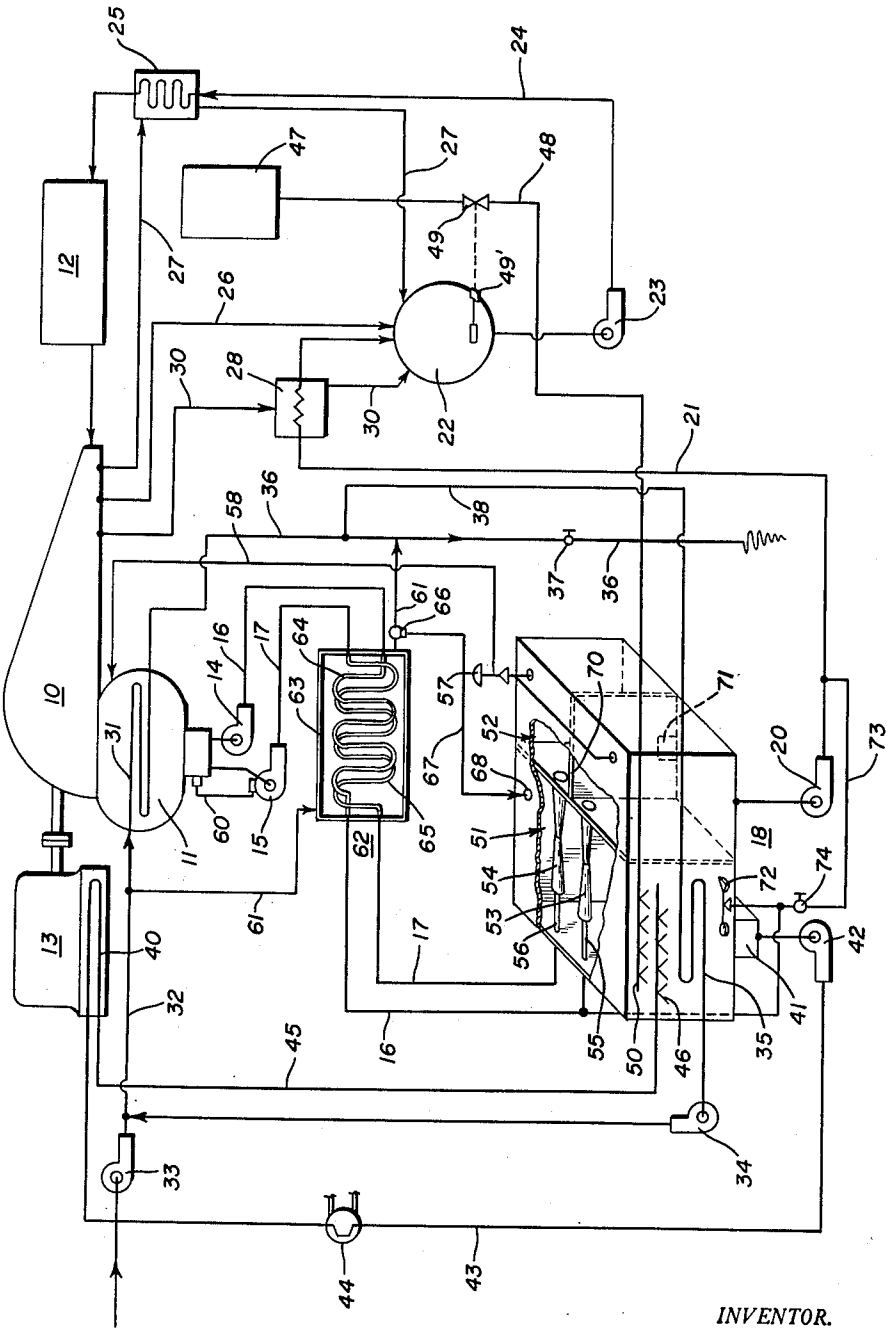
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STEAM DRIVE PRIME MOVER SYSTEM

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STEAM DRIVE PRIME MOVER SYSTEM

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4 Claims. (Cl. 60—95)

This invention relates to the regenerative heat cycle in steam-driven, turbo-electric generating plants, and particularly to high-efficiency, super-regenerative, heat closed-cycle systems of the type disclosed and claimed in my co-pending application, Serial No. 66,374, filed December 20, 1948, now Pat. No. 2,707,239. The present invention is an improvement on the invention of the said application and may be called a compound super-regenerative heat cycle.

In the aforesaid application there is disclosed and claimed a closed-cycle steam turbo-electric generating system wherein sensible heat of the condenser cooling water circuit is employed to convert water into vapor at subatmospheric pressure. The vapor is generated in a chamber maintained at subatmospheric pressure conditions by the operation of one or more jet pumps utilizing the kinetic energy of large volume condensate flow pumped from the hot well of the condenser by one or more pumps. The jet pumps discharge into a second container or chamber maintained at a pressure substantially higher than the first chamber; by this operation, the vapor is condensed and the latent heat converted into sensible heat by the admixture with discharged condensate. This system effectively uses heat otherwise wasted through a cooling water circuit to a cooling tower, spray pond, or other heat dissipating means and results in increased efficiency for the over-all system.

It is an object of the present invention to provide a closed-cycle, steam-generating system of the foregoing type including an improved arrangement for further increasing the utilization of available heat in the system. Further objects and advantages of this invention will become apparent as the following description proceeds, and the features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In carrying out the objects of this present invention, in one embodiment thereof, a closed-cycle, steam, turbo-electric generating system of the type disclosed in the aforesaid application is provided with a cooling water bypass around the condenser cooling coils and a heat exchanger is associated with the bypass and with the conduits carrying condensate from the condenser hot well to the jet pumps. In this heat exchanger, heat is transferred from the hot condensate to the bypassed cooling water and the condensate is thereby subcooled. The operation of the jet pumps by use of the subcooled condensate results in maintaining a substantially lower absolute pressure and temperature in the cooling or vaporizing chamber. The pressure will be lower than that in the main condenser and there results an effective increase in the net efficiency of the system. The pressure within the evaporating chamber is maintained substantially constant at a predetermined low value by automatically controlling the rate of flow of cooling water through the heat exchanger in the bypass.

For a better understanding of the invention, reference may be had to the accompanying drawing, the single figure of which is a schematic diagram of a closed-cycle, steam turbo-electric generating system embodying the present invention.

Referring now to the drawing, there is illustrated a steam turbine **10** and a surface condenser **11** and a boiler **12** connected in a closed circuit. The turbine is coupled to drive an electric generator **13**. The closed circuit includes condensate pumps **14** and **15** connected in parallel to supply hot condensate through conduits **16** and **17** to a heat conserving unit **18**. Condensate from the unit **18** is supplied by a pump **20** and a conduit **21** to deaerator **22** in which it is returned to a boiler **12** by operation of a pump **23**, discharging through a conduit **24** and feed water heater **25**. Bleed steam is supplied to heat the deaerator through a conduit **26** and also through a conduit **27**, which supplies the preheater **25**. The condensate supplied to the deaerator through the line **21** is heated in a preheater **28** by steam bled from an intermediate stage of the turbine through a conduit **30**; the condensed bleed steam is conducted to the deaerator from the preheater.

A cooling water circuit is provided to cool the condenser **11**. The cooling water circuit for the condenser includes a cooling coil **31** in the condenser which is supplied with cooling water through a conduit **32** by operation of pumps **33** and **34**. The pump **33** supplies the main cooling water from a suitable make-up water source and the pump **34** supplies recirculated, cooled water from a coil **35** in the heat conserving unit **18**. A major portion of the water heated by absorption of heat in the condenser is discharged through a conduit **36** with the water from the bypass **61** under control of a manual valve **37**; the remaining portion flows through a conduit **38** to the cooling coil **35** of the unit **18**.

The generator **13** is air or hydrogen cooled, the gas being passed over a cooling coil **40** in the generator casing. Cooling water is supplied to the coil **40** from a sump **41** of the unit **18** by operation of a pump **42** connected to the coil by conduit **43**. An oil cooler **44** is connected in the conduit **43** for cooling the lubricant for the generator and turbine bearings. The cooling water heated in the coil **40** is returned to the unit **18** through a conduit **45** and a spray head **46** within the casing of the unit. Make-up water may be supplied to the heat conserving unit **18** from a high-level storage tank **47** through a conduit **48** and a spray head **50** within the unit casing. The flow of water through the conduit **48** is controlled by a valve **49**, actuated by water level control **49'** in the deaerator **22**.

The operation of the unit **18** is to conserve heat and return it to the primary system, the same as that disclosed in the aforesaid co-pending application. The unit **18** comprises a first chamber **51** in which the sprays **46** and **50** are arranged and a second chamber **52** from which condensate is returned to the system by operation of the pump **20**. Condensate from the condenser is delivered through the conduits **16** and **17** into two jet pumps **53** and **54** respectively, through nozzles **55** and **56**. The pumps **53** and **54** have their vapor inlets in the chamber **51** and their outlets in the chamber **52** and by their operation utilize the kinetic energy of the large mass flow of condensate to maintain a low subatmospheric pressure in the chamber **51**; and water in the chamber **51** is evaporated by the heat extracted from coil **35** and effectively cools the water in the coil. The second chamber is maintained at a relatively low pressure but above the vapor pressure of the water or condensate at the conditions of discharge from the jet pumps. This substantially prevents evaporation in the second chamber and assures condensation of the vapor discharge reaching the chamber through the jet pumps. The required pressure is maintained by operation of an automatic differential pressure valve **57** con-

nected in a line 58 between the top of the chamber 52 and the condenser 11.

During their operation, the jet pumps withdraw vapor from the chamber 51 and discharge condensate and vapor into the chamber 52 under the increased back pressure conditions; thus, the vapor is condensed and the resulting conversion of latent to sensible heat increases the temperature of the condensate in the chamber 52. The pump 14 and jet pump 55 normally are operated continuously; the pump 15 and jet pump 56 are operated when the level of condensate in the condenser rises to a predetermined value at which time a sensing water level control 60 initiates operation of the pump 15 and maintains it in operation until the normal level of condensate is restored.

In order to increase further the effectiveness of the system, and to return more heat to the primary closed circuit, an arrangement is provided for subcooling the condensate delivered by the pumps 14 and 15. This makes it possible to maintain pressures in the evaporator chamber 51 below the pressure in the condenser which produces large terminal differences and permits condensate to be cooled to a lower temperature. In the embodiment illustrated, a cooling water bypass 61 is connected between the discharge side of the cooling water pump 33 ahead of condenser and the condensing cooling water coil and discharge line 36, and a heat exchanger 62 is provided to transfer heat from the condensate water flowing in the conduits 16 and 17 to the bypass cooling water in conduit 61. The heat exchanger 62 comprises a housing 63 connected in the bypass conduit 61 and its extended surface coils 64 and 65 are arranged within the housing and connected in the conduits 16 and 17, respectively.

The flow of cooling water through the casing 63 of the heat exchanger 62 is controlled by an automatic valve 66 connected by control line 67 to a sensing control 68 responsive to a condition of the vapor within the chamber 51. Control 68 has, by way of example, been shown as responsive to the temperature of the vapor in the chamber and, by operating the valve 66, maintains a predetermined substantially constant temperature within the chamber 51 and thereby maintains the corresponding pressure in the chamber at a predetermined selected value. It is thus apparent that by controlling the rate of flow of cooling water through the bypass conduit 61 in accordance with the conditions within the chamber 51, it is possible to maintain the heat conserving unit 18 in operation with a lower operating pressure within the chamber 51, which absolute pressure may be less than that maintained within the condenser 11. As a result of this decreased pressure maintained in the chamber 51, more water may be evaporated in the chamber and a greater quantity of latent heat removed from the condenser cooling water to the coil 36 and converted to sensible heat within the chamber 52. By providing both the heat transfer surfaces 64 and 65 in a common heat exchanger or casing 63, the conditions within the chamber 51 are maintained at their substantially constant value regardless of the number of pumps 14 and 15 in operation. This provides a simplifier arrangement requiring but a single control valve equipment for any number of condensate pumps.

The chamber 52 is provided with a partition 70 forming separate pump discharge compartments each vented through the valve 57 at line 58 and which are in communication below the liquid level at the bottom through an opening 71. In order to prevent lowering of the water level in the chamber 51 below a predetermined minimum, a float control 72 is provided to supply condensate from the conduit 16 whenever the level reaches the predetermined minimum; condensate may also be supplied to the valve 72 from the pump 20 through line 73 when a manual valve 74 is opened.

The heat exchanger 62 operates to provide colder condensate at the jet pumps and in the outlet from the unit 18. The heating of this condensate by bleed steam in the preheater 28 retains the heat in the primary condensate circuit while reducing the amount of latent heat to be

removed by the main condenser cooling coil; this latent heat removed by the condenser coil is normally wasted through the main condenser cooling water discharge line 35. This reduction in the total amount of steam to be condensed in the condenser with respect to the total amount of steam supplied to the turbine is a direct economy and improves the overall heat cycle.

At certain times when the operating conditions of the system do not require precooling of the condensate to maintain the required pressures in the unit 18, the automatic control 68 will stop the flow of condensate through the bypass 61. During normal operation, the control 68 maintains uniform temperature conditions in the evaporator chamber 51 and the cooling water supplied to the generator coil 40 is at uniform temperature; this provides ideal working conditions for the generator and minimizes difficulties which may otherwise arise because of expansion and contraction due to wide temperature changes.

For purposes of illustration and not by way of limitation but solely as an example the following data indicate the operating characteristics of a 100,000 kilowatt turbo generator system embodying the invention:

Steam supply to turbine, B. t. u. per hour	895,200,000
Heat gain in make-up water (spray 50), B. t. u. per hour	14,200,000
Generator cooler loss (spray 46), B. t. u. per hour	6,830,000
Total (neglecting oil cooler), B. t. u. per hour	21,030,000
Temperature of condensate, ° F	101
Condensate to jet pumps, pounds per hour	487,000
Temperature of jet pump discharge, ° F	123.3
Jet compression	3.74 to 1
Pressure in condensers, Hg	2″
Pressure in chamber 51, Hg	1″
Pressure in chamber 52, Hg	3.74″
Heat loss to circulating water, B. t. u. per hour	10,200,000
Net gain, B. t. u. per hour	[1] 10,830,000

[1] Or 1.21%.

From the foregoing it is apparent that this invention provides a simple and effective arrangement for securing increased efficiency in regenerative cycle steam systems such as those of the aforesaid copending application.

While the invention has been described in connection with a specific turbo-electric steam system various other applications and modifications will occur to those skilled in the art. Therefore it is not desired that the invention be limited to the specific details illustrated and described and it is intended by the appended claims to cover all modifications which fall within the spirit and scope of the invention.

I claim:

1. In a steam-driven prime mover system including a boiler and a turbine and a condenser connected in a closed circuit, and a cooling water circuit for said condenser, a heat conservation apparatus including means providing first and second closed chambers, a jet pump connecting said chambers and having an inlet in communication with the first chamber and an outlet for discharge into the second chamber, means for forcing condensate from said condenser through said jet pump to maintain a subatmospheric pressure in said first chamber, means for supplying water to said first chamber to be evaporated therein, means for bypassing cooling water around said condenser, heat exchange means arranged to transfer heat from the condensate supplied to said jet pump to the cooling water in said bypassing means for subcooling the condensate supplied to said pump whereby a lower pressure may be produced in said first chamber than in said

condenser, means for maintaining a subatmospheric pressure in said second chamber higher than the vapor pressure of the water discharged by said jet pump, and means for returning to the condensate portion of said closed circuit water heated in said second chamber by operation of said pump.

2. A steam-driven prime mover system including a heat conservation apparatus as set forth in claim 1, including means responsive to a condition of the vapor in said first chamber for controlling the rate of flow of cooling water through said bypass means to maintain the pressure in said first chamber substantially constant.

3. In a steam-driven prime mover system including a boiler and a turbine and a condenser connected in a closed circuit, and a cooling water circuit for said condenser, a heat conservation apparatus including means providing first and second closed chambers, a plurality of jet pumps, each of said jet pumps connecting said chambers and having an inlet in communication with the first chamber and an outlet for discharge into the second chamber, separate means including separate conduits for each of said jet pumps for forcing condensate from said condenser through each of said jet pumps to maintain a subatmospheric pressure in said first chamber, means for supplying water to said first chamber to be evaporated therein, means for bypassing cooling water around said condenser, each of said conduits including a

heat transfer surface, heat exchange means including a common housing for said heat transfer surfaces and connected in said bypass means for transferring heat from the condensate in said conduits to the cooling water in said bypass means for subcooling the condensate supplied to said pumps whereby a lower pressure may be produced in said first chamber than in said condenser, means for maintaining a subatmospheric pressure in said second chamber higher than the vapor pressure of the water discharged by said jet pump, and means for returning to the condensate portion of said closed circuit water heated in said second chamber by operation of said pump.

4. A steam-driven prime mover system including a heat conservation apparatus as set forth in claim 3 including means responsive to a condition of the vapor in said first chamber for controlling the rate of flow of cooling water through said housing to maintain the pressure in said first chamber substantially constant.

References Cited in the file of this patent

UNITED STATES PATENTS

1,869,190	Ehrhart	July 26, 1932
2,278,085	Ostermann	Mar. 31, 1942

FOREIGN PATENTS

361,260	Germany	Oct. 12, 1922