United States Patent

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[54] **VAPOR GENERATOR**
4 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **60/73,**
122/479, 60/102, 60/104, 60/105
[51] **Int. Cl.** **F01k 7/16**
[50] **Field of Search** 60/73, 102,
104; 122/479, 479A

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ABSTRACT: An improved marine vapor generator of the type which includes a reheater and the means for tempering the heating gases flowing toward the reheater. The tempering means operates to control the reheater outlet steam temperature during ahead operation and to protect the reheater tube metal during astern operation of the ship propulsion system. The tempering means includes a duct arranged to discharge a regulable quantity of heated combustion air into the heating gases flowing toward the reheater. An alternative arrangement uses unheated combustion air as the tempering agent. A third arrangement uses low temperature gases as the tempering agent and includes a gas recirculating fan.

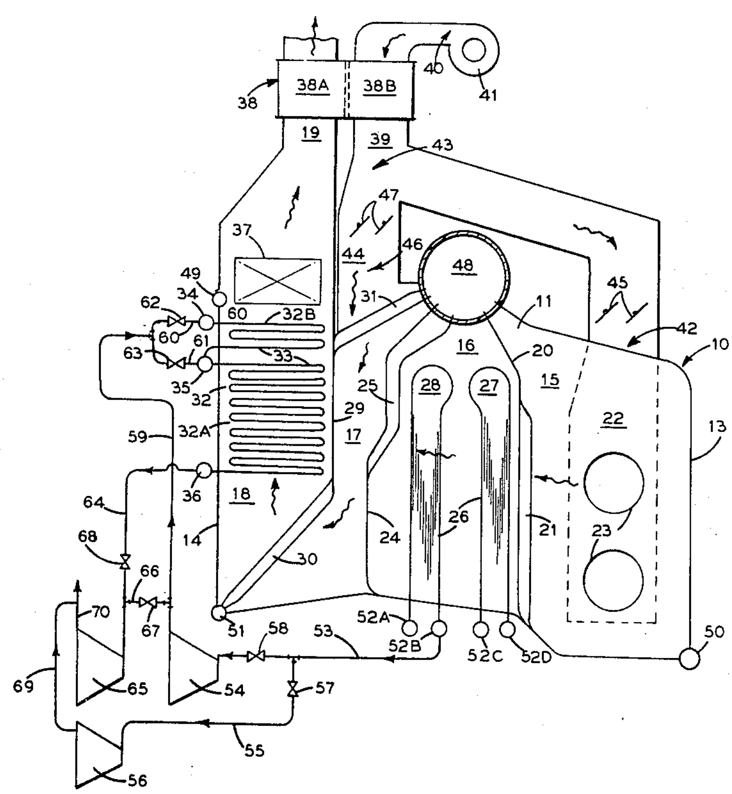

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FIG. 3

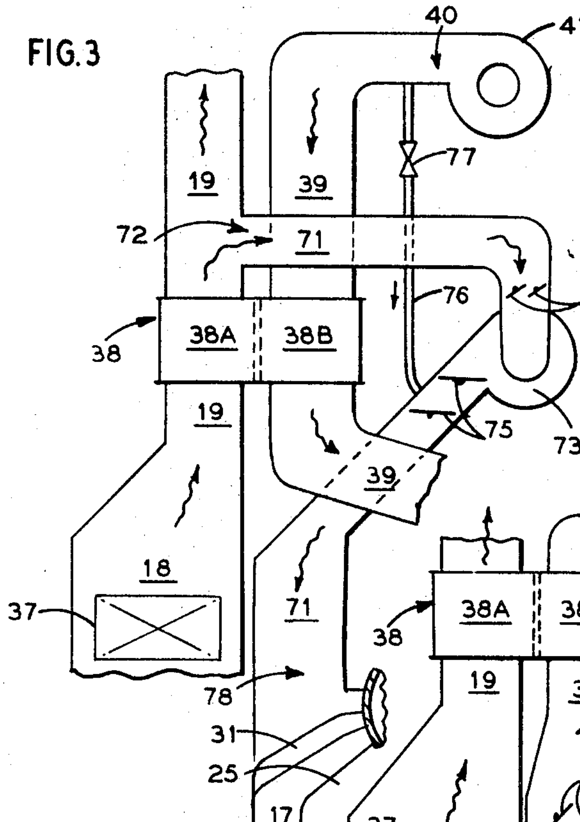


FIG. 2

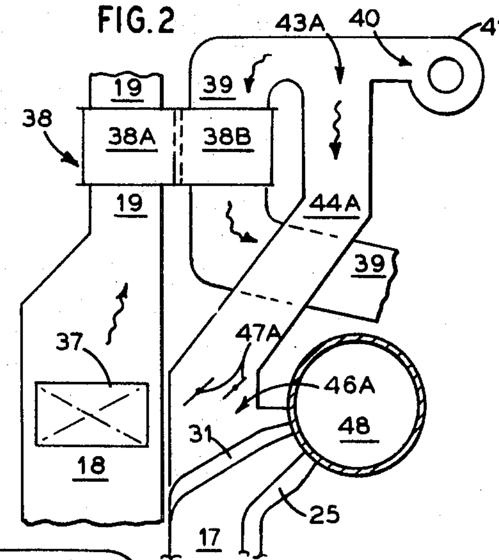
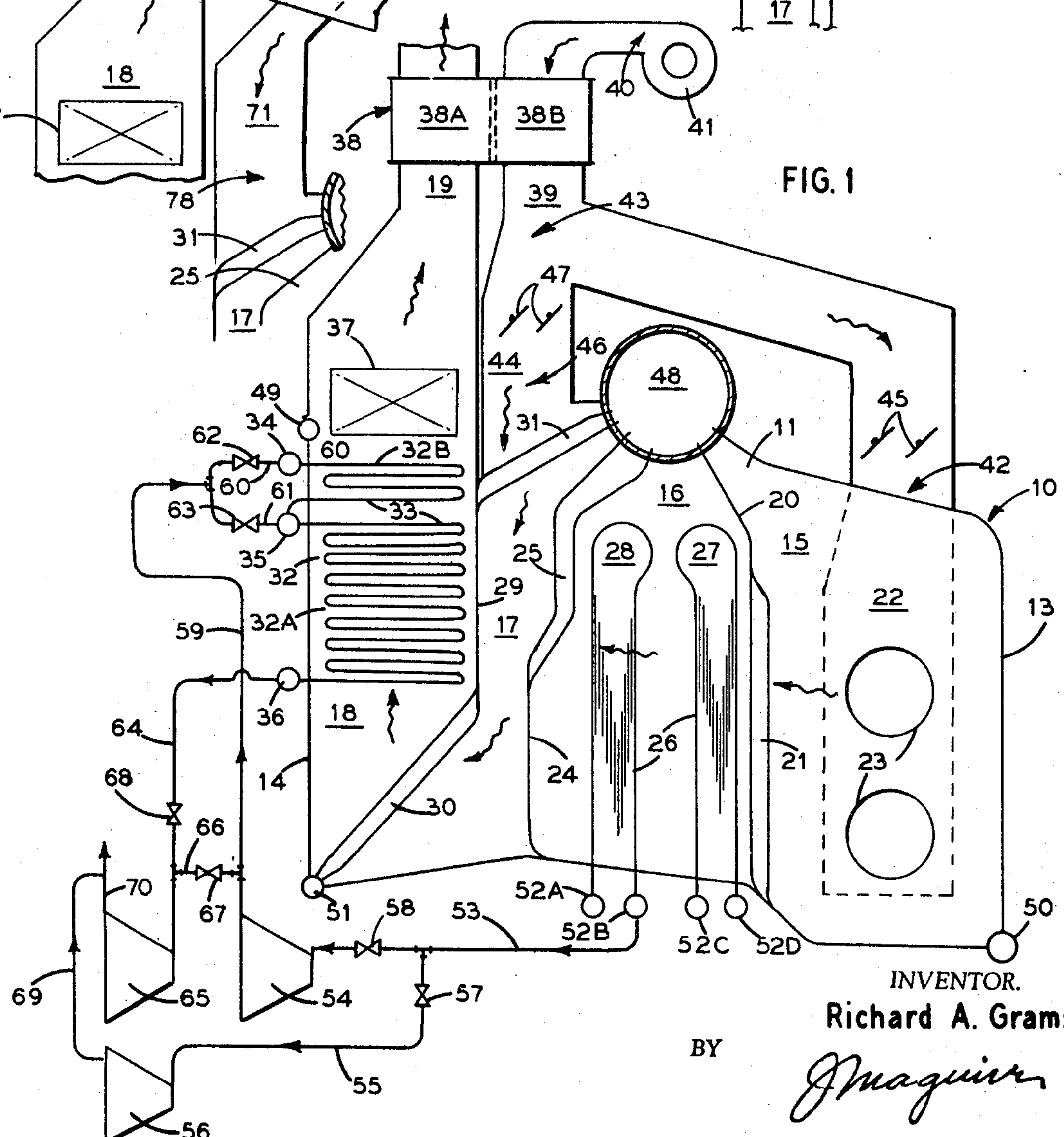


FIG. 1



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VAPOR GENERATOR

The invention relates to a ship propulsion system and more particularly to marine-type vapor generators equipped with a reheater and the means for controlling the temperature of the flue gases passing over the said reheater.

The reheating of steam between turbine stages is well recognized as a desirable step in obtaining the high efficiencies required of today's power plant systems, however, the application of the reheat principle to a ship's propulsion system introduces certain factors which are not normally encountered in stationary installations. One such factor is the practice of excluding the reheat system from the steam cycle during astern operation, certain types of maneuvering and during in-port operation of the ship's power plant.

Heat exchanger surface intended for the superheating or reheating of steam is normally located in zones where operating gas temperatures are far above recognized design temperature use limits for metals, however, such use is made possible by the cooling effect on the metal derived from steam passing through the tubes of these heat exchangers. A problem arises during astern operation, maneuvering and in-port operation when no steam is being passed through the reheater, thereby producing a condition where tube metal temperatures will exceed safe design limits unless remedial measures are taken. One manner of overcoming this problem has been to locate the reheater in one of two parallel gas passes and to provide dampers for preventing the flow of hot combustion gases over the reheater when the latter is not in use, as is shown in U.S. Pat. No. 3,280,559.

The present invention eliminates the requirement of parallel gas passes and the dampers in high gas temperature locations associated with these gas passes, and provides protection for a reheater by introducing a low temperature gaseous fluid into the heating gas stream ahead of the reheater, thereby lowering the gas temperature to an acceptably safe limit before it enters the reheater gas pass. The low temperature gaseous fluid may be combustion air taken from the air inlet duct or flue gas taken from the gas stream either before or after the air preheater. This combustion air or flue gas is introduced into a convection gas pass at a position between the superheater and reheater gas passes, and combines with the heating gases being discharged from the superheater gas pass to lower the temperature of these heating gases prior to their entering the reheater gas pass.

A primary object of the invention is to provide reheater tube metal protection during astern operation, maneuvering and in-port operation when no steam is being passed through the reheater. This is achieved by introducing sufficient quantities of low temperature gaseous fluid into the convection gas pass so as to lower the temperature of the heating gases to a value commensurate with the allowable temperature use limits of the reheater tube metal.

Another object of the invention is to provide means for protecting the reheater metals without imposing a difficult or impossible control problem respecting the superheater steam temperature. This is accomplished by locating the mixing point of the low temperature gaseous fluid with the heating gases downstream, gas flowwise, of the superheater surface. It can be readily seen that if steam generating apparatus of the general type disclosed by applicant should have this mixing point upstream, gas flowwise, of all or part of the superheater surface, that superheater or part of it would be exposed to mass gas flows and temperatures that would differ substantially for astern and forward operation at equal firing rates. Obviously this would impose a most difficult operating burden on the system for controlling superheater steam temperature over the unit's load range.

A further object of the invention is the control of reheat steam temperature during normal ahead operation when steam is passed through the reheater by regulating the temperature of the heating gases entering the reheater gas pass. This is accomplished by controlling the quantity of flue gas or combustion air being introduced into the convection gas pass for mixing with the heating gases.

In the drawings:

FIG. 1 is a diagrammatic sectional side view of an improved vapor generator having steam lines from the generator connecting to the forward and astern turbine drives and using combustion air as the low temperature gaseous fluid.

FIG. 2 is a partial diagrammatic side view showing an alternate source for the combustion air used as low temperature gaseous fluid in the vapor generator of FIG. 1.

FIG. 3 is a partial diagrammatic side view using flue gas as the low temperature gaseous fluid in the vapor generator of FIG. 1.

Referring to FIG. 1 there is shown a boiler setting **10** comprising a front wall **11** and a rear wall **12** (not shown) and sidewalls **13** and **14**. The setting is partitioned into a furnace chamber **15**, a superheater gas pass **16**, a convection gas pass **17** and a reheater gas pass **18** which extends to an outlet gas pass **19**. Furnace chamber **15** is defined by sidewall **13** and sections of front and rear walls **11** and **12** and a partition wall **20** which has a staggered tube section forming a screened inlet **21** to the superheater gas pass **16**. The furnace section of front wall **11** includes the windbox **22** and associated front wall openings **23** to accommodate the fuel burning equipment (not shown).

The superheater gas pass **16** is defined by partition wall **20** and sections of front and rear walls **11** and **12** and a partition wall **24** which has a staggered tube section forming a screened first inlet **25** to the convection gas pass **17**. The superheater gas pass **16** contains the entire superheater heat exchanger surface composed of upright generally U-shaped tubes **26** spaced across the whole width of the gas pass and comprising a primary superheater **27** and a secondary superheater **28**, serially arranged in that order in the direction of gas flow.

Convection gas pass **17** is a vertically elongated pass disposed intermediate of and laterally adjoining superheater gas pass **16** and reheater gas pass **18** and is defined by partition wall **24** and sections of front and rear walls **11** and **12** and a partition wall **29** which has a staggered tube lower section forming a screened outlet **30** and a staggered tube upper section forming a screened second inlet **31**.

Reheater gas pass **18** is a vertically elongated pass adjacently parallel to convection gas pass **17** and defined by partition wall **29** and sections of front and rear walls **11** and **12** and sidewall **14**. Reheater gas pass **18** includes a reheater **32** comprising sinuous tubes **33** forming a main tube bank **32A** and an auxiliary tube bank **32B**, both banks being disposed across the width of the gas passage. Inlet header **34** connects to the inlet end of tube bank **32B**, intermediate header **35** connects to the outlet end of tube bank **32B** and the inlet end of the tube bank **32A** and outlet header **36** connects to the outlet end of tube bank **32A**. The reheater gas pass **18** may also include other heat exchange surface, for example, the economizer **37** located downstream gas flowwise of reheater **32**.

Outlet gas pass **19** is a vertically elongated gas pass located above and in communication with the outlet of reheater gas pass **18**. The outlet gas pass **19** is associated with the gas side **38A** of a regenerative-type air heater **38**.

Air inlet duct **39** forms a passage having an inlet end **40** connected to a forced draft fan **41**, and an outlet end **42** connected to the windbox **22**. Air inlet duct **39** is associated with the air side **38B** of regenerative air heater **38** and includes flow control dampers **45** located near the first outlet end **42** adjacent windbox **22**.

Tempering duct **44** forms an interconnecting passage between the air inlet duct **39** and the convection gas pass **17**, by having its inlet end **43** connected to air duct **39** at a point downstream air flowwise of air heater **38** and its discharge end **46** connected to the convection gas pass second inlet **31**. Flow control dampers **47** are included in the tempering duct.

The steam generating and heating sections of the boiler include a steam drum **48**, a collection header **49** and supply headers **50** and **51**. For the sake of clarity, additional headers, risers, downcomers and the connecting steam piping between drum **48** and superheater headers **52A**, **52B**, **52C** and **52D** are not shown since the physical arrangement of these is conventional and not part of the invention, as such.

Steam supply line **53** connects the outlet header **52B** to the inlet side of a forward drive high-pressure turbine **54**. A steam supply auxiliary line **55** connects the inlet side of an astern drive high-pressure turbine **56** to the steam line **53**. Shutoff valves **57** and **58** are located downstream flowwise of the juncture point between steam lines **53** and **55**. A steam exhaust line **59** connects the outlet side of high-pressure turbine **54** to reheater inlet header **34** by way of line **60** and to reheater intermediate header **35** by way of line **61**. Shutoff valves **62** and **63** are located in the lines **60** and **61**, respectively. A steam supply line **64** connects the reheater outlet header **36** to the inlet side of a forward drive low pressure turbine **65**. A crossover steam line **66** interconnects steam lines **59** and **64** and includes a shutoff valve **67**. Steam line **64** includes a shutoff valve **68** located upstream flowwise of the crossover line **66**. Steam exhaust lines **69** and **70** extending from the outlet end of turbines **56** and **65**, respectively, discharge into a condenser (not shown).

Referring to FIG. **2** there is shown the upper end of reheater gas pass **18** which includes the economizer **37** and communicates with the outlet gas pass **19**. The forced draft fan **41** connects for discharge into inlet **40** of the air inlet duct **39**. Regenerative air heater **38** has its gas side **38A** associated with the outlet gas pass **19** and its air side **38B** associated with the air inlet duct **39**. A tempering duct **44A** has its inlet end **43A** communicating with the air inlet duct **39** at a point upstream air flowwise of the air heater **38** and an outlet end **46A** discharging into convection gas pass **17** through screened second inlet **31**. Flow control dampers **47A** are located near the outlet end of the tempering duct. Included in this view is a showing of steam drum **48** and the upper portion of screened first inlet **25**.

Referring to FIG. **3** there is shown the upper end of reheater gas pass **18** which includes the economizer **37** and communicates with the outlet gas pass **19**. The forced draft fan **41** connects for discharge into inlet **40** of the air inlet duct **39**. Regenerative air heater **38** has its gas side **38A** associated with the outlet gas pass **19** and its air side **38B** associated with the air inlet duct **39**. A tempering duct **71** has its inlet end **72** communicating with the outlet gas pass **19** at a point downstream gas flowwise of the air heater **38**, and its outlet end **78** discharging into convection gas pass **17** through screened second inlet **31**. A fan **73** of the type used to recirculate flue gases is operatively associated with the tempering duct **71**. Flow control dampers **74** disposed upstream of fan **73** are used to regulate the quantity of gas flowing through tempering duct **71**. Gastight dampers **75** are arranged to close to prevent the reverse flow of gases when the fan **73** is shut down or inoperative. A seal air line **76** supplies pressurized air to the space between the dampers **75** and creates a pressure seal when these dampers are in their closed position. A shutoff valve **77** is included in the seal air line **76**.

In the normal ahead or forward operation of the ship propulsion system, the steam-water fluid flow path through the vapor generator and associated turbines shown in FIG. **1** is as follows: A controlled quantity of feedwater is admitted to economizer **37** and is convectively heated by the flue gases flowing over the tubes. The heated water is then introduced in steam drum **48** to maintain a predetermined water level. A natural circulation cycle takes place whereby water from steam drum **48** is circulated through downcomers (not shown) to supply headers **50** and **51** etc. The water leaving the supply headers is heated, becoming a steam-water mixture during its passage upwardly through the tubes of front and rear walls **11** and **12**, sidewalls **13** and **14** and partition walls **20**, **24** and **29**. The steam-water mixture is returned to steam drum **48** directly from the partition walls and enclosure walls. The saturated steam leaving drum **48** is conveyed through appropriate piping (not shown) to be passed serially through the primary and secondary superheaters **27** and **28**. These superheater sections are arranged for series flow and may include an attemperator (not shown) between the primary superheater outlet header **52C** and the secondary superheater inlet header **52A** for superheated steam temperature control. The superheated steam upon leaving the secondary superheater outlet header **52B** is conveyed by supply line **53** to the forward drive high-pressure turbine **54**, shutoff valve **58** being in a wide open position. Shutoff valve **57** in supply line **55** is in the closed position to prevent the flow of superheated steam to the astern drive turbine **56**. Steam leaving the forward drive high-pressure turbine **54** is conveyed by exhaust line **59** to be selectively introduced into reheater **32** through the inlet header **34** and/or the intermediate header **35**. This dual steam entry arrangement into the reheater offers a means of controlling the reheat steam temperature by varying the amount of reheater heating surface through which steam is being passed. Thus, the reheat outlet steam temperature may be increased by introducing all of the steam through inlet header **34** and passing it through banks **32B** and **32A** or, conversely, it may be reduced by introducing the steam through intermediate header **35** and passing it only through bank **32A**. As will be observed it is also possible to pass steam in proportionate amounts into both headers **34** and **35** simultaneously. The reheated steam leaving the outlet header **36**, is conveyed by supply line **64** to the forward drive low pressure turbine **65**. Steam leaving turbine **65** discharges through exhaust line **70** is condensed and returned to the condensate system (not shown) for use as feedwater for the vapor generator.

During normal ahead or forward operation of the steam propulsion system, the steam-water fluid flow path for the vapor generator and turbines associated with the alternative arrangements shown in FIGS. **2** and **3** remain the same as that described in FIG. **1**.

During normal astern operation of the ship propulsion system, the steam-water fluid flow path for the vapor generator and turbines shown in FIG. **1** differs from normal ahead or forward operation in that upon leaving secondary superheater **28**, the steam is directed to a high-pressure condensing-type turbine **56**, normally referred to as an astern turbine, and whose direction of rotation is opposite from that of turbine **54** which is used for ahead operation. Since for this service there customarily is no flow through the reheater, the steam leaving the astern turbine is condensed and returned to the condensate system (not shown) for use as feedwater for the vapor generator.

During normal astern operation of the ship propulsion system, the steam-water fluid flow path for the vapor generator and turbines associated with the alternative arrangements shown in FIGS. **2** and **3** will be the same as that described for FIG. **1**.

In accordance with the present invention, during normal ahead and astern operation of the ship propulsion system, the combustion gas path for the vapor generator shown in FIG. **1** is as follows: The forced draft fan **41** supplies combustion air to the inlet end **40** of the air inlet duct **39**, the combustion air is heated as it passes through the air side **38B** of regenerative air heater **38**. Depending on the position of the flow control dampers, a portion of the combustion air flowing in air inlet duct **39** downstream air flowwise of air heater **38** may be admitted through inlet **43** to the tempering duct **44**, the remainder of the combustion air being regulated by the control dampers **45** for discharge through inlet **42** into the windbox **22**. The combustion air is introduced through burner openings **23** to mix with the burning fuel and the resultant heating gases transfer a portion of their heat content to the water cooling tubes lining furnace enclosure **15**, thereafter, the heating gases are discharged through screened inlet **21** into superheater gas pass **16** where heat from the gases is transferred to the superheater and saturated wall enclosure surfaces. From passage **16** the heating gases are discharged through screened first **25** into the convection gas pass **17**. While in this convection gas pass, the heating gases mix with that portion of the combustion air which is being discharged from tempering duct **44** through the screened second inlet **31** and the resultant mixture of heating gases and air is directed downwardly toward screened outlet **30** with heat being transferred to a portion of the water cooled enclosure walls of passage **17**. The gases discharging into reheater gas pass **18** are directed upwardly across reheater **32** and economizer **37** with heat being transferred to the reheater, the economizer and the saturated wall enclosure surfaces. The gases emerging from passage **18** discharge into the outlet gas pass **19** and flow through the gas side **38A** of the air heater **38** wherein heat is transferred to that portion of air heater surface for subsequently raising the temperature of the incoming air when the surface is rotated to the air side **38B**.

During the normal ahead operation of the ship propulsion system, reheater outlet steam temperature is controlled by modulating the control dampers **47** thereby varying the quantity of air supplied and consequently the temperature of the heating gases and air mixture entering the reheater gas pass **18**, since the temperature of the air supplied via duct **44** is lower than the temperature of the combustion gas leaving screened inlet **25**. A closing of dampers **47** will decrease the quantity of combustion air being admitted to gas passage **17** thus reducing the cooling effect of the air on the heating gases entering the gas pass **17**, the combined flow of air and gas entering gas pass **18** resulting in a rise in reheat steam temperature for equivalent steam flows. The converse effects will result from an opening of the dampers **47** with the accompanying increase in the quantity of combustion air admitted to gas passage **17**.

During astern operation of the ship propulsion system there will be no steam flow through the reheater **32** with the result that the tube metal temperature will closely approximate the temperature of the gases flowing past the reheater **32**. It therefore becomes absolutely essential to limit the temperature of the gases entering the reheater gas pass **18** to safe allowable operating limits for tube metal temperature. The present invention accomplishes this by the opening of the control dampers to admit sufficient combustion air into the convection gas pass **17** to reduce the temperature of the heating gases to the required limits.

During normal ahead and astern operation of the ship propulsion system, the combustion air and gas path for the vapor generator associated with the alternative arrangement shown in FIG. **2** will be the same as that described for FIG. **1**, with the exception that the portion of combustion air being admitted to tempering duct **44A** will be taken from the air flowing in air inlet duct **39** upstream air flowwise of air heater **38**.

During normal ahead and astern operation of the ship propulsion system, the combustion air and gas path for the vapor generator associated with the alternative arrangement shown in FIG. **3** will be the same as that described for FIG. **1**, with the following exceptions: All of the combustion air is delivered to the windbox **22** since the alternative arrangement does not have a tempering duct connected to the air inlet duct **39**. A portion of relatively low temperature gases passing through the outlet gas pass **19** is directed into the tempering duct inlet end **72** located downstream flowwise of regenerative air heater **38**. This portion of low temperature gases is conveyed by tempering duct **71** through the second inlet screen **31** into convection gas pass **17**. The fan **73** provides the necessary suction and discharge pressures to maintain a positive flow of low temperature gases from the outlet gas pass **19** to the convection gas pass **17**. Whenever fan **73** is not operating, the gas tight dampers **75** will be in a shut position and the seal air line shutoff valve **77** will be open to introduce pressurized air into the space between the dampers **75** thereby preventing any reverse flow of gases through tempering duct **71**.

I claim:

1. In a ship propulsion system wherein superheated and reheated steam is selectively supplied to a forward drive turbine and only superheated steam to an astern drive turbine, the combination with the propulsion system of a vapor generator comprising:

walls defining a setting;

partition wall means dividing the setting into a furnace, a superheater gas pass laterally adjoining the furnace and arranged to receive all of the furnace gas outflow, a reheater gas pass, and a vertically elongated convection gas pass disposed intermediate and laterally adjoining the superheater and reheater gas passes and arranged for gas discharge through an outlet at the lower end portion of the reheater gas pass, said convection gas pass having adjacent first and second inlets at the upper end portion thereof, said first inlet being arranged to receive all of the gas outflow from the superheater gas pass;

an outlet gas pass arranged to receive all of the gas outflow from the reheater gas pass;

at least one bank of superheater tube banks positioned in the superheater gas pass;

a plurality of fluid heating tube banks including at least one reheater tube bank positioned in the reheater gas pass, said reheater tube bank being arranged upstream gas flowwise of the remaining fluid heating tube banks in said reheater gas pass;

firing means associated with said furnace to produce heating gases for flow through the setting;

a forced draft fan;

an air inlet duct connected to the forced draft fan for delivering combustion air to said firing means; and

tempering means for introducing a low temperature gaseous fluid through the second inlet of the convection gas pass, said tempering means including a tempering duct flow-connecting the air inlet duct to the second inlet of said convection gas pass.

2. A ship propulsion system according to claim **1** wherein the tempering duct includes a damper for regulating the quantity of flue gas passing therethrough.

3. A ship propulsion system according to claim **2** wherein the air inlet duct includes heat exchange means for heating the combustion air, the tempering duct being flow-connected to the air inlet duct downstream air flowwise of said heat exchange means.

4. A ship propulsion system according to claim **2** wherein the air inlet duct includes heat exchange means for heating the combustion air, the tempering duct being flow-connected to the air inlet duct upstream air flowwise of said heat exchange means.