and supplies power to the circuit to which it and the other dynamos 13, 13 are connected.

When it is unnecessary to run without any part projecting, the valve 37 may also be closed, and the air taken into the admission receiver through the valve 38 which is opened for the purpose, and which puts the admission receiver into communication with the body of the ship. Air is admitted into the body of the ship in any convenient way, for example, as is well known in the art, through one of the periscope tubes or a separate tube emerging above the surface.

It is of course well known to operate submarines by stored air, and the Fulton and Nordenfeldt submarines were so operated, in the one case the air being furnished to the motive power (human) and in the other case to the motive power generator (steam boiler). It is also well known to supply it to burn fuel used in driving internal combustion engines, as for example in torpedoes, where compressed air is used to burn alcohol which heats the air and, expanding it, drives the gas turbine or combined gas and air turbine which turns the propellers.

But until the present invention this method had the following disadvantages which have prevented it from coming into use for submarines, or for enabling torpedoes to have the desired long range and speed *i. e.*:—

1. It left a bubble track which disclosed the position of the submarine and made much noise.

2. The weight per H. P. hour was too large.

3. The space per H. P. hour was too large.

4. They could not be run at any considerable depth on account of the back pressure of the water, and even at moderate depths were very inefficient.

While storage batteries have been practically universally used for under water power, they have the following disadvantages, *i. e.*:—

a. They are dangerous, the sulfuric acid ones from the generation of chlorin, and the alkaline ones from the generation of hydrogen.

b. They deteriorated rapidly in use.

c. The weight per H. P. hour was too great.

d. The space per H. P. hour was too great.

By applicant's invention these defects are removed, *i. e.*:—

A. There is no back pressure when running submerged at any depth.

B. There is no bubble track.

C. The method is absolutely safe, and in addition provides a very large storage capacity of air or oxygen for the crew in case of accident, sufficient to last for several weeks.

D. The weight per H. P. hour is only a fraction of that of storage batteries.

E. The space per H. P. hour is only a fraction of that of storage batteries.

F. The operation is more noiseless than that of storage batteries, as alternating current generators and motors may be used for driving the screw propellers, and thus all commutator noise eliminated.

The following figures show the comparative weights and volumes occupied by applicant's apparatus as compared with those of the present storage batteries.

In the tables, Method A is where applicant used compressed air; Method B is where applicant used compressed oxygen, of approximately 95% purity, such as is readily obtained from any oxygen plant without too much trouble, or by electrolysis. The figures are taken from a memorandum forwarded to the U. S. Navy Department in 1915, and so far as they relate to Navy apparatus have been checked by the Department.

Method A.

Standard Navy air tank weights, empty	1, 250 lbs.
It contains at standard pressure, (2,250 lbs.)	24. 4 c. ft.
This weighs at standard pressure	274 lbs.
The oxygen in this air weighs	57. 7 lbs.
The weight of oil it will burn is	16. 75 lbs.
At 0.4 lb. oil per H. P. hour this gives	42 H. P. hrs.
The work done by the air in expanding is	20 H. P. hrs.
Total work is	62 H. P. hrs.
Work lost in recompressing exhaust gases	30 H. P. hrs.
Net available work	32 H. P. hrs.
Weight of tanks, air and oil, total	1, 540 lbs.
Weight per H. P. hour, Method A	50 lbs.
Weight per H. P. hour, storage batteries (1 hour discharge rate, Navy standard) not including accessories	340 lbs.
Volume per H. P. hour, Method A	0. 8 c. ft.
Volume per H. P. hour, storage batteries (Navy standard rate, 1 hour discharge, not including battery accessories)	1. 5 c. ft.
Saving in weight by Method A	85%
Saving in space by Method A	45%

Method B.

Oxygen in tank weighs	280 lbs.
Weight of oil this will burn	82 lbs.
Cost of production of oxygen	$2.80
At 0.25 lb. per H. P. hour this gives	328 H. P. hrs.
Work done by oxygen in expanding	20 H. P. hrs.
Total work	348 H. P. hrs.
New work available, after subtracting 30 H. P. hours for recompressing exhaust gases	318 H. P. hrs.
Weight per H. P. hour	5 lbs.
Space per H. P. hour	0.08 c. ft.
Saving in weight by Method B	98%.
Saving in space by Method B	93%.

As applied to torpedoes, where a bubble track is permitted, it will be seen that Method A gives three times the power, and Method B sixteen times the power. If the bubble track is suppressed, Method A gives 50% more power, and Method B fifteen times the power.

To prevent an oil track from forming from oil leaking out of the propeller tube and rising to the surface, I use a lubricant formed of a metallic soap, as stearate of calcium or oleate of calcium or oleate of lead or a heavily chlorinated but neutral oil, so that on creeping out of the propeller tube it will sink and not rise to the surface.

In using Method B, *i. e.*, oxygen storage, I prefer to use the exhaust gases to dilute the oxygen in the cylinder. I may do this by mixing them before passing into the admission receiver, or by not scavenging perfectly, *i. e.*, only scavenging out about 20% of the exhaust gases and adding to the 80% remaining in the cylinder about 20% of oxygen. In this way only about one fifth as much exhaust gas per H. P. hour has to be recompressed as when air is used.

When exhausting overboard it is very advantageous to cool the exhaust gases first as shown, by the coils 17, 17, as in this way the back pressure is reduced and the volume diminished about 75%, and thus less work is done in exhausting when running deep, though it is true that as a rule this is not important as when running deep it is generally desired to have no bubble track.

While this invention has been described as applied to submarines in particular, it is applicable to other purposes such as torpedoes and also for railway operation through long tunnels where the exhaust gases will foul the atmosphere of the tunnel. Moreover, so far as I know, the recompressing and storage of the used gases is new with me, and the necessary apparatus therefor may be applied to other internal combustion engines than that described in my patent. I have shown the apparatus in diagrammatic form only in the drawings, as the elements are all old and well known and need no elaboration to those skilled in the art. In using the term "anaeroergic" in describing my invention I mean working in the absence of the atmosphere as an analysis of the word will show.

What I claim as my invention is:—

1. An internal combustion engine, having means connected thereto adapted to store gas under pressure greater than atmospheric pressure, and means also connected thereto whereby the exhaust gases therefrom may be collected, recompressed and stored in said gas-storage means when said gas-storage means are empty.

2. An internal combustion engine, means comprising one or more tanks connected to said engine and adapted to store gas at a pressure greater than atmospheric pressure, means connected to said engine and connectible to each of said tanks in turn whereby the exhaust gases may be recompressed and stored in each of said tanks when it is empty, and means to cool said exhaust gases located between said engine and said compressing means.

3. An internal combustion engine comprising a tank to store gas under pressure greater than atmospheric pressure, means whereby fuel is supplied to said engine, connections whereby said gas is also supplied to said engine to furnish a means of combustion, and means operable by said engine to recompress the gaseous products of combustion and store them in said tank when empty.

4. An internal combustion engine and means for supplying fuel thereto comprising one or more tanks adapted to store gas under pressure greater than atmospheric pressure, means comprising connections between each of said tanks in turn and said engine whereby gas is supplied to said engine and connections between said engine and each of said tanks whereby the exhaust gases from said engine may be stored in each of said tanks when empty including gas-compressing means located between said engine and said tanks.

5. An internal combustion engine, means comprising a series of tanks connected with the engine and adapted to store gas for use with said engine under a pressure greater than atmospheric pressure, and an additional similar tank normally empty, and means connected to said engine and connectible to each of said tanks in turn whereby the exhaust gases may be recompressed and stored in said filled tanks when empty and in said normally empty tank before any one of said gas-storage tanks becomes empty.

REGINALD A. FESSENDEN.