

# United States Patent

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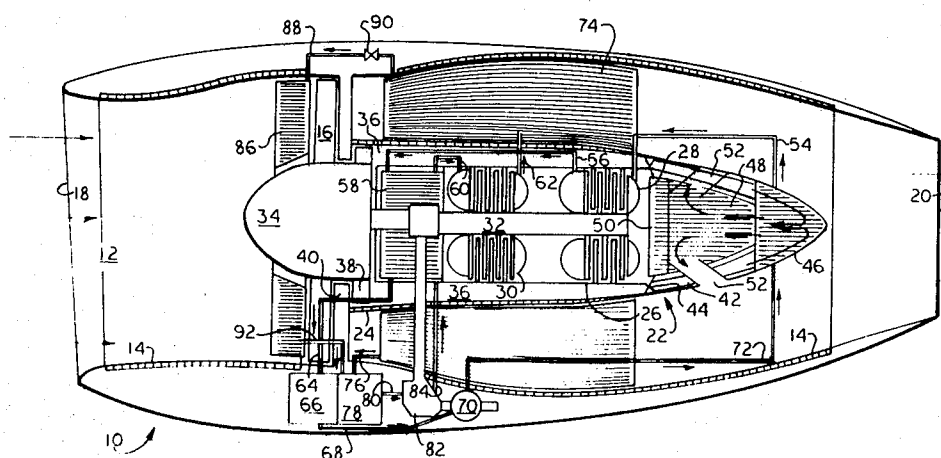
**ABSTRACT:** System comprises duct with entire powerplant within duct. Axial flow compressor driven by multiple vapor turbines produces entire thrust in form of airflow. Combustor uses minor portion of airflow to combine with fuel and burn to produce heat to vaporize highest temperature boiling working fluid, such as mercury. In two turbine system, first fluid operates first turbine and exhaust goes to heat exchanger which condenses mercury vapor and boils second fluid such as water thus producing water vapor. This water vapor operates second turbine which is coupled to first turbine. Exhaust from second turbine goes to condenser in airflow so that all rejected heat is added to airflow within duct to increase its energy. Can use two or more fluids with successively higher boiling points. Combustion gases may also pass from mercury vaporizer to water preheater and superheater and then discharge into airflow to add remaining heat energy. Vaporizer, turbines, and heat exchangers, except water condenser, all within a center body to further conserve heat. Combustion gases mix with air within duct so there is no primary combustion gas jet. High velocity of airflow is still much lower than turbojet, producing considerable noise reduction. All heat rejected or lost goes into airflow to produce maximum efficiency. Relatively low temperature makes possible maximum use of acoustic surfaces inside duct. High cycle efficiency will result in low hydrocarbon exhaust emission.

**[54] VAPOR CYCLE PROPULSION SYSTEM**  
15 Claims, 2 Drawing Figs.

[52] **U.S. Cl.**..... **60/262,**  
60/38, 60/203, 60/267  
[51] **Int. Cl.**..... **F02k 3/04,**  
F02k 5/00, F01k 23/18  
[50] **Field of Search**..... **60/203,**  
262, 226, 267, 266, 38

[56] **References Cited**  
**UNITED STATES PATENTS**

3,007,306	11/1961	Martin.....	60/267
3,016,694	1/1962	Howarth.....	60/266
3,266,246	8/1966	Heller.....	60/38
3,516,249	6/1970	Paxton .....	60/38



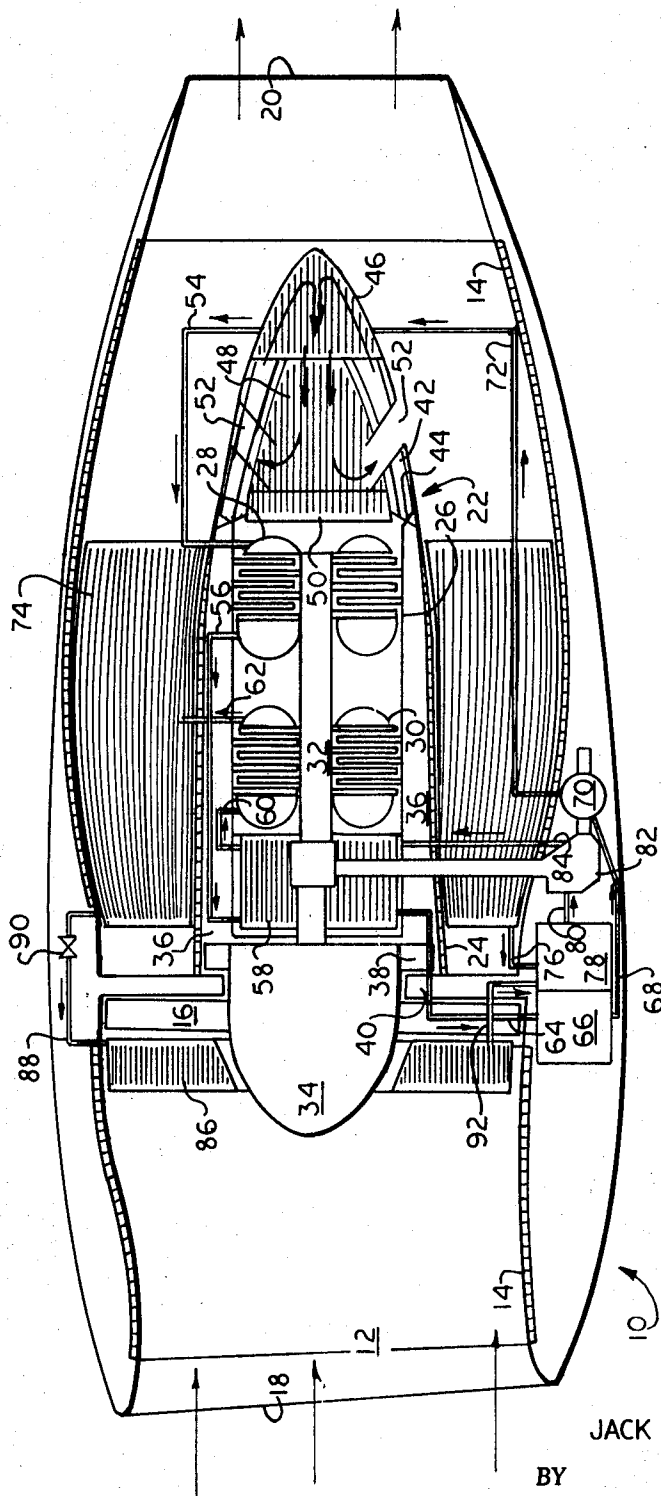


FIG. 1

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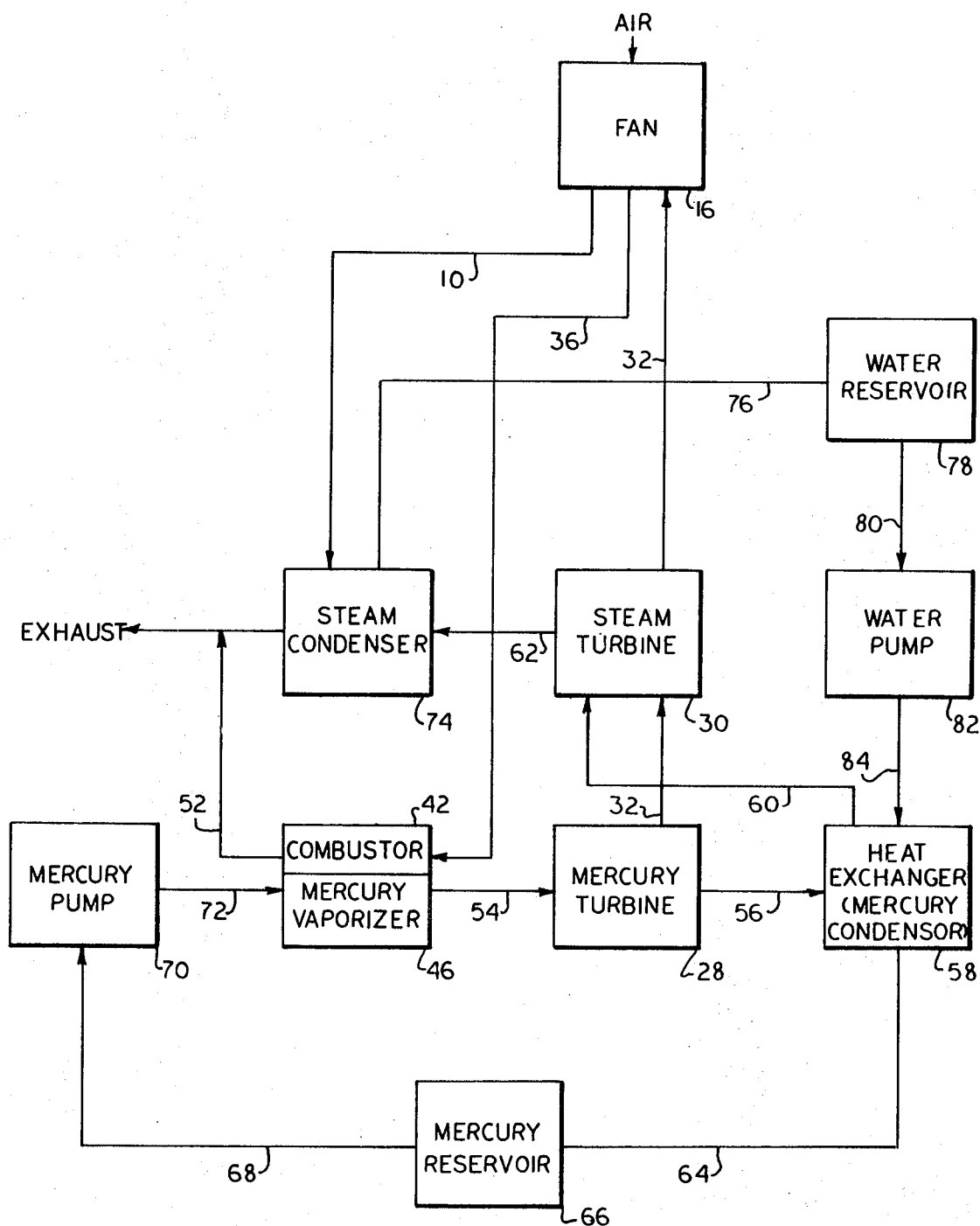


FIG. 2

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## VAPOR CYCLE PROPULSION SYSTEM

### BACKGROUND OF THE INVENTION

This invention lies in the field of jet propulsion engines which produce reaction thrust by ejecting a high-velocity stream of gas from a nozzle or duct. The conventional jet engine of the present time produces power by forcing very hot gaseous products of combustion through a turbine and ejecting the exhaust gas rearwardly to produce a reaction thrust. Such engines operate at the best efficiency available with the present state of the art and, in doing so, create a very high level of sound energy or "noise" in a wide range of frequencies, and a portion of this noise reaches the ground at an energy level which is not acceptable to the public.

The present invention is directed to a jet propulsion system which operates on a different principle which makes more efficient use of the power input, thus minimizing exhaust pollutants, and which eliminates the production of a primary turbine exhaust jet which produces much of the unacceptable noise level referred to above. Many advancements have been made in the conventional type jet engines in recent years. The fan type uses a large proportion of the turbine's power output in the form of shaft horsepower with a resultant increase in efficiency but the turbine exhaust is still sufficient to produce a very high sound level. Temperatures and pressures have been brought up to the limits of safe use of the turbines, producing high thrust-to-weight operation and increased efficiency, but these factors have also contributed to the high noise level. Attempts to reduce noise have been confined primarily to variations in nozzle configuration or addition of structures to modify jet flow. Hence, this type of engine has reached a virtual plateau in efficiency, thrust-to-weight ratio and noise emission.

### SUMMARY OF THE INVENTION

The present invention provides a jet propulsion system of superior efficiency and substantially reduced noise level by the use of an improved basic power cycle and a configuration of components to produce virtually the maximum possible specific shaft horsepower and by the reduction of the high velocity turbine exhaust jet.

This invention is an improvement over the invention disclosed in my earlier patent application Ser. No. 41,925, filed on June 1, 1970. In that application, a system was disclosed which included a power plant located entirely within an air duct, driving an axial flow compressor also located within the air duct and producing substantially its entire thrust of by the flow of air. A vapor cycle turbine was used to produce power for the compressor and all heat lost or rejected from the powerplant was transferred to the airflow to increase its energy content. The present invention utilizes the same principles but provides a more efficient power supply, resulting in greater utilization of the fuel energy and concomitant reduction in pollutant emission.

Generally stated, in the presently preferred form, the system comprises a longitudinally extensive duct having a forward air inlet and an aft air outlet generally similar to those used with gas turbines, with airflow-producing means located within the duct. Substantially the entire jet issuing from the duct outlet is air which is forced through the duct by an axial flow compressor located within the duct. In the presently preferred form the compressor shaft is driven by dual or binary cycle vapor turbine means in the form of two discrete turbines, one operated with water vapor and the other operated with mercury vapor.

A combustor is provided which uses a minor portion, which may be as low as 5 percent, of the airflow through the duct and combines it with suitable fuel to provide heat to a mercury vaporizer, or first heat exchanger. Mercury vaporized in the vaporizer is fed to a first turbine which is in driving relation with the compressor shaft, and the exhaust vapor from the turbine flows to a second heat exchanger having mercury on one

side and water on the other. Here the mercury is condensed for return to its vaporizer through a reservoir and pump, and the water is vaporized and fed to the second turbine. The exhaust vapor from the second turbine then flows to a condenser located in the primary fan airstream, where it is condensed for return to the second heat exchanger through a reservoir and pump.

Thus, it will be seen that the heat of condensation of the mercury vapor is not wasted but is used to vaporize the water for use in the second turbine. Turbines produce about the same percentage of mechanical work with various working fluids, and this is generally considered to be about 33 percent. The remaining 67 percent of the mercury heat is not wasted but is transferred to the water, and the second turbine used about one-third of this heat. The result is that the binary cycle utilizes about 55 percent of the heat supplied to produce mechanical work rather than the 33 percent in a single cycle. In most cases the products of combustion also flow through a feed water heater and water vapor superheater to extract the maximum heat of combustion and minimize heat rejection. The efficient utilization of heat input plus the low-pressure combustion process will minimize smog producing pollutants.

While multicycle or polynary cycle vapor turbine systems are not in themselves broadly new, it is new so far as known to locate the entire system within a confined airflow zone so that all of the heat rejected by the combustion gas flow and by the condenser for the lowest boiling point working fluid is added to the airflow within the confined zone so that the added heat energy increases the total thrust. Moreover, all heat generally radiated from the power components is also added to the air flow within the confined zone. Thus 100 percent of the heat energy produced by the combustor is used in mechanical work or is added to the airflow to obtain maximum propulsive efficiency. While the velocity of the airflow is high, it is much lower than that of a turbine exhaust jet and is also much cooler, both features contributing to the production of a much lower noise level. The energy of the combustion flow is greatly reduced by the heat transfer operation and its velocity is much lower than that of turbine exhaust gas, so it is dumped into the confined airflow and thus there is no primary combustion gas jet at the duct outlet. This further contributes to the reduction of the noise level.

It will be understood that three or even more turbines with various working fluids may be used, resulting in higher mechanical work percentages. However, the improvement effect is less with each added cycle, and the practical limit would appear to be a trinary cycle system because of the increase in complexity, weight, and cost. In addition to mercury and water, various other working fluids may be used including most of the alkali metals, such as sodium and potassium.

### BRIEF DESCRIPTION OF THE DRAWINGS

Various other advantages and features of novelty will become apparent as the description proceeds in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic sectional view showing the various components and arrangement of the propulsion system; and

FIG. 2 is a flow chart illustrating the operation of the binary cycle system.

### DESCRIPTION OF PREFERRED EMBODIMENTS

A typical binary cycle system incorporating the invention is illustrated in FIG. 1, in which a longitudinally extending duct 10 having an inner wall 12 is provided on portions of said wall with acoustic surfaces 14 to absorb some of the noise generated by the airflow-producing means. An axial flow compressor 16 centered generally on the longitudinal axis of the duct produces a high velocity, high mass flow of air through the duct from its forward air inlet 18 to its aft air outlet 20 to produce a rearwardly directed propulsive jet.

The compressor is driven by a powerplant substantially completely housed within a generally cylindrical streamlined

center body 22, which also is centered generally on the longitudinal axis of the duct. The center body may also have a portion of its external surface acoustically treated as indicated at 24. In the exemplary form which is schematically illustrated, a shell 26, spaced inwardly from the wall of the center body 22, surrounds a mercury turbine 28 and a steam turbine 30 which may be geared together but preferably are mounted to a single drive shaft 32 as illustrated. The drive shaft is connected at its forward end to the rotatable nose body 34 which carries compressor 16. The center body 22 and shell 26 form between their forward portions a forward air passage 36 of generally annular cross section, and nose body 34 carries a partial stage fan or compressor 38 located aft of the stator 40 at the inlet to passage 36 to force a minor portion of the airflow in the duct rearwardly through the passage at increased pressure.

The aft portion of the annular space between center body 22 and shell 26 forms a combustor 42 which is a passage in continuation of the forward air passage 36, and fuel is added at point 44. The products of combustion flow rearwardly into the first heat exchanger or mercury vaporizer 46, are reversed, and then flow forwardly as indicated by the arrows into a superheater 48. The gases flow forwardly into contact with feed water heater 50 and then laterally through discharge passages 52, mixing with the airflow through the duct and adding their remaining heat energy thereto. Since there is no gas turbine, there is no primary jet to produce the usual extremely high noise levels.

The mercury vapor produced in vaporizer 46 passes through conduit 54 to mercury turbine 28. The exhaust from the turbine, which is still largely vaporous, passes through conduit 56 to the second heat exchanger 58 where it is condensed by transfer of its heat of condensation to the water on the other side of the heat exchanger. This transfer in turn boils the water, and the resulting steam passes through conduit 60 to steam turbine 30. The liquid mercury flows through conduit 64 to reservoir 66, thence through conduit 68 to mercury pump 70, and finally through conduit 72 back to the mercury vaporizer 46.

The exhaust from turbine 30, containing the only remaining heat not used for mechanical work, passes through conduit 62 to condenser 74 which is located in the airflow produced in the duct 10 by compressor 16; and the heat of condensation is added to the energy of the airflow. The water condensed in condenser 74 then flows through conduit 76 to reservoir 78. From the reservoir it passes through conduit 80 to water pump 82 and thence through conduit 84 back to the heat exchanger 58. It will be noted that the heat exchanger 58 is housed entirely within the center body 22 so there is practically no heat loss to the air and no drag in the airflow.

The flow chart in FIG. 2 illustrates the operation as described above and needs no further explanation. The conduits leading to and from the superheater 48 and feedwater heater 50 have been omitted for clarity of illustration since the manner of arranging the flow paths is well known.

An auxiliary condenser 86, similar to condenser 74, is located ahead of compressor 16 and is flow connected to condenser 74 by conduit 88 having a control valve 90. It is also provided with a condensate flow return conduit 92 leading to water reservoir 78. This secondary condenser may be cut in when necessary to provide extra cooling for high-load and high-temperature conditions. Both of these condensers may have suitable acoustic surfaces to absorb noise generated by the compressor and emitted axially forwardly and rearwardly. Since these condensers are exposed to airflow whenever the powerplant is in operation, they provide the necessary cooling for ground runup etc. when there is no forward motion. This avoids the need for any type of ground cooling accessory.

It will be apparent that the system disclosed herein produces jet propulsion at reduced noise levels because the jet exhaust is cooler than that of a gas turbine and its velocity is less than that of a gas turbine. It is highly efficient because it produces a maximum of mechanical work per unit of fuel, and a minimum

of heat discharge. This, coupled with the feature of low pressure combustion, will result in less hydrocarbon and nitro-oxygen emissions. Moreover all of the radiated or rejected heat energy is added to the airflow within a confined zone to increase the net thrust. It is also possible to use the rejected heat for anti-icing, cabin heating, etc., in suitable installations, thus reducing the number of accessory heating devices which must be provided for modern airplanes.

Having thus described the invention, what is claimed as new and useful and is desired to be secured by U.S. Letters Patent is:

1. A jet propulsion system comprising a longitudinally extensive duct having a forward air inlet and an aft air outlet, and airflow-producing means located entirely within said duct; said means including axial flow compressor means and vapor turbine means for driving the compressor means, vaporizable working fluid means for operation of the turbine means; and heating means for vaporizing the working fluid means, said turbine means comprising a plurality of discrete turbines, each adapted for operation with a different working fluid; said vaporizable working fluid means comprising a plurality of different working fluids, each adapted for operation of one of said turbines; said working fluids having successively high boiling points; said heating means including a first heat exchanger flow connected to the working fluid having the highest boiling point to vaporize the fluid for operation of its associated turbine; a second heat exchanger flow connected to said highest boiling point fluid at the exhaust side of its associated turbine and also flow connected to the working fluid having the next highest boiling point to transfer heat from the first said fluid to the second said fluid and to condense the first said fluid and vaporize the second said fluid; and condenser means located in the airflow through the duct; said condenser means being flow connected to the lowest boiling point fluid at the exhaust side of its associated turbine and serving to liquefy vapor exhausted from said last-mentioned turbine and transfer the heat of condensation to the airflow.

2. A system as claimed in claim 1; the working fluids comprising a plurality of alkali metals.

3. A system as claimed in claim 1; the working fluids comprising mercury and at least one alkali metal.

4. A system as claimed in claim 1; the working fluids comprising water and at least one alkali metal.

5. A system as claimed in claim 1; the working fluids comprising water and mercury.

6. A system as claimed in claim 1; said heating means further including combustion means for combining a portion of the airflow through the duct with fuel to provide a source of heat; said first heat exchanger being connected to said combustion means for flow of the products of combustion through said first heat exchanger; and an additional heat exchanger connected to said first heat exchanger to receive the products of combustion therefrom and exhaust them into the airflow within the duct; said additional heat exchanger being also flow connected to the working fluid having the next highest boiling point to transfer a portion of the remaining heat of combustion to said fluid to superheat it.

7. A jet propulsion system comprising a longitudinally extensive duct having a forward air inlet and an aft air outlet; and elongate center body having a central longitudinal axis substantially centered on the longitudinal axis of the duct and located entirely within the duct; and axial flow compressor located within the duct to produce airflow from the inlet to the outlet thereof; power supply means for driving the compressor; said power supply means being located within the center body; said power supply means including a combustor to supply heated products of combustion; a heat exchanger to receive the products of combustion; and a plurality of discrete turbines connected in driving relation to the compressor; each turbine being adapted to operate with a different working fluid having successively higher boiling points; conduit means connecting the heat exchanger to a first one of said turbines for flow of the highest boiling point fluid thereto; a second heat

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exchanger flow connected to the exhaust side of the first said turbine and to the supply side of a second said turbine to condense the vapor of the first fluid and to vaporize the second fluid; condenser means located in the airflow through the duct; and second conduit means connected to the exhaust side of the last of said turbines to conduct vapor of the lowest boiling point fluid to the condenser means, said condenser means serving to liquefy vapor of said lowest boiling point fluid and transfer the heat of condensation to the airflow to increase its energy content; and means to discharge the products of combustion from the first said heat exchanger into the airflow within the duct to further increase its energy content.

8. A system as claimed in claim 7; said turbines being connected in axial alignment to a common drive shaft substantially coaxial with said duct.

9. A system as claimed in claim 7; said condenser means extending at least partially across said duct and being located downstream of the compressor to add its heat energy to the air after it has passed through the compressor.

10. A system as claimed in claim 9; said condenser means being in the form of annulus and surrounding said center body.

11. A system as claimed in claim 7; and second condenser means extending at least partially across said duct upstream of

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the compressor and adapted to be flow connected to the exhaust from the turbine means to provide additional cooling during high-power and high-temperature conditions.

12. A system as claimed in claim 7; and a combined supply fluid preheater and vapor superheater for the lower boiling point fluid located adjacent to the first said heat exchanger; the means for conducting products of combustion from the combustor to the duct passing successively through the first said heat exchanger and the combined preheater and superheater.

13. A system as claimed in claim 12; said combustor being in the form of a passage within the center body and surrounding said combined preheater and superheater and exiting into the first said heat exchanger.

14. A system as claimed in claim 13; a forward air passage within the center body and surrounding the turbines and having an inlet adjacent to the compressor and an outlet communicating with the combustor passage; and said compressor having a partial stage for forcing air at high velocity into said forward air passage.

15. A system as claimed in claim 7; and acoustic surfaces on portions of the outer wall of the center body and the inner wall of the duct to absorb sound generated by the compressor.

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