An external supply pipe is disclosed, for supplying steam to a mid-span packing disposed about a shaft coupling a high pressure (HP) and an intermediate pressure (IP) section of an opposed flow steam turbine. The external supply pipe is disposed on an exterior of the steam turbine casing, which allows for direct measurement of steam flow to the mid-span packing.
EXTERNAL MIDSSPAN PACKING STEAM SUPPLY

BACKGROUND OF THE INVENTION

[0001] The invention relates generally to steam turbines having an opposed flow high pressure (HP) section configuration. More particularly, the invention relates to direct measurement of flow into the IP section.

[0002] In steam turbines having an opposed flow HP/IP section arrangement, steam typically enters near the center of the casing, and flows through the stages of the HP section to exhaust through a reheater. Following reheating, the steam re-enters the casing near the center, and flows in the opposite direction through the stages of the IP section. After passing through the IP section, the steam eventually travels downstream to the low pressure (LP) section.

[0003] The HP and IP sections are coupled by a shaft having a mid-span packing disposed about the shaft. The mid-span packing limits leakage of steam from the HP to the IP section, and allows the IP section to cool. The mid-span packing is wholly contained within the shell encasing the steam turbine. Accordingly, in order to quantify flow through the mid-span packing, it is typically inferred rather than directly measured.

[0004] A quantification of steam volume leakage from the HP to the IP section is important for use in calculations evaluating performance of the steam turbine. For example, the steam leakage influences calculated efficiency on the IP and low pressure (LP) sections of the steam turbine, and the calculated output of all three (HP, IP, and LP) sections. One method of inferring anticipated flow through the mid-span packing is the use of an N2 inference test. However, the N2 inference test is complicated to perform, may take one or more days to complete, requires significant cooperation from the customer and/or unit operators, and are only completed on units with precision contractual tests or units that are the subject of characterization tests. Because of these constraints, an assumed value for this flow is used on the majority of performance analyses. Additionally, N2 inference tests estimate flow through the mid-span packing with an associated degree of uncertainty which is so large as to limit the usefulness of the determination.

[0005] Another method is the use of an N2 blowdown test. Like the N2 inference test, the N2 blowdown test requires specific turbine operating conditions and dedicated testing time. Even with these provisions, the results still only provide an estimate for estimating leakage through the mid-span packing, with significant associated uncertainty.

BRIEF DESCRIPTION OF THE INVENTION

[0006] A first aspect of the disclosure provides an opposed flow steam turbine comprising: a high pressure (HP) section and an intermediate pressure (IP) section connected by a shaft; a mid-span packing disposed about the shaft between the HP section and the IP section; a casing disposed about the steam turbine, substantially enclosing the HP section, the IP section, the shaft, and the mid-span packing; and a supply pipe for supplying steam to the mid-span packing, wherein the supply pipe is disposed substantially on an exterior of the casing.

[0007] A second aspect of the disclosure provides an external supply pipe for supplying steam to a mid-span packing of an opposed flow steam turbine having a casing, wherein the supply pipe is disposed substantially on an exterior of the casing.

[0008] A third aspect of the disclosure provides a method of controlling a steam flow entering an intermediate pressure (IP) section of an opposed flow configuration steam turbine, the method comprising: providing a supply pipe coupled at an upstream end to a throttle steam line, and at a downstream end to a mid-span packing, and supplying through the supply line a known quantity of steam. The mid-span packing is disposed about a shaft coupling a high pressure (HP) section and the IP section; and providing cooling to the IP section. The HP section is substantially sealed. The supply pipe is disposed substantially on an exterior of a casing enclosing the steam turbine.

[0009] These and other aspects, advantages and salient features of the invention will become apparent from the following detailed description, which, when taken in conjunction with the annexed drawings, where like parts are designated by like reference characters throughout the drawings, disclose embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 shows a schematic diagram of an opposed flow steam turbine.

[0011] FIG. 2 shows a schematic diagram of an opposed flow steam turbine in accordance with an embodiment of the disclosure.

[0012] FIG. 3 shows a schematic diagram of a portion of the opposed flow steam turbine of FIG. 2, in accordance with an embodiment of the disclosure.

[0013] FIG. 4 shows a schematic diagram of a portion of the opposed flow steam turbine of FIGS. 2-3, in accordance with an embodiment of the disclosure.

[0014] It is noted that the drawings of the disclosure are not necessarily to scale. The drawings are intended to depict only typical aspects of the disclosure, and therefore should not be considered as limiting the scope of the disclosure. In the drawings, like numbering represents like elements between the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0015] At least one embodiment of the present invention is described below in reference to its application in connection with the operation of a steam turbine. Although embodiments of the invention are illustrated relative to an opposed flow HP/IP configuration steam turbine, it is understood that the teachings are equally applicable to steam turbines in general having a packing disposed between two sections, the packing being encased inside the casing. Further, at least one embodiment of the present invention is described below in reference to a nominal size and including a set of nominal dimensions. However, it should be apparent to those skilled in the art that the present invention is likewise applicable to any suitable steam turbine. Further, it should be apparent to those skilled in the art that the present invention is likewise applicable to various scales of the nominal size and/or nominal dimensions.

[0016] With reference to FIG. 1, an opposed flow steam turbine 10 is described. As shown, opposed flow steam turbine 10 includes a first, or high pressure (HP) turbine section 12 operatively connected to a second, intermediate pressure (IP) turbine section 14 by a rotor or shaft 16. A mid-span
packing 18 is disposed about shaft 16 between HP section 12 and IP section 14. Mid-span packing 18 may include a plurality of packing rings not individually shown in the figures, but as known in the art. Mid-span packing 18 serves to substantially prevent or limit leakage or flow of steam along shaft 16 between HP section 12 and IP section 14, and facilitates cooling of IP section 14. A shell or casing 20 substantially encloses HP section 12, IP section 14, shaft 16, and mid-span packing 18, along with other features of gas turbine 10.

[0017] With continued reference to FIG. 1, in operation of steam turbine 10, high pressure, high temperature steam is delivered to HP bowl 22 by means of a conduit 24. Once the steam enters HP section 12, the steam flows through the stages of HP section 12 and exits HP section 12 after the final stage. From there, the steam is routed to reheater 26 via line 28. Reheated steam is then supplied to IP bowl 30 by line 32. Steam flows through the stages of IP section 14, and exits IP section 14 via line 34. From there it may eventually continue downstream, e.g., to a low pressure (LP) section (not shown).

[0018] During operation of the steam turbine of FIG. 1, a fraction of the high temperature, high pressure steam flows 36 along shaft 16 within mid-span packing 18 and into IP section 14. This fraction of the high pressure, high temperature steam bypasses HP section 12 and reheater 26. This can impact the overall efficiency of IP section 14, subsequent downstream sections, and various measures of performance of steam turbine 10 as a whole.

[0019] As shown in FIGS. 2-4, according to embodiments of the disclosure, steam turbine 10 may additionally be provided with a supply pipe 40 for supplying steam to mid-span packing 18. Supply pipe 40 is disposed substantially on an exterior of casing 20, such that it is accessible from an exterior of steam turbine 10 without disassembly. Supply pipe 40 may be connected at an upstream end 42 to throttle steam line 44, and at downstream end 46 to mid-span packing 18.

[0020] As shown in FIGS. 3-4, supply pipe 40 may further include a control valve 48 for setting a desired flow rate, and therefore the volume, of steam delivered to mid-span packing 18 through supply pipe 40. As shown in FIG. 4, supply pipe 40 may additionally include a flanged orifice 52, which may include at least one pressure tap 54 on a flange 56 thereof for measuring steam flow. Flanged orifice 52 may be downstream of control valve 48 on supply pipe 40. In further embodiments, supply pipe 40 may further include a thermowell 50 for measuring a temperature on an interior of the supply pipe 40. The temperature data obtained by thermowell 50 may be used in calculations related to the power output and/or efficiency of steam turbine 10. In some embodiments, thermowell 50 may be downstream of flanged orifice 52.

[0021] Through the use of some or all of the foregoing features, supply pipe 40 may deliver steam to mid-span packing 18 at a known flow rate, and in a known volume. This allows for direct measurement of steam flow to mid-span packing 18. The accuracy and precision of a direct measurement will be significantly higher relative to that of inferences made through, e.g., an N2 inference test or an N2 blowdown test, and will have significantly reduced uncertainties associated with the measurements. The measured flow may be compared to design specifications, which may be used to identify performance shortfalls in new units as well as degradation on units in service such as, e.g., a change in packing clearance in mid-span packing 18. Further, the measured flow through supply pipe 40, together with an N2 inference test, may be used to determine the quantity of flow through other flow paths, or a constant measured flow during a time period.

[0022] In addition to the foregoing supply pipe 40 and steam turbine 10 including a supply pipe 40, a method is provided for controlling a steam flow entering an IP section of an opposed flow configuration steam turbine.

[0023] In an embodiment, the method includes providing a supply pipe and coupling the supply pipe at an upstream end to a throttle steam line, and at a downstream end to a mid-span packing. The mid-span packing may be disposed about a shaft coupling a high pressure (HP) section and the IP section of the steam turbine, and may further provide cooling to the IP section.

[0024] The method may further comprise supplying steam through the supply line, and particularly, may include supplying steam through the supply pipe at a known rate and a known volume. The supply pipe may be disposed substantially on an exterior of a casing enclosing the steam turbine.

[0025] In one embodiment, the HP section may be substantially sealed such that steam may not flow out of the HP section toward the IP section, and the steam leakage flow from the HP section to the IP section may be nominal. Further, the steam flow into the IP section may be substantially supplied by the supply pipe, i.e., the steam flow into the IP section may substantially not be provided through leakage from the HP section along the mid-span packing. In various embodiments, the known quantity of steam supplied through the supply line flows from the mid-span packing into the HP section and the IP section depending on a pressure in each of the respective HP and IP sections.

[0026] In some embodiments of the method, the method may include setting a desired flow rate for steam delivered through the supply pipe via a control valve. In further embodiments, the method may include measuring a temperature on an interior of the supply pipe using a thermowell. In still further embodiments, the method may include providing a flanged orifice on the supply line, the flanged orifice further including at least one pressure tap on a flange thereof. In various embodiments of the foregoing method, the known volume or flow rate of steam supplied to the mid-span packing is used to determine at least one of: an HP section power output, an IP section power output, an IP steam path efficiency, an LP section power output, or an LP efficiency. Because the quantity of steam provided to the mid-span packing via the supply pipe is known with minimal or negligible uncertainty, the amount of steam flowing into each of the HP section and the IP section can be determined with significantly less uncertainty relative to calculations that are possible based on, e.g., the N2 inference test.

[0027] As used herein, the terms “first,” “second,” and the like, do not denote any order, quantity, or importance, but rather are used to distinguish one element from another, and the terms “a” and “an” herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item. The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., includes the degree of error associated with measurement of the particular quantity). The suffix “(s)” as used herein is intended to include both the singular and the plural of the term that it modifies, thereby including one or more of that term (e.g., the metal(s) includes one or more metals). Ranges disclosed herein are inclusive and independently combinable (e.g., ranges of “up to about 25 mm, or, more specifically, about 5 mm to about 20 mm.”)
inclusive of the endpoints and all intermediate values of the ranges of “about 5 mm to about 25 mm,” etc.).

While various embodiments are described herein, it will be appreciated from the specification that various combinations of elements, variations or improvements therein may be made by those skilled in the art, and are within the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. An opposed flow steam turbine comprising:
   a high pressure (HP) section and an intermediate pressure (IP) section connected by a shaft;
   a mid-span packing disposed about the shaft between the HP section and the IP section;
   a casing disposed about the steam turbine, substantially enclosing the HP section, the IP section, the shaft, and the mid-span packing; and
   a supply pipe for supplying steam to the mid-span packing, wherein the supply pipe is disposed substantially on an exterior of the casing.

2. The opposed flow steam turbine of claim 1, wherein the supply pipe is connected at an upstream end to a throttle steam line.

3. The opposed flow steam turbine of claim 1, wherein the supply pipe further comprises a control valve for setting a desired flow rate for steam delivered through the supply pipe.

4. The opposed flow steam turbine of claim 1, wherein the supply pipe further comprises a thermowell for measuring a temperature on an interior of the supply pipe.

5. The opposed flow steam turbine of claim 1, wherein the supply pipe further comprises a flanged orifice, the flanged orifice further including at least one pressure tap on a flange thereof.

6. The opposed flow steam turbine of claim 1, wherein the mid-span packing limits a steam flow to the IP section, and provides cooling to the IP section.

7. The opposed flow steam turbine of claim 1, wherein the supply pipe delivers a known quantity of steam to the mid-span packing.

8. An external supply pipe for supplying steam to a mid-span packing of an opposed flow steam turbine having a casing, wherein the supply pipe is disposed substantially on an exterior of the casing.

9. The external supply pipe of claim 8, wherein the supply pipe further comprises a control valve for setting a desired flow rate for steam delivered through the supply pipe.

10. The external supply pipe of claim 8, wherein the supply pipe further comprises a thermowell for measuring a temperature on an interior of the supply pipe.

11. The external supply pipe of claim 8, wherein the supply pipe further comprises a flanged orifice, the flanged orifice further including at least one pressure tap on a flange thereof.

12. The external supply pipe of claim 8, wherein the supply pipe delivers a known quantity of steam to the mid-span packing.

13. A method of controlling a steam flow entering an intermediate pressure (IP) section of an opposed flow configuration steam turbine, the method comprising:
   providing a supply pipe coupled at an upstream end to a throttle steam line, and at a downstream end to a mid-span packing, the mid-span packing being disposed about a shaft coupling a high pressure (HP) section and the IP section; and
   supplying through the supply line a known quantity of steam, wherein the supply pipe is disposed substantially on an exterior of a casing enclosing the steam turbine, and wherein the mid-span packing provides cooling to the IP section, and the HP section is substantially sealed.

14. The method of claim 13, wherein the leakage flow from the HP section to the IP section is nominal.

15. The method of claim 14, wherein the steam flow into the IP section is substantially supplied by the supply pipe.

16. The method of claim 13, wherein the known quantity of steam supplied through the supply line flows from the mid-span packing into the HP section and the IP section depending on a pressure in each of the HP section and the IP section.

17. The method of claim 13, further comprising setting a desired flow rate for steam delivered through the supply pipe with a control valve.

18. The method of claim 13, further comprising providing a thermowell for measuring a temperature on an interior of the supply pipe.

19. The method of claim 13, further comprising providing a flanged orifice on the supply line, the flanged orifice further including at least one pressure tap on a flange thereof.

20. The method of claim 13, further comprising:
   using the known quantity of steam supplied to the mid-span packing to determine at least one of:
   an HP section power output, an IP section power output, an IP steam path efficiency, an LP section power output, or an LP efficiency.

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