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DOUBLE REHEAT COMPOUND TURBINE POWERPLANT

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3 Claims. (Cl. 60—73)

This invention relates to elastic fluid turbine powerplants, particularly to very large capacity compound steam turbines making use of steam at supercritical pressure and reheating at least twice to a temperature on the order of the initial inlet temperature.

As the cost of fuel has risen higher and higher, powerplant designers have searched diligently for the best arrangement for extremely large capacity turbine plants representing the optimum combination of low manufacturing cost, simple construction and convenient arrangement of the piping connecting the various elements of the turbine with the steam generator and reheaters, with simplified foundation and condenser arrangement, and lending itself to a neat, symmetrical station layout.

As the demand for improved thermal efficiency has increased, an increasing number of large steam turbine plants have been designed to employ the reheat principle, in which the motive fluid is returned to the boiler for reheating, at least once in its trip through the turbines, to a temperature which may be on the order of the initial inlet temperature. A further step has been to increase the pressure level at which the plant operates, and steam pressures have now risen into the supercritical pressure region, roughly above 3500 p.s.i.a. It then becomes advantageous to go to a "double reheat" arrangement, in which the motive fluid is reheated twice to the initial inlet temperature. This involves a substantial amount of piping connecting the respective turbine components with the steam generator and reheating devices. It therefore becomes important, both from the standpoint of complexity and first cost and from the standpoint of maintenance, that the piping arrangement be as simple and symmetrical as possible. If the designer does not exercise care, such a compound double reheat plant may have certain turbine casings which are comparatively simple, while the majority of the piping connections are concentrated on other casings. This makes the design problems exceedingly difficult, and maintenance can be troublesome and expensive on those turbine casings which carry the majority of the piping connections. Also, the size and cost of the building required to house the turbine assembly may be substantially increased if several turbine sections are arranged on a common shaft so that the combined machine becomes of excessive length.

Accordingly, an object of the present invention is to provide an improved double reheat compound steam turbine arrangement in which the various turbine sections are divided evenly into two groups or "elements," with a major portion of one group being identical in construction to the corresponding components of the other group.

A further object is to provide a two-element compound turbine-generator plant in which each element generates power output roughly equal to that of the other, so that identical generators can be employed, and further facilitating arrangement of the station layout since the overall configuration of the two elements is very similar.

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A still further object is to provide an improved double reheat compound turbine arrangement in which a roughly equal number of steam conduit connections are required to each of two turbine elements, thus simplifying the piping and connections to the turbines and achieving optimum accessibility of the piping and turbine sections.

Another object is to provide a large capacity compound turbine arrangement requiring no crossover pipe connecting directly between one element and the other, thus reducing the governing problem which otherwise results when a long, large diameter crossover pipe contains a substantial volume of "uncontrolled" steam which may under certain conditions of operation tend to overspeed certain of the turbine sections.

Other objects and advantages will become apparent from the following description taken in connection with the accompanying drawing, in which the single figure represents an improved double reheat compound turbine powerplant in accordance with the invention, the two turbine elements being shown partly in section, and the piping and steam generating equipment being shown in purely diagrammatic form.

Generally stated, the invention is practiced by dividing the various turbine expansion sections between two independent shafts, each coupled to drive a separate generator, and corresponding turbine sections of the respective elements being identical except for the highest pressure section of each element, the design and arrangement of these highest pressure sections being such that the total output of each turbine element is roughly the same, both at part load and at full load operation.

Referring now more particularly to the drawings, the invention is illustrated as applied to a very large capacity double reheat steam turbine plant having a number of expansion turbine sections grouped on two independent shafts. The "first turbine element" includes a maximum pressure section 1, an intermediate pressure section 2, and a low pressure section 3, having a common rotor driving a generator 4. The "second turbine element" comprises the high pressure section 5, intermediate pressure section 6, and low pressure section 7, connected to drive generator 8. The steam generating and reheating components comprise a suitable boiler feed pump shown diagrammatically at 9, a steam generator 10, a first reheater 11, and a second reheater 12. The low pressure turbine sections 3, 7 exhaust to separate condensers 3d, 7d, or to a common condenser (not shown), from which condensate is returned by way of suitable feed water heaters (not shown) to the feed pump 9. The valve means controlling the flow of motive fluid includes stop valve means indicated diagrammatically at 10b in the maximum pressure steam supply conduit 10a, and suitable control valve mechanism illustrated diagrammatically at 10c, located closely adjacent the inlet to the maximum pressure section 1. Partly expanded steam leaves the maximum pressure section 1 through conduit 11a and after being reheated in the first reheater 11 is supplied by conduit 11b to the high pressure section 5 of the secondary turbine element, this flow being under the direct control of the reheat stop valve 11c and reheat intercept valve 11d. Here again, it will be observed that the intercept valve 11d is located closely adjacent (in this case directly on), the casing of the high pressure section 5. Steam exhausted from section 5 passes by way of conduit 12a to the second reheater 12, thence by way of conduit 12b to both the intermediate sections 2, 6. This flow is controlled by the second reheat stop valves 12c and the respective intercept valves 12d, 12e located on the respective casings of turbine sections 6, 2.

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As will be apparent from the drawing, the low pressure sections 3, 7 are each actually "triple flow" units. That is, part of the steam exhausted from the intermediate pressure section 2, roughly a third of the flow, passes directly through the immediately adjacent low pressure section 3a. The remaining two-thirds of the flow goes by way of the crossover pipe 2a to the common inlet chamber of the "opposed flow" low pressure sections 3b, 3c. Similarly, after passing through the intermediate pressure section 6, the steam flow in the second turbine element divides three ways, passing through the low pressure section 7a and the opposed flow low pressure sections 7b, 7c, in parallel. Thus the lowest pressure portion of this powerplant is actually a "six-flow" arrangement, since there are six substantially identical low pressure expansion sections in parallel flow arrangement.

With this arrangement, it is possible to design both turbine elements for operation at 3600 r.p.m., as contrasted with other cross compound turbine plants in which it has been considered necessary to employ one 3600 r.p.m. element and one 1800 r.p.m. element, in order to obtain the requisite aggregate flow path area for the low pressure steam. Thus with the present invention it becomes feasible to make the two turbine elements completely identical in construction throughout a major portion of the apparatus. Specifically, it will be observed from the drawing that the low pressure turbine sections 3, 7 and the two intermediate pressure sections 2, 6 are complete duplicates. It will be apparent from the drawing that these elements represent the major fraction of the apparatus employed. It is, of course, of extreme importance from the standpoint of low manufacturing cost, and from the standpoint of furnishing and stocking spare parts for maintenance during the life of the machine, that such a large portion of the apparatus can be exact duplicates.

In order to equalize the power output of the two turbine elements, it is necessary that the maximum pressure section 1 and the high pressure section 5 employ a different number of stages of expansion. Specifically, the design and number of stages in the high pressure section 5 is so selected that the power output of this section is as close as possible to that of the fewer expansion stages contained in the maximum pressure section 1. Thus, since the respective intermediate pressure sections and low pressure sections are complete duplicates, it follows that the total capacity of the first turbine element will be substantially identical to that of the second turbine element. This in turn means that the generators 4, 8 may be duplicates. With this arrangement, the total power output of the plant is divided roughly equally between the first and second turbine elements, both at part load operation and at full load. This greatly simplifies the electrical operation of the plant, since the identical generators 4, 8 may be readily connected together electrically to a common distribution network, without the operating problems which arise when generators of different speed or of substantially different capacities, are connected to a common distribution network.

A number of most important advantages result from this improved compound turbine arrangement. Foremost among these is the fact that there is no "crossover pipe" communicating between a higher pressure section of the first turbine element and a lower pressure section of the second element. This means that there is no steam conduit of substantial length and volume and having no valve means for controlling this volume of steam when the governing mechanism calls for a sudden load change. Inspection of the drawing will reveal that all conduits which contain no valves communicate with the heating devices 11, 12, not with the other turbine element. Stated conversely, every steam supply conduit is provided with one or more valve means immediately

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adjacent the connection of the steam conduit with the turbine section it serves. Thus there is no substantial volume of steam "uncontrolled" by an appropriate valve device, which volume of steam would be free for uncontrolled expansion through the next lower pressure turbine section in the event of sudden reduction in load output. Thus the governing problem is very much simplified. It may be noted further that the only "uncontrolled crossover conduits" are the comparatively short conduits 2a, 6a, which communicate between sections of the same turbine element, not from one turbine element to the other.

Another very important practical advantage lies in the fact that the first and second turbine elements can either be located closely adjacent to one another or at a considerable distance apart, resulting also from the fact that all "uncontrolled" piping communicates with the heating devices, not between elements, and there are appropriate control valves immediately adjacent the entrances to the respective turbine sections. If it is desired to locate both elements closely adjacent, they may conveniently be mounted on a common foundation structure, and may also be provided with a single transversely disposed condenser receiving steam from all six of the low pressure sections. It is of course also possible, where desired, to use separate condensers for each element.

It is also significant that by dividing the turbine expansion sections between two elements which are so nearly identical, and so very similar in size and external configuration, the problem of arranging the station layout is much simplified, as compared with the problems involved in designing a plant having elements of substantially different size and configuration. It may be noted that not only the foundation structure but also the lubricating oil feed and drain piping may be entirely or substantially identical on the respective first and second elements.

In connection with the simplification of the piping required in this compound plant, it is significant to note that the first and second turbine elements each require the same number of piping connections. That is, each has two steam inlet connections, one connection to a reheater, and equal numbers of connections to the condenser. Furthermore, these connections are located in similar positions on the first and second elements. This makes for optimum accessibility of the piping and connections thereof to the turbine casings, and permits a symmetrical layout of the piping to the first and second elements.

By way of example, it may be noted that in a turbine plant of the type described having a total capacity of 450,000 kw., steam may be supplied by the steam generator 10 at a pressure of 3500 p.s.i.a. and a temperature of approximately 1050° F. The motive fluid exhausts at about 970 p.s.i.a. and 720° F. into the conduit 11a. The temperature of the steam supplied by reheater 11 through conduit 11b may again be on the order of 1050° F. The pressure in the second reheat conduit 12a may be on the order of 320 p.s.i.a. and at a temperature of about 780° F. The discharge temperature of the steam supplied by reheater 12 to the conduit 12b may again be on the order of 1050° F. The steam expands in the low pressure sections 3, 7 from about 290 p.s.i.a. to condenser pressure, which may be on the order of 1½ inches of mercury, absolute. As noted above, both turbine elements may operate at 3600 r.p.m.

It will be seen that the invention provides a large capacity compound turbine powerplant in which numerous stages of expansion are divided into sections, the sections being grouped into two elements and arranged in such a manner that the rather complex piping connections required to the two reheaters are simplified, there are no long "uncontrolled" crossover pipes between elements to create serious governing problems, the design and arrangement of foundation, station layout, and condenser connections are greatly simplified, and engineering and

manufacturing costs can be reduced by the very substantial extent to which the two turbine elements are mechanical duplicates.

While only one embodiment of the invention has been described specifically, it will be appreciated by those acquainted with the steam turbine art that many substitutions and modifications could be made. It will, of course, be appreciated that the valve mechanism and the piping arrangement is illustrated in purely diagrammatic form in the drawing and could take many equivalent forms. The invention may be applicable to elastic fluid turbine plants using motive fluids other than steam. It is, of course, intended to cover by the appended claims all such modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A compound multiple reheat elastic fluid turbine powerplant comprising means for generating elastic motive fluid at a first maximum inlet pressure and first temperature, said first maximum pressure being above the critical pressure of the fluid, a first reheater connected to reheat partly expanded fluid to substantially said first temperature, a second reheater connected to receive still further expanded fluid and reheat it to substantially said first temperature, a plurality of turbine fluid expansion sections comprising a first turbine element having a maximum pressure section, an intermediate pressure section, and a low pressure section with rotors connected together in tandem, and a second turbine element comprising a high pressure section, an intermediate pressure section, and a low pressure section with rotors connected together in tandem and physically separate from the rotor of said first turbine element, first maximum pressure conduit means supplying motive fluid from said generating means to the inlet of said maximum pressure section of the first turbine element, second conduit means supplying motive fluid exhausted from the maximum pressure section to said first reheater, third conduit means supplying reheated motive fluid from the first reheater to said high pressure section of the second turbine element, fourth conduit means supplying motive fluid exhausted from said high pressure section to said second reheater, fifth conduit means supplying reheated motive fluid from the second reheater in parallel to both the intermediate pressure sections of said first and second turbine elements, sixth conduit means supplying motive fluid exhausted from the intermediate pressure section of the first turbine element to the low pressure section of the first element, and seventh conduit means supplying motive fluid exhausted from the intermediate pressure section of the second turbine element to the low pressure section of the second element.

2. A compound multiple reheat turbine powerplant in accordance with claim 1, in which the design and number of expansion stages in the maximum pressure turbine section of the first turbine element is such that said maximum pressure section has substantially the same power output as that of the high pressure turbine section of the second turbine element, the second reheat sections and

low pressure sections of the first and second turbine elements being respectively of substantially identical construction, whereby the total power output of the first turbine element is substantially equal to that of the second turbine element.

3. A compound multiple reheat steam turbine powerplant comprising means for generating steam at a first maximum inlet pressure and first temperature, said first maximum pressure being above the critical pressure of the steam, a first reheater connected to receive partly expanded steam and to reheat it to substantially said first temperature, a second reheater connected to receive still further expanded steam and reheat it to substantially said first temperature, a plurality of turbine expansion sections comprising a first turbine element having a maximum pressure section, an intermediate pressure section, and a low pressure section connected together in tandem to drive a first load device, and a second turbine element comprising a high pressure section, an intermediate pressure section, and a low pressure section mechanically independent of said first turbine element and connected in tandem to drive a second load device, first maximum pressure conduit means supplying motive fluid from said steam generator to the inlet of said maximum pressure section of the first turbine element and including control valve means adjacent said maximum pressure inlet, second conduit means supplying steam exhausted from the maximum pressure section to said first reheater, third conduit means supplying reheated steam from the first reheater to said high pressure section of the second turbine element and having valve means adjacent the inlet to the high pressure section, fourth conduit means supplying steam exhausted from the high pressure section to said second reheater, fifth conduit means supplying reheated steam from the second reheater in parallel to the intermediate pressure sections of both the first and the second turbine elements and including separate control valve means immediately adjacent the respective inlets to said intermediate pressure turbine sections, sixth conduit means supplying steam exhausted from the intermediate pressure section of the first turbine element to the low pressure section of the first element, and seventh conduit means supplying steam exhausted from the intermediate pressure section of the second turbine element to the low pressure section of the second element.

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