W. L. R. EMMET.

SYSTEM OF SHIP PROPULSION.

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1,304,289.

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Fig. 1.

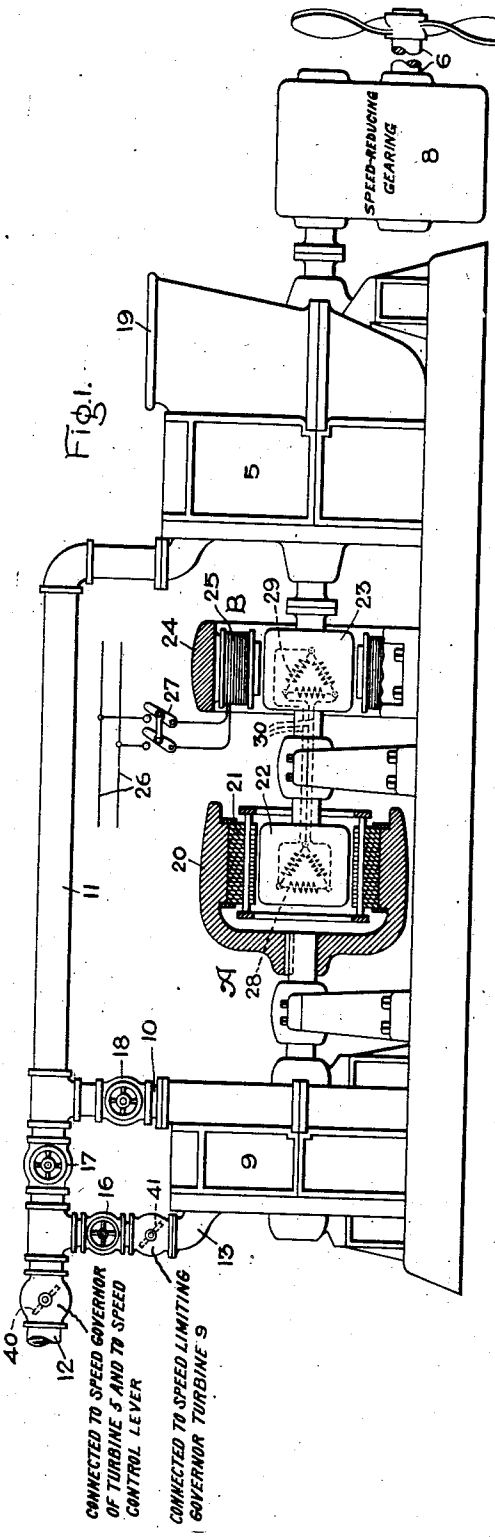
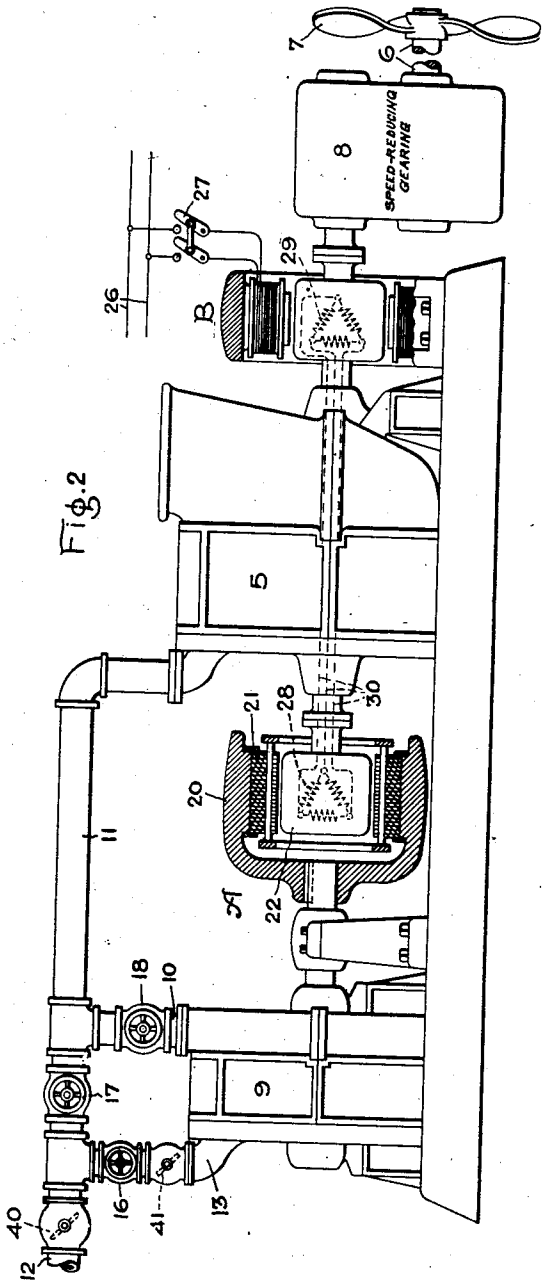


Fig. 2.



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SYSTEM OF SHIP PROPULSION.

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To all whom it may concern:

Be it known that I, WILLIAM L. R. EMMET, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Systems of Ship Propulsion, of which the following is a specification.

My invention relates to ship propulsion and in particular to systems of ship propulsion in which the ship's propellers are driven directly or indirectly by elastic fluid turbines, such as steam turbines. The object of the invention is to provide an improved system of ship propulsion. Other objects of the invention will be pointed out in the course of the following description.

The system of my present invention is particularly adapted for use on vessels where efficient operation over two speed ranges must be had, as, for example, over a high range of speeds and over a lower range of speeds. In such ships, economic operation of the propelling apparatus must be obtained over the desired range of high speeds, including full speed, and also over a suitable range of lower speeds, which I will term the cruising speeds. The present invention more particularly relates to systems of propulsion in which the prime-mover, such as a steam turbine, is mechanically coupled, either directly or through suitable speed reducing means, to the propeller shaft. Speed variations of a ship propelled by such a system can be obtained by varying the admission of operating fluid to the turbine, but efficient operation over such a wide range of speeds as would include both the high and cruising speeds of the ship cannot be satisfactorily obtained merely by varying the steam admission to the turbine, since if the turbine is designed and proportioned for high efficiency at its high speeds, its efficiency will be much poorer at the relatively low speeds corresponding to the cruising speeds of the ship.

The power required to propel a vessel varies approximately as the cube of her speed, and, accordingly, at cruising speeds considerably less than the maximum power of the propelling equipment is required for driving the ship, and greater economy could be obtained by using a small high pressure turbine operating at a higher speed in series with the main turbine, which latter in such a case would be used as a low pressure turbine. The difficulty in practically employing such a system lies in the fact that the full speed of the main turbine is so high that it is practically necessary to connect this turbine to the propeller shaft by speed reducing gearing, and, since for economic operation the speed of the auxiliary turbine should be as high as the full speed of the main turbine, a still greater speed reduction would be necessary between the auxiliary turbine and the propeller shaft if this turbine is to drive the propeller at the lower cruising speeds. The aim of my present invention is to provide an improved arrangement of apparatus in a system in which two turbines are operated in series so that the two turbines can operate at different speeds and deliver power to the same shaft. In another aspect the object of my invention is to provide an electromagnetic device for operatively connecting together two turbines, one of which is supplied with exhaust fluid from the other, so as to establish a relation between the turbines by which one operates at a higher speed than the other.

In carrying out my present invention I provide a main turbine, directly or indirectly coupled to a propeller shaft. This turbine is designed to efficiently drive the propeller at high speeds and is furthermore capable of economic operation when supplied with the exhaust steam of an auxiliary or cruising turbine, which latter is operatively connected to the main turbine through an electromagnetic device so as to assist in driving the propeller. The speed relation of the cruising and main turbines when the exhaust of the former is supplied to the admission of the latter is established, within the limits of its electrodynamic capacity, by the electromagnetic device. In its preferred form the electromagnetic device consists of an induction generator having one of its elements driven by the main turbine and the other by the auxiliary turbine and a synchronous motor having one of its elements stationary and the other mounted on the shaft of the main turbine, with the armature elements of the generator and motor electrically connected together to produce opposite directions of phase rotation. The arrangement of the apparatus in and the mode

of operation of the system of my present invention will be best understood from the following description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of an electric system of ship propulsion embodying my present invention; and Fig. 2 diagrammatically illustrates a modified arrangement of the propelling apparatus.

Referring first to Fig. 1 of the drawings, there is diagrammatically represented a main elastic fluid turbine 5, such as a steam turbine, designed for high efficiency as a high-speed high-pressure machine and adapted for economical operation at a lower speed when supplied with elastic fluid of a lower pressure. The main turbine 5 is mechanically coupled to a propeller shaft 6 upon which is mounted a propeller 7. For efficient operation the speed of the propeller should be relatively much lower than the speed of the turbine 5, and, accordingly, it is generally necessary to interpose suitable speed reducing means, such as the speed reducing gearing 8, between the turbine shaft and the propeller shaft. The gearing 8 may consist of any suitable marine gearing, preferably of the elastic or flexible type.

An auxiliary or cruising turbine 9, designed for high efficiency as a high-speed high-pressure machine, has its exhaust 10 communicating with the admission pipe 11 of the main turbine 5. A main supply pipe 12, communicating with a suitable source of elastic fluid, such, for example, as the boilers of the ship, is arranged to supply elastic fluid to the admission 13 of the cruising turbine 9 and to the admission pipe 11 of the main turbine 5. Three valves 16, 17 and 18 are shown for controlling the steam admission to the turbines 5 and 9. When valves 16 and 18 are closed and valve 17 open, the main turbine 5 receives steam directly from the boilers, and its exhaust 19 may be connected to a suitable condenser, as well understood. Under this condition of operation the main turbine runs at its high speeds with high efficiency. If valves 16 and 18 are open and valve 17 closed the auxiliary turbine 9 receives steam directly from the boilers and exhausts into the admission of the main turbine. Under this condition the auxiliary turbine is adapted to operate at a higher speed than the main turbine, but at the same time the driving of the main turbine at a relatively low speed with relatively low pressure steam is economical.

An electromagnetic device comprising a polyphase induction machine A and a polyphase synchronous machine B is employed for operatively connecting the cruising turbine to the main turbine. The field magnet structure 20 of the induction machine is of the overhung type and is keyed to the shaft of the auxiliary turbine 9 whereby it is adapted to be rotated by the cruising turbine. The field winding of the induction machine may be a squirrel cage winding 21, as is well understood in the art. The armature core 22 of the induction machine is mounted on the shaft of the main turbine 5. The armature core 23 of the synchronous machine B is also mounted on the shaft of the main turbine 5, while the field magnet structure 24 of the synchronous machine is stationary. The field winding 25 of the synchronous machine is adapted to be supplied with direct current from any suitable source, such as the D. C. mains 26, and a suitable switch 27 is employed for controlling the excitation of the synchronous machine. The polyphase armature winding 28 of the induction machine A is electrically connected to the polyphase armature winding 29 of the synchronous machine B by means of conductors 30 extending through an axial hole in the shaft upon which the cores 22 and 23 are mounted. The windings 28 and 29 are electrically so connected as to produce opposite directions of phase rotation.

The operation of the system of Fig. 1 is as follows:—For full and high speed operations of the ship, the switch 27 is open, valves 16 and 18 are closed, and valve 17 is open. Live steam is thus admitted to the main turbine 5, which, accordingly, operates at its high speed thereby driving the propeller 7 at such a speed as is required for navigating the ship at high speed. During this condition of operation the auxiliary turbine 9 is idle and the field magnet structure 20 of the induction machine remains at rest. Speed variations of the propeller and hence of the ship for this condition of operation can be obtained by controlling the admission of steam to the turbine 5, and for this purpose a valve 40 is included in the main supply pipe 12. The valve 40 is designed to be operatively connected to a speed governor on the main turbine 5 and to a suitable speed control lever, substantially as described in my U. S. Letters Patent No. 1,137,308, dated Apr. 27, 1915.

For the navigation of the ship at relatively lower speeds, such as her cruising speeds, an arrangement of the propelling apparatus is made by which the operating speed of the main turbine 5 is materially reduced. This condition of operation is obtained by closing the switch 27 and valve 17, and opening valves 16 and 18, whereby the field of the synchronous machine B is energized and high pressure steam is admitted directly to the cruising turbine 9, while the main turbine 5 operates with exhaust steam received from the cruising turbine. The relative speeds of the turbines 5 and 9 will depend upon the design of the electrical machines A and B, and in particular upon the ratio of the number of poles of these ma-

chines. This will perhaps be better understood by considering for the moment the induction machine A as a motor supplied with electric energy from the synchronous machine B. The induction machine will then run up to a speed slightly below its synchronous speed, which means that the rotatable field magnet structure 20 will rotate at a speed equal to the speed of its rotating primary core 22 plus the synchronous speed of the induction machine minus its slip. If live steam is now supplied to the auxiliary turbine 9 until it acts as a prime-mover and drives the rotatable field magnet structure 20, the actual speed of the latter will increase to a value slightly above its synchronous speed plus the speed of the rotating core 22, and consequently the induction machine will cease to act as a motor and will operate as a generator delivering energy to the synchronous machine B, which latter now runs as a motor and assists in driving the shaft of the main turbine 5. The induction generator A receives its excitation from the synchronous machine B, as is well understood in the art.

The relative speeds of the two turbines are thus established by the electrical relations of the two machines A and B, within the electrodynamic capacity of the latter machines, and thus the turbine 9 rotates at a speed equal to the synchronous speed of the induction machine A plus its slip faster than the main turbine 5. The design of the electrical apparatus and of the turbines in the equipment illustrated in the accompanying drawings may for the purposes of explanation be assumed to be such that the main turbine 5 runs under this condition of operation at a speed substantially one-half its full speed under the operating arrangement first described, but since the turbine 5 receives steam of a relatively low pressure from the exhaust of the auxiliary turbine its operation at this lower speed is economical. The cruising turbine will, accordingly, operate at substantially double the speed of the main turbine plus the slip of the induction machine. With a high speed main turbine such as would be used in a vessel propelled through gearing, this doubling of the speed affords an amply high speed for advantageous design of the cruising turbine which is intended to give its best results when the vessel is running at relatively low speeds.

The same objects can obviously be accomplished by different arrangements of the apparatus of the system, although the arrangement shown in Fig. 1 is now deemed to be the preferable form for most cases. The induction machine and synchronous machine can, if desired, be placed on opposite ends of the main turbine and can be electrically connected together, either axially through the shaft or by means of collector rings and leads. Such an arrangement of the apparatus is diagrammatically represented in Fig. 2 of the accompanying drawings. In Fig. 2 the induction machine A is positioned between the auxiliary turbine 9 and the main turbine 5, while the synchronous machine B is positioned between the main turbine 5 and the speed reducing gearing 8. Corresponding elements of the systems of Figs. 1 and 2 are designated by the same reference numerals. It will further be understood that the relative positions of the armature and field elements of either or both of the machines A and B can be reversed if any conditions render such reversal desirable. The particular arrangements shown in the accompanying drawings avoid moving contacts and are, therefore, desirable for most cases.

In Figs. 1 and 2 of the drawings I have shown a valve 41 included in the admission pipe of the auxiliary turbine 9. This valve is adapted to be connected to a speed responsive device of the speed governor type on the auxiliary turbine 9, substantially as described in my U. S. Letters Patent No. 1,137,593, dated Apr. 27, 1915. The valve 41 thus operates to limit the speed of the auxiliary turbine without shutting the turbine down. The valve 40 is operated, as previously described, to adjust the admission of steam to the main turbine, or to the auxiliary turbine, depending upon the arrangement of the apparatus, for obtaining variations of the ship's speed over both her high and cruising speed ranges. Adjustment of the valve 40 thus serves to vary the speed of the main turbine when the apparatus is arranged for the high speed range and of both turbines when the apparatus is arranged for the lower range of speeds. As the speed of the ship is increased from her cruising speed by increasing the steam admission to the auxiliary turbine the action of the latter becomes less effective and at any desired point the full speed connections can be made by opening switch 27, opening valve 17 and closing valves 16 and 18. This can be advantageously done by gradually opening valve 17 thereby gradually admitting live steam to the main turbine until the back pressure on the auxiliary turbine is such that it is doing little work, whereupon the valves 16 and 18 are closed and the switch 27 is opened.

The mode of operation of the apparatus of my present system will it is believed be clearly understood by those skilled in the art from the foregoing description and explanation. The electromagnetic device consisting of the induction and synchronous machines establishes such a relation between the turbines that they can run at different speeds and deliver power in conjunction to the propeller shaft. Since the relative speeds of the two turbines are established by

the electromagnetic device, within the limits of the latter's electrodynamic capacity, this relation can obviously be varied by varying the design of the device, as, for example, by changing the ratio of the pole numbers of the induction and synchronous machines. Where the design of the apparatus is such that the cruising turbine runs at substantially twice the speed of the main turbine, substantially one-half of the power of the auxiliary turbine is converted into electric energy, while the other half of the power of this turbine is delivered direct to the main turbine shaft through the torque of the induction generator. The power of the auxiliary turbine which is converted into electric energy by the induction generator is also delivered to the shaft of the main turbine by the synchronous motor. Since only one-half of the total power of the auxiliary turbine is turned into electric energy, the size of the motor-generator combination need be only about one-half what it would have to be if all of the power of the auxiliary turbine were converted into electric energy and delivered to the propeller shaft, and hence the electrical losses are only about half as great as they would be in the latter case. It will of course be understood that the relative amount of the auxiliary turbine's total power which is electrically delivered to the shaft of the main turbine depends upon the relative speeds of the two turbines, and thus again upon the design of the electrical apparatus connecting the turbines.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, an electric generator having two rotatable elements, one of which is adapted to be driven by the main turbine and the other by the auxiliary turbine, an electric motor having two elements one of which is stationary and the other is connected to said main turbine, and means electrically connecting said motor to said generator.

2. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, an alternating current dynamo-electric machine having two rotatable elements one of which is adapted to be driven by the main turbine and the other by the auxiliary turbine, a second alternating current dynamo-electric machine having two elements one of which is stationary and the other connected to said main turbine, and means electrically connecting said dynamo-electric machines so that one of said machines is driven as a generator and the other operates as a motor and assists in driving said propeller.

3. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, an alternating current generator having two rotatable elements one of which is adapted to be driven by the main turbine and the other by the auxiliary turbine, an alternating current motor having two elements one of which is stationary and the other is rotatable and connected to said main turbine, and means electrically connecting the rotatable element of said motor to said generator.

4. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, an alternating current induction generator having two rotatable elements one of which is adapted to be driven by the main turbine and the other by the auxiliary turbine, an alternating current synchronous motor having two elements one of which is stationary and the other is connected to said main turbine, and means electrically connecting said motor to said generator so that the motor assists in driving the propeller.

5. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, a dynamo-electric machine having two rotatable elements one of which is adapted to be driven by the main turbine and the other by the auxiliary turbine, a second dynamo-electric machine having two elements one of which is stationary and the other is connected to one of said turbines, and means electrically connecting said dynamo-electric machines so that one of said machines operates as a generator and supplies electric energy to the other machine whereby the latter machine operates as a motor and assists in driving the propeller.

6. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, and an electromagnetic device operatively connecting said turbines together and adapted to establish a relation between the turbines whereby the auxiliary turbine operates at a higher speed than the main turbine.

7. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, and an electromagnetic

device comprising an alternating current generator and an alternating current motor operatively connecting said turbines together and adapted to establish a relation between the turbines whereby the auxiliary turbine operates at a higher speed than the main turbine.

8. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, and an electromagnetic device operatively connecting said turbines together and adapted to establish a relation between the turbines whereby the auxiliary turbine operates at a higher speed than the main turbine, said electromagnetic device comprising an alternating current induction machine and an alternating current synchronous machine electrically connected together so that one of said machines operates as a generator and supplies electric energy to the other machine whereby the latter machine operates as a motor and assists in driving the propeller.

9. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, a polyphase alternating current dynamo-electric machine having two rotatable elements one of which is adapted to be driven by the main turbine and the other by the auxiliary turbine, a second polyphase alternating current dynamo-electric machine having two elements one of which is stationary and the other is rotatable and connected to said main turbine, and means electrically connecting said dynamo-electric machines to give relatively opposite directions of phase rotation and so that one of said machines operates as a generator and supplies electric energy to the other machine which operates as a motor and assists in driving the propeller.

10. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, an alternating current induction generator having two rotatable elements one of which is adapted to be driven by the main turbine and the other by the auxiliary turbine, an alternating current synchronous motor having two elements one of which is stationary and the other is connected to said main turbine, and means electrically connecting said motor to said generator so that a substantial part of the power of said auxiliary turbine is converted into electric energy by said generator and delivered by said motor to the shaft of said main turbine.

11. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, and electromagnetic means operatively connecting said auxiliary turbine to said main turbine, said electromagnetic means comprising two dynamo-electric machines electrically connected together so that a substantial part of the power of said auxiliary turbine is converted into electrical energy by one of said machines and delivered by the other of said machines to the shaft of said main turbine.

12. A system of ship propulsion comprising a propeller, a main elastic fluid turbine coupled to said propeller, an auxiliary elastic fluid turbine arranged to exhaust into said main turbine, an alternating current dynamo-electric machine having two rotatable elements one of which is adapted to be driven by the auxiliary turbine, a second alternating current dynamo-electric machine having two elements one of which is stationary, the second element of each of said dynamo-electric machines being mounted on the shaft of said main turbine, and means electrically connecting said dynamo-electric machines together so that a substantial part of the power of said auxiliary turbine is converted into electric energy by one of said machines and delivered by the other of said machines to the shaft of said main turbine.

In witness whereof, I have hereunto set my hand this 14th day of March, 1916.

WILLIAM L. R. EMMET.