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HIGH TEMPERATURE TURBINE NOZZLE RETAINING MEANS

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FIG. 1.

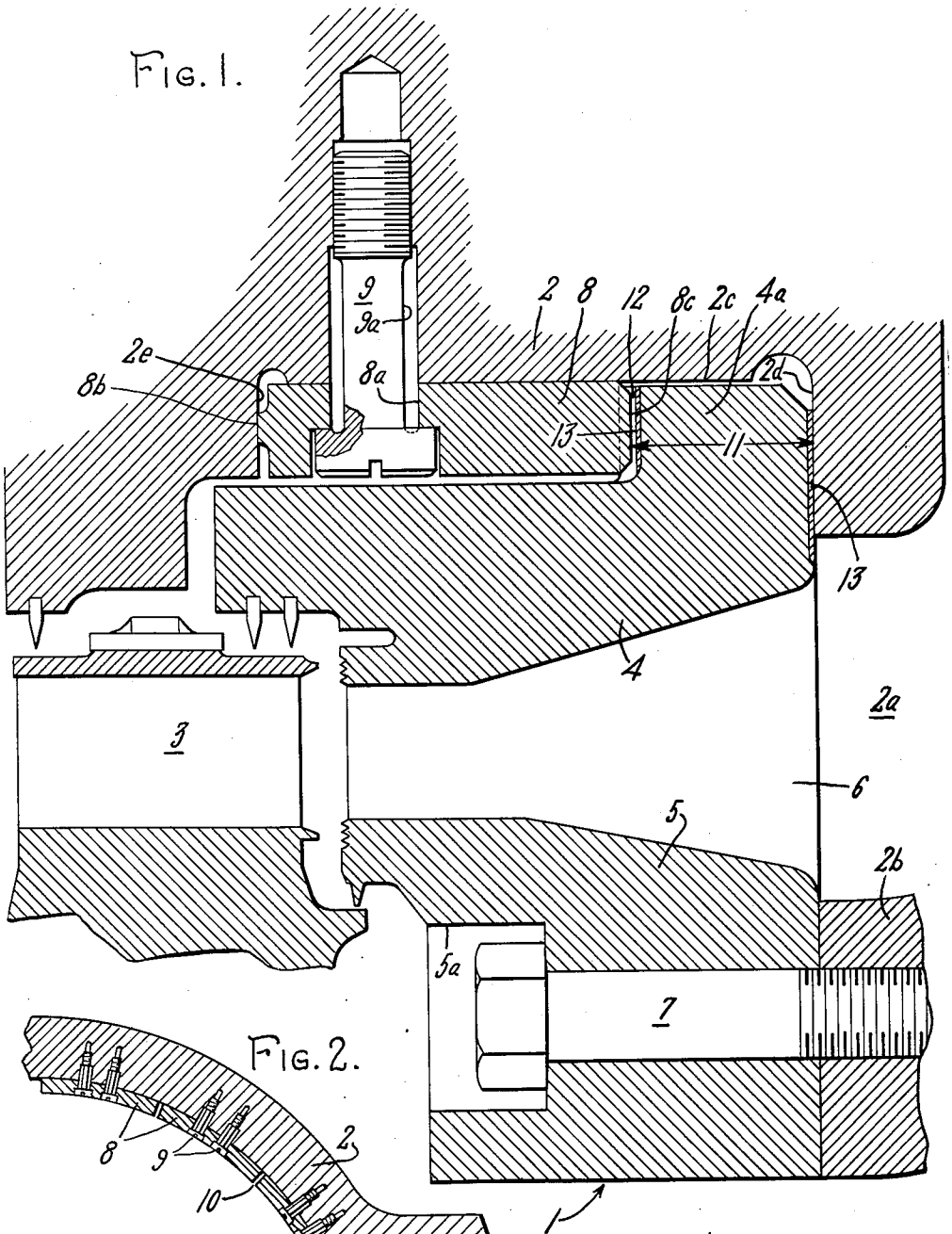
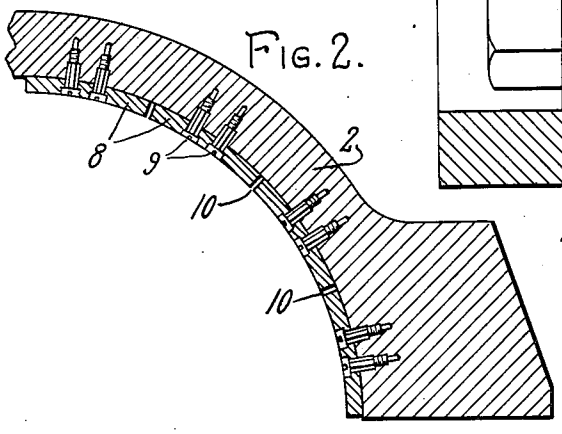


FIG. 2.



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HIGH TEMPERATURE TURBINE NOZZLE RETAINING MEANS

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The present invention relates to an improved locking key for a member, such as a steam nozzle, which must be held securely in position during operation at elevated temperatures, but which must be easily removable at room temperatures.

Modern steam turbine powerplants operate at exceedingly high temperatures and pressures in order to achieve maximum efficiency. The first stage nozzle, which furnishes the motive fluid to the first row of turbine buckets on the rotor receives the steam at a temperature on the order of 1050° F., which is the maximum practicable if "ferritic" alloys are used in the construction of the nozzle and of the shell portions to which the nozzle is attached. At the same time, the pressure drop in the motive fluid across the nozzle results in a substantial thrust on the nozzle. Hence, special care must be given to the means for retaining the nozzle in place against these forces at these elevated temperatures.

Steam nozzles are often constructed in segments or "arcs" which have suitable flanges or lips for attaching the nozzles to the shell or to the nozzle chest. Since the nozzle is designed to be supported against the axial thrust exerted by the motive fluid on the nozzle and since the low pressure side of the nozzle must operate with close clearances to the first bucket stage, the available space for attaching the outer rim of the nozzle arc is quite limited.

One method used for holding the outer rim of the nozzle has been through the use of a caulking piece, which is inserted after the nozzle is in place. Additional means are then necessary to prevent the caulking pieces from dropping down into the steam path. With this arrangement, the caulking piece and its holding device are subjected to the high motive fluid temperature. The inner edge of the nozzle arc may be held in place by means such as axial bolts attached to an axially facing flange on the shell or on the nozzle chest. Although there is ample room for the bolts holding the inner edge of the nozzle arc, the space available at the outer rim is limited and the use of a caulking piece with additional means to hold it in place has not been entirely satisfactory.

It is a well known fact that the so-called "austenitic" alloys which are often used in turbine construction for extra high temperature and pressure applications, such as the inner shell of a double shell turbine operating at supercritical pressure, have thermal coefficients of expansion which are significantly higher than the coefficients of expansion of the so-called "ferritic" or lower temperature alloys. These differences in thermal coefficients of expansion often give rise to troublesome design problems where parts of the two different classes of alloys are designed to operate side by side. The present invention, however, utilizes this previously troublesome characteristic to great advantage.

Accordingly, one object of the invention is to provide an improved locking means for holding a member such as a steam turbine nozzle which is operating at elevated temperatures in fixed relation to another member such as a turbine shell.

Another object is to provide means for securing a member in place at elevated temperature, which allows ready disassembly of the member from the locking means at reduced temperatures.

A more specific object is to provide an improved locking key for retaining the outer periphery of an arcuate steam nozzle in place at elevated temperatures against the force exerted by the steam on the nozzle where the locking means is protected from the elevated temperature by the nozzle itself.

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of practice, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

FIG. 1 is an elevation drawing, partly in section, of a first stage steam nozzle together with its associated supporting shell structure; and

FIG. 2 is an end view, in reduced scale, of a portion of the turbine shell showing the circumferential disposition of the special retaining means.

Generally stated, the invention is practiced by affixing a key to the turbine shell having a thermal coefficient of expansion substantially different from that of the turbine shell. The key has a surface which is arranged to cooperate with a surface on the turbine shell so as to loosely accommodate an outer peripheral flange of the nozzle "arc" when the turbine is at room temperature. At elevated temperatures, the difference in expansion of the key and the turbine shell causes the key and shell cooperating surfaces to tightly grasp the turbine nozzle rim and hold it in place.

Referring now to FIG. 1 of the drawing, a first stage nozzle segment or "arc," shown in cross-section at **1**, is disposed in a turbine shell **2** so as to direct the motive fluid flow from a conduit **2***a* defined by shell **2** to a first stage turbine wheel **3**. The shell **2** is generally made in two halves fitting together along a horizontal centerline and the top half is lowered into place after the turbine rotor is in place.

It is understood that, for the purposes of this invention the exact shape and disposition of shell **2**, other than the portions immediate to nozzle **1**, are not important. Shell **2** may be the inner shell of a double shell turbine where the pressure drop is divided across two separate casings to reduce the stress on the casings. Also, it is understood that the designation of member **2** as a shell does not preclude that it be a separate piece, such as a free expanding nozzle chest which is attached to the shell at its outer portion.

Nozzle **1** comprises an outer arcuate shroud **4**, and an inner massive shroud **5** radially separated from shroud **4** and carrying therebetween a number of airfoil-shaped deflecting vanes **6**. The inner shroud **5** is secured to a circumferential axially extending flange **2***b* on shell **2** by bolts **7** fitting in recesses **5***a*.

Disposed radially outward from nozzle **1** in shell **2** is a circumferential groove **2***c* of an axial length roughly corresponding to the axial length of outer shroud **4**. Groove **2***c* has axially facing opposed end walls **2***d*, **2***e*.

Disposed in circumferential groove **2***c* are a number of arcuate keys **8** whose axial dimension occupies a substantial portion of the axial dimension of circumferential groove **2***c*. A locating screw **9** passing through hole **8***a* in key **8** affixes the key to the turbine shell. Screw **9** has a reduced diameter portion **9***a* to provide flexibility and to reduce the stress on screw **9** when the key moves axially.

Referring to FIG. 2, the disposition of several arcuate keys **8** is shown on shell **2**. There it will be noted that the arcuate keys are separated circumferentially by clearance gaps **10** to form a segmented construction for thermal expansion in a circumferential direction. Thus keys

8 are mounted in recess 2c for thermal expansion both axially and circumferentially.

One axial edge of key 8 defines a circumferential surface 8b which abuts the end wall 2e of recess 2c. The other edge 8c of key 8 is separated from end wall 2d by space 11. A circumferential radial flange 4a on outer shroud 4 extends radially outward into space 11 forming a close clearance gap 12 with surface 8c on the key when the turbine is at reduced temperatures. Clearance gap 12, of course, could be on the other side of flange 4a from that shown, or could be divided into two smaller clearances on both sides of flange 4a. Flange 4a may also be furnished with suitable hard surfaces by nitriding as shown at 13. The austenitic key 8 is made of such an axial length that after nozzle 1 and key 8 are assembled in the shell, about .002 inch of clearance per inch of axial length of key 8 remains in space 12 around the flange 4a. This clearance allows the nozzle to be easily disassembled from the shell at room temperature.

It should be apparent from the drawing that the axial length of key 8 is selected to occupy a much greater axial portion of slot 2c than does the flange 4a on the nozzle. Here the key has a length on the order of three inches while the flange 4a has an axial length on the order of one and a half inches. The operation of the improved nozzle retaining means is greatly enhanced by maintaining the axial length of key 8 as great as conveniently possible.

The shell 2 as shown here is fabricated from a ferritic alloy which will withstand the contained pressures at a temperature on the order of 1050° F. A suitable alloy for this use is ASTM #389, which is one of the so-called "ferritic" steels suitable for casting a high pressure turbine casing. ASTM #389 has a linear coefficient of thermal expansion on the order of 6.7×10^{-6} in./in. ° F., this being representative of ferritic alloys.

Key 8, on the other hand, is manufactured from a material having a substantially higher linear coefficient of thermal expansion than that of shell 2 and may for example be manufactured from an alloy known as A–286 developed by Universal Cyclops Company. This alloy has a thermal coefficient of expansion of 9.9×10^{-6} in./in. ° F., which figure is generally representative of the "austenitic" alloys.

It will be immediately observed that there is a substantial difference in these coefficients of expansion and that two pieces of metal, one of each material, placed side by side would vary in their overall length when heated to a high temperature. Specifically, with the metals illustrated, the piece of metal of austenitic alloy would have a change in length per inch of length almost 50% greater than that of the ferritic metal. It will be understood that the actual change in length is also dependent upon the total length of the piece being heated and that the longer the piece, the greater the change in length.

The method of assembling the nozzle to the shell should now be apparent. Assuming that the shell is divided into upper and lower halves joining along a horizontal centerline, the kays 8 are bolted into recesses 2c by screws 9. Then the nozzles 1, which may be in one or more segments for each shell, are inserted into the shell halves, the flanges 4a entering space 11 in a radial direction. The bolts 7 are then used to secure the inner edges of the nozzles to the shell. Thereafter the shell halves can be joined about the rotor.

The operation of the nozzle locking key at elevated temperatures will now be described. As the motive fluid begins passing through conduit 2a, the shell 2, nozzle 1, and key 8 will all begin to heat. Eventually, the various parts will obtain equilibrium temperatures approximating that of the motive fluid, i.e. in the neighborhood of 1050° F. although the shell and key will usually be less in temperature than the nozzle. Shell 2, of course, expands when it is heated, both circumferentially and axially. Key 8 bolted to the shell by screws 9 also expands both circumferentially and axially, but at a substantially faster rate than shell 2 due to its greater coefficient of expansion.

Since keys 8 are arcuate segments and are separated at their circumferential joints, there is no interference due to the more rapid circumferential "growth" of the austenitic key with respect to the shell 2.

On the other hand, the different rates of expansion cause key 8 to rapidly close the small clearance gap 12 between the key and flange 4a, with the result that very soon key 8 is restrained at one edge by its circumferential surface 8b abutting against the recess end wall 2e, and with its other end 8c squeezing flange 4a against the opposite recess end wall 2d. The degree of clearance previously allowed between key 8 and nozzle flange 4a is such that the compressive stresses now introduced in key 8 due to its more rapid rate of growth are not such as to cause key 8 to fail but, on the other hand, are retained within safe limits.

As mentioned previously, the reduced diameter portion 9a of screw 9 allows the key to shift axially without imposing a severe shearing stress on screw 9. Also, the generous length provided between the threads and the point of contact of screw 9 with the key serves to distribute any bending stresses induced in screw 9 by the differential thermal expansion.

The operation thus described of key 8 at elevated temperatures serves two purposes. Primarily, it holds the nozzle firmly in place against the force of the motive fluid at elevated temperatures and prevents it from moving axially toward the rotor wheel 3 with possible reduction of operating clearances and damage to the rotor wheel. Secondarily, it helps to form a tight seal against leakage between flange 4a and shell 2.

It will be noted that the construction is quite simple and that it occupies very little space. The outer shroud 4 of the nozzle almost completely conceals and guards the highly stressed compression key 8 against direct contact with the hot motive fluid.

Also, the improved nozzle locking key shown has the added advantage that when the steam temperature is reduced and the clearance again appears around flange 4a, the outer rim is free for ease of disassembly by removing bolts 7 and drawing the nozzle arc 1 radially inward from the space 11. The hard facing 13 acts to prevent "galling" from repeated contractions and expansions.

It is, of course, also within the contemplation of the present invention to utilize other materials than the austenitic and ferritic materials referred to herein, which are given by way of example. The important criterion is the selection of two materials having coefficients of thermal expansion which are sufficiently different to provide the desired closing force for the length of the piece used.

The invention is not limited to a key member having the higher coefficient of expansion and disposed in a recess to provide a closing gap for gripping a flange or other protuberance, but understanding the principle of the invention, it would likewise be possible to construct a retaining key having a lower coefficient of thermal expansion than the supporting structure. With this arrangement, the key would tend to shorten relative to the supporting structure at elevated temperatures. Thus suitable "prongs" extending from the key and the member in which the key is attached, which extend into a suitable recess in the nozzle rim with close clearances, would grip the sides of the recess at elevated temperatures.

While the invention has been described as applied to a locking key for holding the outer rim of a first stage turbine nozzle in place, it is apparent that the invention would be equally applicable in other high temperature devices where a secure holding of a member is desired at high temperatures, but where ease of disassembly is desired at normal temperatures. Specifically, the invention would be quite suitable for gas turbines which employ

relatively high temperatures, and other applications will occur to those skilled in the art.

Also, numerous changes and substitutions of equivalents might be made in the nozzle locking key disclosed herein. It is, of course, desired to cover by the appended claims all such modifications as fall within the true spirit and scope of this invention.

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

1. Locking means for holding first and second members in fixed relation at elevated temperatures comprising a first member defining a relatively inaccessible recess with opposed end walls, a second member defining a flange portion extending into said recess adjacent one end wall thereof, and key means disposed between said flange portion and the other recess end wall defining a clearance gap therewith for ease of disassembly of the first and second members at room temperatures, the linear coefficient of thermal expansion of said key means being greater than that of the first member to a degree sufficient for the key means to close the clearance gap and exert a holding force on the second member flange at a preselected elevated temperature.

2. Locking means for holding first and second members in fixed relation at elevated temperatures comprising a first member defining a relatively inaccessible recess with opposed end walls, a second member defining a flange portion extending into said recess adjacent one end wall thereof, and key means mounted in said first member recess for thermal expansion therewith, said key means having opposite end portions adjacent the second member flange portion and the other recess end wall respectively and defining clearances with the flange portion for removing the second member at room temperatures, the linear coefficient of expansion of said key means being greater than that of the first member to a degree sufficient for the key means to close the clearances and exert a holding force between the first member recess end wall and the second member flange at a preselected elevated temperature.

3. Locking means for holding first and second members in fixed relation at elevated temperatures comprising a first member, key means disposed on the first member, means restricting the movement of the key means in one direction with respect to the first member, and a second member having a portion fitting loosely and defining clearances at room temperature with first and second opposed surfaces defined by the first member and key means respectively, said first and second surfaces being relatively inaccessible and substantially normal to the direction in which key movement is restricted, the coefficient of expansion of said key means being substantially different from that of said first member so that the key length will change with respect to the first member at elevated temperatures

to cause the first and second surfaces to grasp said second member portion, whereby the second member portion will be held in place by the key means and first member surfaces at a preselected elevated temperature.

4. Locking means for holding first and second members in fixed relation at elevated temperatures comprising a first member defining a relatively inaccessible first recess, key means attached to said first member and defining a second smaller recess with the first member, and a second member defining a flange loosely disposed in said second recess and defining clearances with the key and first member at room temperatures, the linear coefficient of expansion of said key means being greater than that of the first member to a degree sufficient for the key means to expand relative to the first member to remove said clearances, whereby the key and the first member portions will exert a holding force on the flange of the second member at a preselected elevated temperature.

5. Nozzle locking means for a high temperature turbine nozzle or the like comprising a cylindrical shell defining a circumferential groove therein with opposed axially facing end walls, said shell also defining a radially inward axially facing circumferential flange, arcuate nozzle means arranged to be secured to said shell flange and including an outer circumferential radial flange extending into said shell groove adjacent one end wall thereof, and key means comprising a plurality of arcuate segments disposed in the shell circumferential groove between said nozzle means outer flange and the other shell groove end wall and defining a clearance gap therewith for ease of disassembly of the shell from the nozzle means at room temperatures, the linear coefficient of expansion of said key means being greater than that of the shell to a degree sufficient for the key means to close the clearance gap and exert a holding force on the nozzle outer flange at a preselected elevated temperature.

6. Turbine nozzle locking means according to claim 5 wherein the shell is of a ferritic alloy and where the key means is of an austenitic alloy.

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