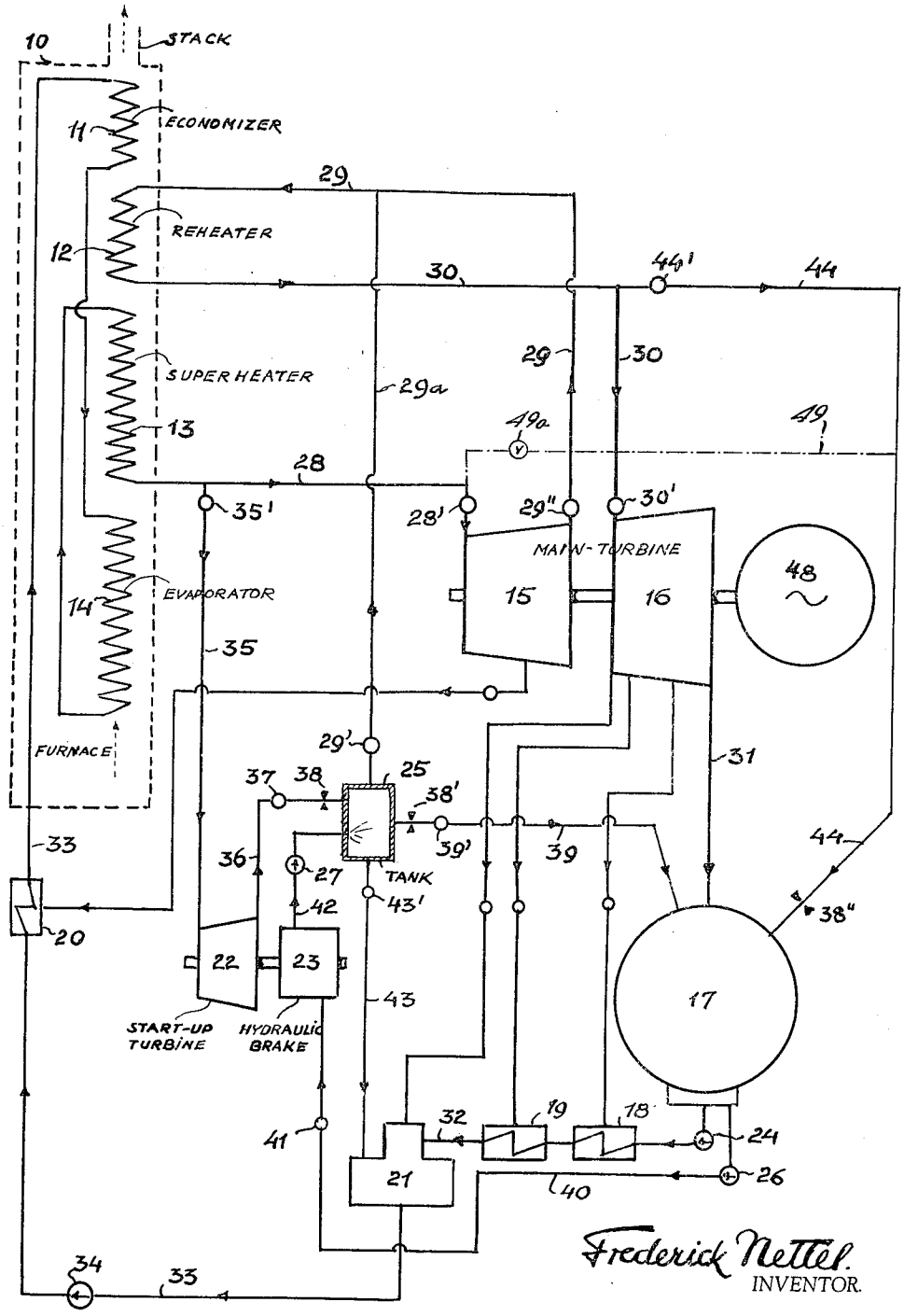
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METHOD AND MEANS FOR STARTING AND STOPPING ONCE-THROUGH HIGH-PRESSURE STEAM BOILERS

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METHOD AND MEANS FOR STARTING AND STOPPING ONCE-THROUGH HIGH-PRESSURE STEAM BOILERS

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The known once-through steam boilers, for example the Benson, Sulzer and more recently the combined circulation type, require for starting and stopping complicated by-pass valve and tank systems. For starting, their basic purpose is to create a sufficient water and steam flow through the boiler to cool it before the main turbine, normally fed by the boiler, goes into operation. The by-pass valves must also go into operation if for some reason steam demand drops suddenly, for example if the steam turbine loses its load by tripping out of the generator it drives.

With increasing boiler outputs the amounts of energy that have to be dissipated in the steam by-pass circuits have reached practically unmanageable values. For example a 900 mw. boiler-turbine set has to dissipate about the equivalent of 150 mw. As expressed by a maker of such boilers: "The sheer impact of such requirements puts enormous burdens on the acceptability of supercritical (boiler) design for ever increasing sizes." He continues: "In the by-pass system this energy is dissipated in various ways; while a fraction may be utilized in the process, the larger part is transferred to the condenser (of the main turbine). On its way to the condenser, however, dissipation of energy in the form of vibration, noise, radiation, erosion and cavitation is unavoidable. Designers and operators of such systems presenlty in operation . . . have gained thorough respect for the task of handling this energy." (See "Combustion" April 1962.)

To ease this situation somewhat, it has also been proposed to provide a pump in a pipe short-circuiting the evaporating part of the boiler, consisting mainly of the tubes in the furnace walls, to assist in the cooling of these walls during the starting of the boiler. While this appears a step in the right direction, other equally exposed boiler parts such as the super-heater and reheater remain mostly uncooled. Furthermore, this re-circulation offers little protection in the case when the boiler steam flow more or less suddenly stops, as in the case when the main generator trips out.

A full-size throttle by-pass valve system with all accessories therefore remains necessary also in this case, unless safety valves are allowed to open, which is undesirable. This invention aims principally at providing a vastly simplified by-pass system which avoids to a very great extent energy dissipation by throttling of high-pressure steam while recovering a part of its heat regeneratively.

Other and further objects and advantages will become apparent from the following description and the accompanying drawing, which shows in diagrammatic form an embodiment of my invention by way of non-limiting example. The single drawing illustrates a power plant with a once-through reheat boiler supplying a main steam turbine driving an electric generator, the turbine being equipped for using the reheated steam, and a start-up set consisting of a second turbine driving a hydraulic brake during the start-up of the boiler.

The main object of my invention is achieved in a power plant comprising a once-through steam boiler, a first (main) steam turbine, a condenser connected to the exhaust of said turbine, a second (start-up) steam turbine connected to the steam boiler in parallel with the first turbine condensing means connected to the outlet of the second turbine, and a hydraulic brake driven by the second turbine, by the following steps: connecting said second turbine with the boiler during the starting of the boiler, dissipating the mechanical output of said second turbine in said hydraulic brake, condensing the low-pressure steam issuing from the second turbine, heating fluid by leading it through said hydraulic brake, disconnecting said second turbine from the boiler when the steam furnished by the boiler has reached a temperature sufficient to start the first steam turbine, and starting the latter by admitting steam issuing from the boiler.

Another object of my invention is attained by using the condenser of the first turbine also for the second turbine.

A further object of my invention is realized by using condensate from the condenser as cooling fluid in the hydraulic brake.

Still another object of my invention is achieved by operating the second turbine with a substantial backpressure, reducing the pressure of the exhaust of the second turbine by throttling before it enters the condenser of the first turbine.

An additional object of my invention is realized by injecting the water heated in the hydraulic brake into the exhaust of the second turbine for cooling it and partly condensing it.

A further object of my invention is attained by leading steam partly expanded in the second turbine through the reheater or reheaters for cooling these parts while the boiler is being started.

Another additional object of my invention is achieved during stopping of the boiler when the steam flow to the first turbine is sharply reduced or stopped, by starting the second turbine in order to maintain a sufficient water and steam flow, respectively, through the boiler until it has cooled down.

The second turbine is designed for a steam throughput necessary to cool the boiler components, mostly tubes, sufficiently. Depending on detail design, a steam flow of between 20 and 30 percent of the boiler full-load flow has been found to be adequate for this purpose. Thus for a boiler of a full-load flow of, say 3,000.000 lbs./h., the second turbine will have to be laid out for a throughput of abt. 750.000 lbs./h. If, for example the start-up turbine is designed as backpressure turbine expanding to 100 p.s.i., it may give an output of about 50.000 HP. Such output can be easily dissipated in a high-speed hydraulic brake, which works with condensate as coolant, entering at about 90° F., heating the water to about 180° F. and even more. By returning this water into the feedwater cycle, the heat equivalent of the output of the start-up turbine is regeneratively recovered.

The start-up turbine has to work only during the starting of the boiler which may take place according to local conditions in intervals of several weeks or months. This makes the efficiency of the start-up turbine unimportant and for economic reasons the simplest high-speed design of lowest cost is proper. The start-up turbine also does not need regulating valves, a stop valve being adequate. Under these conditions the cost of the set consisting of the start-up turbine and dynamometer can be expected to be lower than the many extra-high pressures throttle by-pass valves with controlled water injection and drives required in conventional plants, quite apart from the difficulties in operation and maintenance of such valves, as mentioned before.

It is within the scope of my invention to use the low-pressure exhaust of the start-up turbine for creating a cooling steam flow through the reheat section or sections of the boiler during starting of the boiler, and to provide sealing steam to the labyrinth seals of the main turbine and, if so desired, to turn over the main turbine by leading this steam into the low-pressure part of said

turbine and then into the condenser before admitting high-pressure steam into it. It is finally also within the scope of my invention to start a boiler feed pump or other auxiliaries by means of said low-pressure steam before the main turbine can supply such steam. Turning now in more detail to the drawing, the dotted rectangle shown diagrammatically the once-through boiler **10**, with an economizer **11**, a reheater **12**, a superheater **13**, and an evaporator **14**. **15** is the high-pressure part of the main steam turbine, **16** its low-pressure part, **17** the main condenser, **48** the main generator driven by the main turbine. **18**, **19** and **20** are conventional regenerative feedwater heaters connected to the main turbine, while **21** is a deaerator tank. **22** is the start-up steam turbine, **23** a hydraulic brake driven by the start-up turbine. **25** denotes a low pressure tank. **24** is the main condensate pump, **26** and **27** auxiliary pumps. As shown, the main turbine normally receives steam through pipe **28**. Partly expanded steam flows from the outlet of the high-pressure turbine **15** through the pipe **29** into the reheater **12**, leaving the latter through the pipe **30** to enter the low-pressure turbine **16** and from there through the pipe **31** into the main condenser **17**. The condensate is pumped by the condensate pump **24** via the pipe **32** through the feedwater heaters **18** and **19** into the de-aerator tank **21** and from there via the pipe **33** by the main boiler feed pump **34** through the high-pressure feedwater heater **20** back into the economizer **11**.

A pipe **35** with interposed valve **35'**, branched off from the high-pressure pipe **28**, connects with the inlet to the start-up turbine **22**. The exhaust from this turbine is in communication with the closed tank **25** through the pipe **36** with interposed valve **37** and throttle plate **38**. The tank **25** is further connected with the condenser **17** by means of the valve pipe **39**, equipped, if desired, with another throttle plate **38'**. During start-up, the hydraulic brake **23** receives condensate from the condenser **17** through the pipe **40** with interposed valve **41** by means of the auxiliary pump **26**. Heated water leaves the hydraulic brake **23** via the pipe **42** with interposed auxiliary pump **27** and flows into the tank **25**. A valved water pipe **43** connects the tank **25** with the de-aerator **21**.

Starting of the plant from cold proceeds as follows: After starting firing and heating up the furnace to suit the particular boiler type, a water flow is led through the furnace tubes. This flow is provided by a feedwater pump and is, during the initial phase of boiler starting, led back into the condenser. This may be done by the pipe **49**, shown dash-dotted, with interposed valve **49*a***. During this initial stage the pressure in the evaporator and superheater is maintained at a much lower level than the rated boiler pressure, say at 600 to 700 p.s.i. Soon the water temperature will rise, and when it has reached abt. 500° F., evaporation will begin. In the superheater the steam will be heated to, say 600 to 650° F. This temperature is still too low for the main turbine to start on, but sufficient to begin operation of the start-up turbine **22**. Accordingly, the valve **35'** is opened, and while the turbine **22** picks up speed, the hydraulic brake **23** is put into operation by feeding condensate into it through the pump **26**, pipe **40** and valve **41**.

The expanded steam is led via the pipe **36**, with valve **37**, open, into the closed tank **25** and thence via the pipe **39**, with valve **39'** open, into the condenser **17**, which under starting conditions may be assumed to be working at near-atmospheric pressure.

As the start-up operation proceeds, the speed of the boiler feedwater pump **34** is gradually increased. As consequence the pressure of the steam issuing from the superheater **13** will raise until the rated boiler pressure of, say, 3500 p.s.i. is reached. This pressure now also prevails at the inlet of the start-up turbine **22** and when it is reached the discharge pressure in pipe **36** will rise to, say, 100 p.s.i. The throttle plates **38** and **38'** before and/or behind the tank **25** are provided for reducing this pressure to the desired tank pressure and to an acceptable pressure in the condenser.

In conjunction with the rising pressure, the pressure of the steam issuing from the superheater **13**, its temperature also rises, but not until it has reached abt. 850° F. or more, can it be used for rolling the main turbine, and during this entire period the start-up turbine **22** has to remain in operation.

All through this period the hydraulic brake **23** is operating, transforming the mechanical output of the start-up turbine **22** into heat by raising the temperature of the water flowing through the brake, the heated water is led into the tank **25**.

There it mixes with the steam coming from the start-up turbine **22**, condensing it partially or completely. The auxiliary pump **27** interposed in the pipe **42** creates in **25** a water spray for better mixing of steam and water. The valve **29'** interposed in the pipe **29*a*** connecting tank **25** with the inlet pipe **29** to the reheater **12**, which had been closed so far, is now opened as the steam temperature furnished by the boiler rises. Low-pressure steam now flows through the reheater **12**, cooling it, and is discharged into the main condenser via the pipes **30** and pipe **44** with valve **44'** open. The water collecting in the tank **25** may be discharged into the de-aerator tank **21** via the pipe **43**, with the valve **43'** open.

Obviously, while the boiler heats up, all component parts such as the evaporator **14**, the superheater **13** and the reheater **12** are cooled by the steam flow through the start-up turbine **22**, which can be designed for any desired percentage of the full-load throttle flow of the main turbine. 20 to 30 percent will mostly be satisfactory.

When the steam furnished by the boiler reaches a temperature of about 850° F., the main turbine is connected by opening the valves **28'**, **29''**, **30'** while the valves **35'**, **37**, **29'**, **39'**, **41**, **43'** and **44'** are closed.

The main steam turbine is now connected to the boiler in the conventional manner, with the feedwater heaters preheating the condensate before it reaches the economizer.

If now for some reason it is necessary to reduce the load on the main turbine more or less suddenly below a point where the reduced steam flow though the boiler just suffices to cool all components exposed normally to very hot boiler gases, the start-up turbine is started, providing the necessary cooling flow and dissipating the energy no more utilized in the main turbine until the boiler has cooled down; the operation of the start-up turbine is substantially the same as described for starting the boiler.

Contrary to the presently used by-pass and throttling system, the energy dissipation takes place in the start-up set with hardly any vibration, erosion, undue noise and is all the time under complete control of the boiler operator.

Hydraulic brakes have been found eminently suited for dissipating very large amounts of mechanical energy offered at high rotational speeds. Condensate can be used in these brakes for cooling without danger of contamination. It is within the scope of my invention to use other fluids in the brake, and to use several brakes where the amount of energy to be handled is very high.

The low-pressure steam in the tank **25** may also be used for providing sealing steam for the glands of the main turbine and it may also be used for turning the main turbine over before it is connected to the boiler. For this purpose the valve **30'** is opened permitting the cooling steam, after it has passed the reheater **12**, to enter the low-pressure part **16** of the main turbine in which it expands the condenser pressure and drives the main turbine. This is desirable because it contributes to uniform heating of the rotor of the main turbine when it begins to pick up speed, thereby providing a smoother start.

Having now described and illustrated my invention, I wish it to be understood that it is not limited to the special forms and arrangements of parts herein described and shown, or specifically covered by my claims, which follow.

I claim:

1. In the method of starting and operating a high-pressure once-through steam boiler forming part of a power plant comprising a main first steam turbine adapted to be connected to the steam boiler, a first condenser with a condensate tank, connected to the exhaust of said first steam turbine, a start-up second steam turbine adapted to be connected to the steam boiler in parallel with said first turbine as regards the flow of the steam through them, a second mixing type condenser connected to the outlet of the second turbine, a hydraulic brake driven by said second turbine, the steps of:

connecting the second turbine with the boiler during the starting of the boiler while the first turbine is at standstill and not connected to the boiler,

dissipating the mechanical output of said second turbine in said hydraulic brake as heat and leading condensate from said condensate tank of said first condenser through the hydraulic brake to heat said condensate,

condensing the low-pressure exhaust steam issuing from said second turbine at least partially in the second condenser by mixing it with the heated condensate issuing from the hydraulic brake,

disconnecting the second turbine from the boiler when the steam furnished by the boiler has reached a predetermined pressure and temperature,

at the same time starting the first turbine by connecting it to the boiler, and disconnecting the water flow from the condensate tank of the first condenser to the hydraulic brake.

2. In the method as set forth in claim 1, the step of using the said condenser also as the condenser of the second steam turbine.

3. In the method as set forth in claim 1, the step of operating said second turbine as a back-pressure turbine with a substantial super-atmospheric back pressure, throttling this back pressure and leading the thus throttled steam into the condenser of the first steam turbine.

4. In the method as set forth in claim 1, comprising a boiler with reheater means for steam partly expanded in said first steam turbine, the step of leading exhaust steam from the second turbine into the second condenser for partly condensing it, and leading the uncondensed part into said reheater means.

5. In the method of stopping a high-pressure once-through steam boiler forming part of a power plant comprising a main first steam turbine having a condenser connected to its exhaust, a second start-up steam turbine having a mixing type condenser connected to its exhaust, the inlet of said second steam turbine being adapted to be connected to said steam boiler, a hydraulic brake driven by said second turbine, a water supply for the hydraulic brake, the steps of:

stopping the fuel supply to the boiler, then

disconnecting the first turbine from the boiler,

at the same time connecting the second turbine with the boiler for starting it and the hydraulic brake driven by it,

feeding water from the said water supply into the hydraulic brake, thereby enabling it to dissipate the mechanical output of the second steam turbine into heat while steam flow through the boiler is maintained for the purpose of removing heat accumulated in the boiler material.

6. A power plant comprising a high-pressure once-through type steam boiler, a high-pressure multi-stage first main steam turbine, a first condenser connected to the exhaust of said first turbine, a storage tank for condensate associated with said condenser, a second high-pressure start-up turbine, a mixing type condenser connected to the exhaust of said second turbine, a hydraulic brake in driving relation with said second turbine, first valved pipe means connecting the outlet of said boiler with said first steam turbine, second valved pipe means connecting the outlet of said boiler to the second turbine in parallel to said first turbine as regards the steam flow through the said two turbines, third pipe means connecting the outlet of the said second turbine with the second mixing type condenser, fourth valved pipe means connecting said storage tank for condensate with the hydraulic brake, fifth valved pipe means connecting the outlet from said hydraulic brake with the second mixing-type condenser, and sixth valved pipe means connecting the said mixing type condenser with said first condenser.

7. A power plant as set forth in claim 6, wherein the boiler includes a reheater for steam partly expanded in said first turbine, the first steam turbine having means to discharge partly expanded steam into said reheater and to receive the reheated steam back before it expands further in said turbine, a seventh valved pipe means connecting the second mixing-type condenser with the reheated for cooling the reheater by steam from the second condenser while the boiler is being started, and an eighth valved pipe means connecting the outlet of said reheater with the first condenser.

8. A power plant as set forth in claim 7, in which the first turbine is provided with a valve in the means connecting the reheater with the first turbine, said valve being so designed that it can be opened while the high-pressure part of the first turbine is not connected to the boiler, said valve leading the uncondensed portion of the steam from the second condenser via the reheater into the low-pressure part of the first turbine for turning it over preparartory to connecting the high-pressure part of said first turbine to the boiler.

9. A power plant as set forth in claim 6, in which the second steam turbine is designed to absorb a steam flow of between 10 and 40 weight percent of the full-load steam flow of the boiler.

References Cited by the Examiner

UNITED STATES PATENTS

2,192,759 3/40 Stubbs ---------- 60—105 X

SAMUEL LEVINE, *Primary Examiner.*

ROBERT R. BUNEVICH, JULIUS E. WEST, *Examiners.*