BESCHWERDEKAMMERN DES EUROPÄISCHEN PATENTAMTS

BOARDS OF APPEAL OF THE EUROPEAN PATENT OFFICE

CHAMBRES DE RECOURS DE L'OFFICE EUROPEEN DES BREVETS

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File No.: T 0376/89 - 3.2.4

Application No.: 83 104 171.0

Publication No.: 0 094 529

Classification: F01D 11/02

Title of invention: Rotor stabilising labyrinth seals for steam turbines

D E C I S I O N
of 28 October 1993

Patentee: General Electric Company

Opponent: MAN Energie GmbH

Headword:

EPC: Art. 54 and 56

Keyword: "Novelty (yes)" - "Inventive step (yes)"

Headnote
Catchwords

Europäisches Patentamt | European Patent Office | Office européen des brevets

Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 0376/89 - 3.2.4

D E C I S I O N
of the Technical Board of Appeal 3.2.4
of 28 October 1993

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Decision under appeal: **Decision of the Opposition Division of the European Patent Office dispatched on 30 March 1989 rejecting the opposition filed against European patent No. 0 094 529 pursuant to Article 102(2) EPC.**

Composition of the Board:

Chairman: R.Gryc
Members: M. Hatherly
M. Lewenton

Summary of Facts and Submissions

I. European patent application No. 83 104 171.0, filed on 28 April 1983, was published with the publication No. 0 094 529 and a patent thereon granted on 12 August 1987.

Claim 1 of the patent as granted reads as follows:

"A labyrinth seal for use in a steam turbine having a central rotatable rotor, such seal serving for minimizing leakage of steam between a region of higher pressure and a region of lower pressure through which the rotor extends, and such seal providing stabilization against rotational instabilities of the type caused by steam whirl and comprising, in combination:
a plurality of spaced-apart annular teeth (24-27) affixed to a stationary portion of the turbine between said pressure regions and encircling the rotor substantially coaxially therewith to define chambers (34) between teeth, each tooth of said plurality of teeth extending radially inward to within close proximity of said rotor;
a row of circumferentially spaced-apart flow directing vanes (36) affixed to the stationary portion of the turbine within said higher pressure region and encircling the rotor in proximity to said plurality of annular teeth, each vane of said row having a portion of its planar surface being substantially radially aligned with respect to said rotor, and said planar surface of said vane being angularly inclined with respect to the axis of said rotor such that the vane edge (38) upstream with respect to steam flow is the trailing edge with respect to rotor rotation in order to direct steam passing therethrough into said chambers in a flow

direction counter to the direction of rotor rotation; characterized by a raised annular land (41) on the rotor surface opposite said row of vanes (36) to produce an abrupt radially outward deflection of the steam flow passing axially near the surface of the rotor, the resultant outward flow being carried into the vicinity of said row of vanes so that substantially the entire flow of steam entering said chambers passes through said vane row and enters in a direction counter to the direction of rotor rotation, wherein each vane (37) of said row of flow directing vanes (36) extends radially inward to within close proximity of said raised annular land (41)."

II. The patent was opposed and a decision of the Opposition Division to reject the opposition was dispatched on 30 March 1989.

III. An appeal against this decision was received on 30 May 1989, the fee being paid at the same time. The Statement of Grounds was received on 27 July 1989.

The only document referred to in the appeal proceedings is:

(D): US-A-4 273 510

The Appellant (Opponent) argues essentially that document D discloses not only permissibly the features of the pre-characterising portion of the present Claim 1 but also impermissibly the features of the characterising portion. He maintains that document D concerns in general terms a method and an apparatus for suppressing rotor instabilities independent of the position of the apparatus on the rotor. In his view, the construction according to Claim 1 of the disputed European patent - namely merely the arrangement of a

raised annular land on the rotor surface opposite a row of vanes - is clearly contained in document D and is not new or at least not inventive compared with the construction shown in Figure 4 of document D; moreover the construction shown in Figure 3a comes even closer.

The Respondent (Proprietor) contests this argumentation.

IV. The Appellant requests that the decision under appeal to reject the opposition be set aside and that the patent be revoked in its entirety.

The Respondent requests that the appeal be dismissed and the decision to maintain the patent unamended be confirmed.

Neither party has requested oral proceedings.

Reasons for the Decision

1. The appeal is admissible.

2. *Novelty*

2.1 Taking the embodiments of document D separately, no single embodiment discloses all the features of the granted Claim 1. In particular as far as the embodiments of Figures 3a, 3b and 4 are concerned the planar surface of each vane 6, 6a is parallel to the axis of the rotor whereas Claim 1 specifies (in column 7, lines 42 to 44) that the planar surface of the vane is to be angularly inclined with respect to the rotor axis. Concerning the embodiment of Figures 5 and 6 the raised annular land bearing the number 3 is opposite the seal member 5 (termed annular tooth in the impugned patent) whereas

Claim 1 specifies (in lines 49 to 51) that the raised annular land is to be opposite the row of vanes.

2.2 The Board is moreover satisfied that none of the other prior art documents available to it discloses a labyrinth seal having all the features set out in Claim 1.

Thus the subject-matter set forth in Claim 1 is novel within the meaning of Article 54 EPC.

3. *Closest prior art, problem and solution*

3.1 The Board considers that the seal closest to the present invention is that shown in Figures 5 and 6 of document D. Claim 1 is divided on the basis of this embodiment.

Indeed this prior art seal comprises all the features of the precharacterising portion of Claim 1 and steam flowing along the rotor at a distance from the rotor outer surface passes through the row of vanes to be given a flow direction opposite to that of rotor rotation before passing the seal member 5 to improve rotational stability (in the chamber bounded by the rotor, the stator and the two seal members 5). However if this known seal were not radially offset from the axial flow as is shown in Figure 5 of document D but facing the axial flow, it would have the disadvantage that steam flowing along or close to the rotor outer surface is able to pass through the annular gap between the radially inner ends of the vanes and the rotor surface instead of through the vane row, and so escapes the vane treatment.

3.2 Therefore the Board sees the problem to be solved as being to act on axial flow upstream of the seal to

maximise the effect of the vanes by forcing through the vanes substantially all of the steam that is to pass through the seal member into the chamber, and to minimise the amount of steam passing through the annular gap between the radially inner ends of the vanes and the rotor surface.

3.3 The characterising portion of Claim 1 sets out the features of a raised annular land on the rotor surface opposite the row of vanes, the vanes extending radially inward to within close proximity of the land. The land deflects the surface flow radially outward towards the vane row so that it sweeps across the narrow annular gap between the vanes and the raised land and carries with it steam which would otherwise enter the seal directly through the annular gap (see column 2, lines 47 to 54 and column 5, lines 2 to 13 of the patent). Thus substantially all the leakage steam passing along the rotor (both steam at a distance from the rotor surface and steam originally passing along the rotor surface) passes through the vane row before passing the seal member.

Consequently the Board considers that the problem is solved by the labyrinth seal defined in Claim 1 and in particular by the features of its characterising portion.

4. *Inventive step*

4.1 The particularly relevant labyrinth seals shown in Figures 3a to 6 of document D have the following features in common:

4.1.1 Each of these labyrinth seals is for use in a steam turbine having a central rotatable rotor, serving for minimising leakage of steam between a region of higher pressure and a region of lower pressure through which the rotor extends, and providing stabilisation against rotational instabilities of the type caused by steam whirl.

4.1.2 Each of these particularly relevant labyrinth seals moreover comprises a plurality of spaced-apart annular seal members 5 affixed to a stationary portion of the turbine between said pressure regions and encircling the rotor substantially co-axially therewith to define one (Figures 5 and 6) or more (Figures 3a, 3b and 4) chambers therebetween. Each seal member 5 of said plurality extends radially inward to within close proximity of said rotor. A row of circumferentially spaced-apart flow directing vanes (numbered 6 in Figures 3a and 3b; 6a in Figure 4; 7a in Figures 5 and 6) is affixed to the stationary portion of the turbine and encircles the rotor in proximity to said plurality of seal members 5. Each vane 6, 6a, 7a of said row has a portion of its planar surface substantially radially aligned with respect to said rotor.

4.2 In the embodiment of Figures 3a and 3b and in the embodiment of Figure 4, the planar surface of each vane (6 or 6a respectively) is parallel to the axis of the rotor (instead of being angularly inclined thereto as specified in the present Claim 1). The effect of this is that steam passing through the row of vanes can at most

emerge in a flow direction parallel to the axis of the rotor (and not in a flow direction counter to the direction of rotor rotation).

4.3 These particularly relevant embodiments will now be considered separately without forgetting their common features already referred to above.

4.3.1 Figures 3a and 3b show a shroud band 3 having two annular portions, namely the land bearing the number 3 and the annular portion to the left i.e. upstream thereof. The row of vanes 6, 6a is within the higher pressure region (i.e. upstream of seal members 5).

Attention will be paid firstly particularly to the left-hand annular portion shown on Figures 3a and 3b which is on the rotor surface opposite said row of vanes 6.

The steam flow is intended to pass inside the shroud band 3 i.e. between the land and the axis of the rotor. Any deflection of this intentional steam flow by the perpendicular upstream end face of the left-hand annular portion would therefore be undesirable and unintentional. Thus the upstream end face of the annular land 41 according to the present invention which deliberately deflects steam flow abruptly radially outwardly has a different purpose to the perpendicular end face of the left-hand annular portion shown in Figure 3a of document D. Steam flow along the 45° sloping end face of the left-hand annular portion may also be carried into the vicinity of the row of vanes. However, steam flowing along this sloping end face is not passing **axially** near the surface of the rotor and is not caused to be deflected **abruptly radially** outward, thus the sloping end face does not produce the same

effect as the raised annular land of the present Claim 1.

While Figure 3a is only a diagrammatic representation which cannot be scaled to determine the actual gap between vanes and annular portion, it does not appear that substantially the entire flow of steam entering the chambers defined between the seal members 5 (i.e. passing the left-hand seal member 5 from left to right) would before have passed through said row of vanes 6 since there is apparently a substantial gap both between the vanes and the left-hand annular portion and between the vanes 6 and the rest of the shroud band 3. It is clear that the vanes 6 cannot be so close to the left-hand annular portion and/or shroud band 3 as to touch during operation of the turbine. Moreover the words "within close proximity" in the definition in the present Claim 1 that "each vane of said row of flow directing vanes extends radially inward to within close proximity of said raised annular land" are not absolute. However the Board cannot agree with the Appellant's argument on page 5 of the Grounds of Appeal that the vanes are obviously as close as possible to the rotor surface since Figure 3a is drawn with a generous gap between vane and left-hand annular portion (a much larger gap than that between the seal member 5 and the shroud band 3). This Figure 3a therefore does not give the skilled person an impression which would lead him towards reducing said gap to a dimension such that substantially all the steam flow passes through the vane row before passing the left-hand seal member 5.

4.3.2 Staying with Figures 3a and 3b, attention will now be paid particularly to the right-hand of the two annular portions on shroud band 3, namely the land actually bearing the number 3.

This right-hand raised annular land on the rotor surface is not opposite a row of vanes 6. The land produces an abrupt radially outward deflection of the steam flow passing axially near the surface of the rotor (the steam flow having passed the seal member 5 furthest to the left. The resultant outward flow cannot be carried into the vicinity of said row of vanes since these lie upstream (i.e. to the left) of the seal member 5 furthest to the left. None of the steam is deflected by the land before passing through the row of vanes and the middle seal member 5.

4.3.3 Now considering the embodiment of Figure 4.

The row of vanes 6a is located downstream of the seal member 5 furthest upstream (i.e. furthest to the left) and the row of vanes is therefore not within the higher pressure region. There is a raised annular land (bearing the number 3) on the rotor surface opposite said row of vanes 6a. However the steam flow has already passed the left-hand seal member 5 to enter the left-hand chamber and so, even if the outward flow caused by deflection by the land were to be carried into the vicinity of the row of vanes, it could not be said that substantially the entire flow of steam passes through said vane row before entering said chambers.

The Appellant argues on pages 4 to 6 of his Statement of Grounds of Appeal concerning Figure 4 of document D that a land 3, vanes 6a and additionally seal members 5 are present (which seal members are not present in the present patent). He points out that the seal members keep the steam flow into the chamber as small as possible but there is naturally a small gap between the seal members and the rotor outer surface through which a small amount of steam flows, this small steam flow corresponding to the small steam flow of the impugned

patent, in both cases it being deflected radially outwardly by the vertical face of the land to meet directly the vanes so that the total deflected steam flow passes through the vanes. He maintains that the additional seal members of the citation only influence that part of the steam flow which is not influenced by the characterising features of the arrangement according to the present Claim 1. In his view the part of the steam flow which flows directly along the rotor surface is treated in the same way by the known and present constructions and in principle these constructions are the same.

The present Claim 1 however specifies in column 7, lines 55 to 58 that substantially the entire flow of steam entering said chambers passes through said vane row to enter in a direction counter to the direction of rotor rotation. The flow deflected by land 3 in Figure 4 of document D has already entered the left-hand chamber, thus the vanes could only act on steam already present in the left-hand chamber, this steam would have entered the left-hand chamber with a flow component in the direction of rotor rotation and the vanes could only attempt to reduce or eliminate this already existing flow component. In the arrangement of the impugned patent the vanes act on the steam flow before it enters the chamber. The part of the steam flowing along the rotor surface is not treated the same in the known arrangement and the present invention since in the known construction it is allowed to enter the left-hand chamber before corrective action occurs whereas in the present invention action is taken to prevent steam flowing in the direction of rotor rotation.

Since there is no explanation to the contrary in document D, the skilled person would see the land as cooperating with the middle seal member 5 in the normal

manner of a labyrinth seal and there is nothing in the document to lead him to arrange the vanes and land separately and upstream of the seal members 5. The land and the seal member opposite it form a functional group well known in labyrinth seals and the Board considers that the skilled person would not regard the seal member as being additional since if he were to take the seal member away he would also take away the land with which it cooperates.

4.3.4 Now considering the embodiment of Figures 5 and 6.

As with the embodiments of Figures 3a, 3b, the upstream end face of the shroud band 3 shown on Figure 5 does not have the same purpose as the upstream face of the annular land 41 according to the present invention. Any leakage steam flow in the cited embodiment of Figures 5 and 6 commences by flowing essentially radially in the space between the guide wheel and the shroud band 3 toward the vanes 7a which are located within the higher pressure region. The planar surface of each vane 7a is angularly inclined with respect to the axis of said rotor such that the vane edge upstream with respect to steam flow (the top left-hand edge on Figure 6) is the trailing edge with respect to rotor rotation. Steam passing there through into the chamber positioned between seal members 5 is directed in a flow direction counter to the direction of rotor rotation. The raised annular land (bearing the number 3) on the rotor surface produces an abrupt radially outward deflection of the steam flow passing axially near the surface of the rotor. However the land is opposite the left-hand seal member 5 and not opposite the row of vanes 7a. Accordingly the land cannot direct the flow to the vanes and thus the vanes cannot ensure that the flow enters the chamber via left-hand seal member 5 in a direction counter to the direction of rotor rotation.

4.4 Having considered the embodiments of document D separately, their combination must now be considered.

The Board considers that the particular combination of features set out in Claim 1 could only be arrived at from the separate embodiments of document D as a result of *ex postfacto* analysis, there being no hints in the document D to lead the skilled person to make the specific choices necessary to arrive at the combination in expectation of some improvement or advantage of the seal facing an axial steam flow.

The Board considers that where a seal member is provided opposite a land this would be regarded as a functional group by the skilled person, he would not therefore be led to remove the seal member or to move the land to another place in the labyrinth seal, namely opposite the vanes. Document D does not mention the problem of flow through the gap between the rotor and the vanes of the seal facing the axial steam flow and so does not point the skilled man to solutions to this problem.

4.5 The Opponent argues that the patent claims an arrangement of a raised annular land on the rotor surface opposite a row of vanes and that this arrangement is clearly contained in document D. However the seal located transverse to a steam flow passing axially near the outer surface of the rotor as defined in Claim 1 contains many more features than this and specifies in particular not only a raised annular land and vanes but sets out their relative positions one to the other and to the seal members.

4.6 Therefore in the opinion of the Board, no hint can be found in the available prior art documents to provide a labyrinth seal as claimed, to solve the problem set out in paragraph 3.2.

5. The subject-matter set forth in Claim 1 involves an inventive step within the meaning of Article 56 EPC and is patentable within the meaning of Article 52 EPC. Claims 2 and 3 are dependent on Claim 1 and are therefore also patentable. The patent can thus be maintained in its granted form.

Order

For these reasons, it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

N. Maslin R. Gryc