PATENT SPECIFICATION (11) 1 431 270

1 431 270

(21) Application No. 59359/72 (22) Filed 22 Dec. 1972 (19)

(23) Complete Specification filed 21 Nov. 1973

(44) Complete Specification published 7 April 1976

(51) INT. CL.[2] F01K 7/22

(52) Index at acceptance
F1T B2M7C1 B2M7C2 B2M7F2

(72) Inventors ARNOLD BAINBRIDGE

(54) STEAM TURBINE INSTALLATIONS

(71) We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, London, a British Authority, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to power generating proceses which utilise a steam turbine arrangement. It also concerns steam cycles for the generation of power. The basic object of the invention it to enable the raising of steam in a way which is suited to the peculiarities of operating with liquid metal as a heat transfer medium.

A well known example of the use of liquid metal in power generating processes is where the heat source is a nuclear reactor, the liquid metal in this case being typically sodium. The sodium acts as a coolant in the nuclear reactor and it is common practice for the coolant sodium to constitute a primary circuit and to employ a secondary sodium circuit in the process of transferring heat to the boilers in which the steam is raised. A sodium potassium alloy (NaK) has also been used in the past and lead has from time to time been proposed as an alternative.

For a power generating process utilising an arrangement of steam turbines requiring reheat, the present invention resides, in one of its apects, in a method of raising steam for driving the steam turbines from heat made available by a liquid metal heat transfer medium, this method comprising passing a preheated water feed in heat transfer relationship with the liquid metal through evaporator and superheater stages, supplying superheated steam from the superheater stage to the highest pressure stage of the steam turbine arrangement, and employing steam abstracted intermediate the evaporator and superheater stages to provide reheat for the lower pressure stage of the steam turbine arrangement. The feature of "steam to steam" reheat avoids a further heat transfer with liquid metal and therefore represents a simplification in the required equipment and in the case where sodium is used as the liquid metal an alleviation to some extent of the hazard which is inherent in exchanges of heat between materials which are interactive if direct contact occurs. Since the reheat will be effected on steam at a lower pressure than that made available from the evaporator stage, it may prove wasteful in terms of overall efficiency for the latter to be injected directly; it is therefore preferred that reheat is accomplished by indirect heat exchange and that the reheating steam is passed after condensation either to the preheated water feed or to the means by which this feed is preheated.

For providing the reheat it is necessary that between the evaporator and superheater stages a supply of relatively dry steam is attainable. A once through boiler can meet this requirement in that virtually complete evaporation is achieved in the evaporator stage. However the flexibility of a once through boiler is restricted, especially for low load operation; since low load operation has great importance for a nuclear reactor in view of the need to remove such small quantities of heat as the so-called "decay heat" which is generated after shut-down, it is preferred that a recirculation facility is available so that although the percentage evaporation may be close on 100% at full load this percentage will fall with decreasing load. To afford this recirculaton possibility the method in accordance with the invention includes the further steps of evaporating in the evaporator only a major portion of the preheated water feed and then separating the major steam component from the minor unevaporated component, only the steam component being supplied to the superheater stage.

It is preferred that under normal full load conditions the amount of the feed which remains unevaporated at the end of the evaporator stage is very small and typically is not more than 5% by weight of the feed. Such a small amount of unevaporated feed

implies that a steam drum employed intermediate the evaporator and superheater stages may be smaller than the steam drum which is common in boilers of the conventional recirculation type. The unevaporated feed may be recirculated to rejoin the inlet to the evaporator stage or alternatively may be passed to the means by which the feed is preheated.

In accordance with another aspect of the invention in a power generating process utilising a steam turbine arrangement a steam cycle, for which heat is made available by a liquid metal heat transfer medium, comprises a boiler having an evaporator stage and a superheater stage of which both are adapted to be heated by the liquid metal, a steam drum intermediate the evaporator and superheater stages for separating from the steam component of the evaporator stage output a relatively minor unevaporated component, a steam turbine arrangement having high pressure, intermediate pressure and low pressure stages, a reheater for steam passing from the intermediate pressure to the low pressure stages, and means for supplying steam from the steam drum to act as the heating medium in the reheater.

The invention will be further described by way af example with reference to the drawings accompanying the Provisional Specification in which Figure 1 shows diagrammatically a steam cycle associated with a fast nuclear reactor for the purpose of power generation and Figure 2 shows a modification of the cycle in Figure 1.

In the drawing a superheat stage is indicated at 11 and an evaporator stage at 12, these stages together constituting one unit of a plurality of steam generating units associated with the reactor. Liquid metal, in this case sodium, serves as the heat transfer medium and passes first to the superheater stage and subsequently to the evaporator stage as indicated by the broken lines. This flow of sodium constitutes a secondary coolant circuit which receives its heat by means of intermediate heat exchangers from the sodium in a primary coolant circuit which includes the heat producing core of the nuclear reactor.

The supply of feed water to the steam generating units takes place through a train of low pressure feed heaters indicated generally at 13, a deaerator 14, a boiler feed pump 15 (with an auxiliary feed pump 16 in parallel), and a train of high pressure feed heaters indicated at 17. The feed is admitted to the evaporator stage 12 through a line 18 and within the evaporator stage it passes through banks of tubes over which a flow of the secondary sodium takes place. The various operating conditions are so predetermined that under normal full load conditions about 95% by weight of the feed is evaporated in passage through the evaporator stage and this together with the residual water component is passed to a steam drum 19 in which the steam and water components are separated. The steam component is in turn passed through a line 20 for further heating in a similar fashion in the superheater stage 11, the output from this stage being supplied through a line 21 to the high pressure stage 22 of a turbine set.

The unevaporated feed in the steam drum 19 is withdrawn by a boiler circulating pump 23 and by means of a valve 24 is normally returned to the feed line 18 for recirculation through the evaporator stage; the valve 24 may however be operated to effect direct return to the steam drum, this being necessary in the event that the evaporator stage is to be isolated rapidly.

The turbine set is composed, in addition to the high pressure stage 22, of an intermediate pressure stage 25 and a low pressure stage formed by three units of which two are shown at 26*a* and 26*b*. The exhaust from the high pressure stage is taken to the intermediate pressure stage and the exhaust from the latter is passed through a reheater before admission to the low pressure stage. The reheater comprises two tube-in-shell heat exchangers 27, 28, the intermediate pressure stage exhaust being passed in parallel on the shell side of these exchangers. The heating on the tube side is by means of steam taken from the steam drum 19 through a line 29. After condensation this steam is used in the cycle of Figure 1 to supply supplementary heating of the feed water and to this end is passed to the high pressure feed heaters 17 through a line 30, the condensate being converted back to steam by flashing due to the lower presure prevailing on the heating side of the heaters 17. In the modification of Figure 2 pumps 36 and 37 are arranged to re-establish full feed pressure in the condensate and to return it to the feed line 18, the line 30 being therefore connected to the line 18 in this case.

The exhausts from the low pressure stage of the turbine set are taken in usual manner to a condenser 31 having hot wells 32 and 3. The condensate is returned through a series of conventional devices, including the condenser extraction pumps 34 and 35, for re-entry into the low pressure feed heater train 13.

The output from the evaporator stage (either part of the steam component or part of the unevaporated component) may be diverted controllably as and when required to the means by which the water feed is preheated, that is to say, the high pressure feed heaters 17 in the case of the illustrated steam cycle. A line 38 is shown in Figure 1 for this purpose. The use of this feature is mainly for assisting the maintenance of pre-

heating in situations where the supply of heat normally made available for this purpose becomes deficient due to low turbine load or by an operating fault, such as a tripping of the turbine set. In this way the return temperature of secondary sodium passing back from the evaporator stage to the intermediate heat exchangers is prevented from falling as far as would otherwise be the case and this in turn reduces the magnitude of the temperature cycling range to which the nuclear reactor is subject.

As regards the supply of liquid metal to provide the heat by which the steam is generated, the invention also includes the following features:

(a) the feed and return lines for secondary sodium to and from the steam generating units should respectively include a manifold or other means for ensuring that the secondary coolant is thoroughly mixed and consequently that the distribution of temperature between the intermediate heat exchangers remains as nearly as possible evenly balanced; since the inlet temperature of primary coolant to the reactor is influenced by the intermediate heat exchangers, this expedient helps to prevent uneven temperature distribution in the reactor itself,

(b) the lines for the flow of secondary coolant to and from the intermediate heat exchangers should be kept as far as possible to a minimum; this expedient assists in reducing the amount of insulation and the safeguards which are necessary for countering any possibility of leakage.

WHAT WE CLAIM IS:—

1. A power generating process utilising a steam turbine arrangement wherein the method of raising steam for driving the steam turbines from heat made available by a liquid metal heat transfer medium comprises passing a preheated water feed in heat transfer relationship with the liquid metal through evaporator and superheater stages, supplying superheated steam from the superheater stage to the highest pressure stage of the steam turbine arrangement, and employing steam abstracted intermediate the evaporator and superheater stages to provide reheat for the lower pressure stage of the steam turbine arrangement.

2. A process according to claim 1 including the further steps of evaporating in the evaporator only a major portion of the preheated water feed and then separating the major steam component from the minor unevaporated component, only the steam component being supplied to the superheater stage.

3. A power generating process utilising a steam turbine arrangement wherein a steam cycle, for which heat is made available by a liquid metal heat transfer medium in accordance with the process according to claim 2, comprises a boiler having an evaporator stage of which both are adapted to be heated by the liquid metal, a steam drum intermediate the evaporator and superheater stages for separating from the steam component of the evaporator stage output a relatively minor unevaporated component, a steam turbine arrangement having high pressure, intermediate pressure and low pressure stages, a reheater for steam passing from the intermediate pressure to the low pressure stages, and means for supplying steam from the steam drum to act as the heating medium in the reheater.

4. A power generating process utilising a steam turbine arrangement substantially as hereinbefore described with reference to Figure 1 of the drawings accompanying the Provisional Specification.

5. A power generating process utilising a steam turbine arrangement substantially as hereinbefore described with reference to Figures 1 and 2 of the drawings accompanying the Provisional Specification.

L. A. DUNNILL,
Chartered Patent Agent,
Agent for the Applicants.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1976
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY,
from which copies may be obtained.

1431270 PROVISIONAL SPECIFICATION
1 SHEET

FIG. 1.

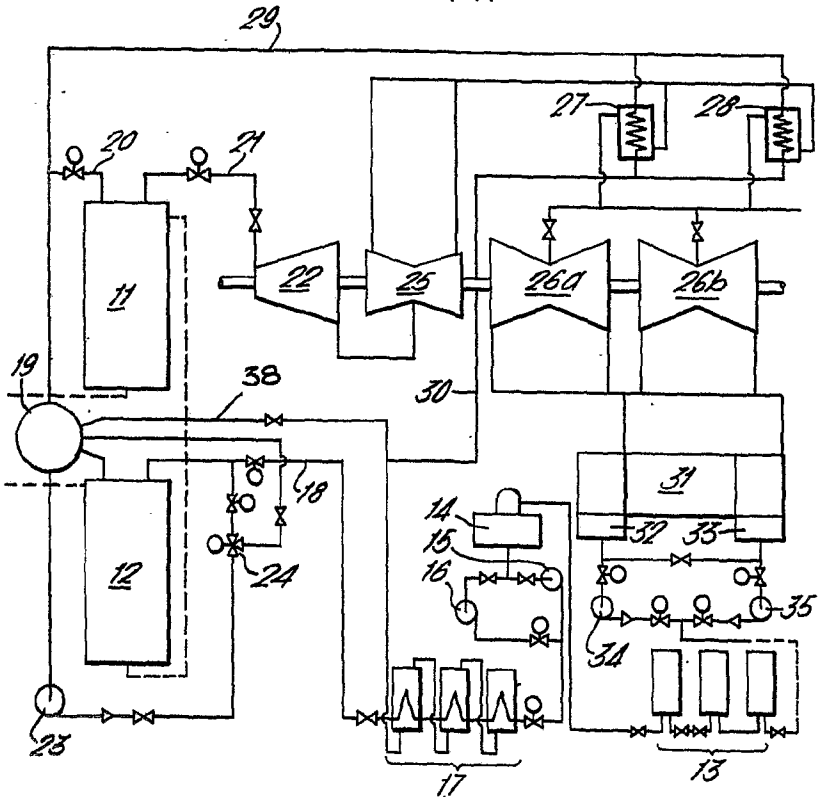

FIG. 2.