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(71) Applicant: **Carrier Corporation**
Palm Beach Gardens, FL 33418 (US)

(72) Inventors:
- **ZHANG, Wei**
  Pudong District, Shanghai 201206 (CN)
- **VERMA, Parmesh**
  Farmington, CT Connecticut 06032 (US)

(74) Representative: **Dehns**
St. Bride's House
10 Salisbury Square
London EC4Y 8JD (GB)

(54) EJECTOR FOR HEAT RECOVERY OR WORK RECOVERY SYSTEM, AND HEAT RECOVERY OR WORK RECOVERY SYSTEM

(57) An ejector 80 for a heat recovery or work recovery system, and a heat recovery or work recovery system comprising said ejector 80 are disclosed. The ejector 80 includes: a high-pressure fluid passage 1 including a high-pressure fluid inlet 11 and a high-pressure fluid nozzle 16; a low-pressure fluid passage 2 including a low-pressure fluid inlet 21 and a suction chamber 22 surrounding the high-pressure fluid nozzle 16; a mixing chamber 3 in fluid communication with the high-pressure fluid passage 1 and the low-pressure fluid passage 2 respectively; and a diffusion chamber 4 downstream of the mixing chamber 3; wherein the high-pressure fluid nozzle 16 includes a constricted segment 13, a throat portion 14, and a diffusion segment 15 in sequence, a distal end of the diffusion segment 15 defines a high-pressure fluid outlet, and a peripheral wall of the diffusion segment 15 has a convex arc shape in a longitudinal section. The ejector 80 has higher efficiency as compared to known ejectors.

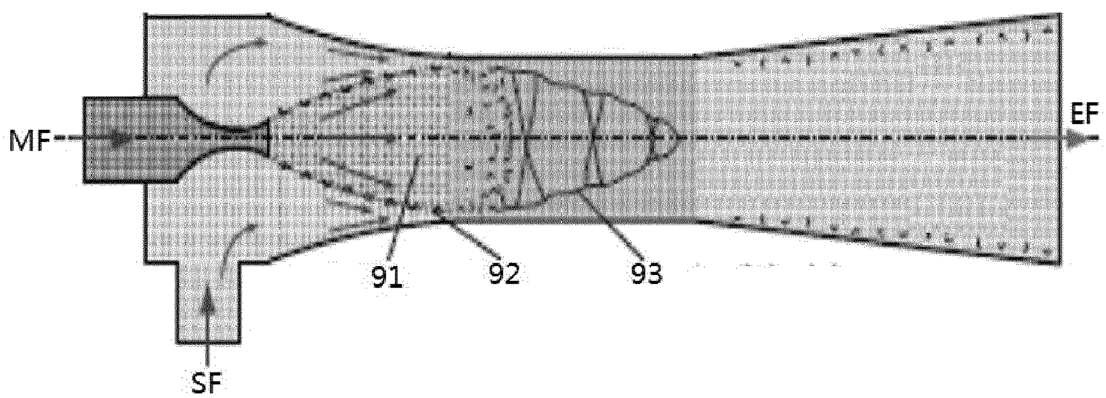

Fig.3

EP 3 879 124 A1

Description

FIELD OF THE INVENTION

[0001] The present disclosure relates to the field of heat recovery or work recovery systems. More specifically, the present disclosure relates to an ejector for a heat recovery or work recovery system, and a heat recovery or work recovery system having such an ejector.

BACKGROUND OF THE INVENTION

[0002] In commercial heat recovery or work recovery systems, especially systems that require a large pressure differential, an ejector is used to improve efficiency. The ejector converts the pressure of the high pressure fluid into kinetic energy, mixes with a low pressure fluid and supplies a mixed medium-pressure fluid to a compressor inlet, thereby increasing the pressure of fluid at the compressor inlet, reducing the requirements on the capacity of the compressor, and improving the efficiency of the system.

[0003] The ejector usually includes a high-pressure fluid nozzle to convert the high-pressure fluid into a high-momentum fluid. The low-pressure fluid is suctioned in with the high-momentum fluid and mixed with the high-momentum fluid in a mixing chamber, then diffuses in a diffusion chamber to increase the pressure of the fluid which is subsequently supplied to the compressor. The efficiency of the ejector is critical to the entire system.

SUMMARY OF THE INVENTION

[0004] An object of at least some embodiments of the present invention is to solve or at least alleviate problems existing in the related art.

[0005] In one aspect, an ejector for a heat recovery or work recovery system is provided, which includes: a high-pressure fluid passage including a high-pressure fluid inlet and a high-pressure fluid nozzle; a low-pressure fluid passage including a low-pressure fluid inlet and a suction chamber surrounding the high-pressure fluid nozzle; a mixing chamber in fluid communication with the high-pressure fluid passage and the low-pressure fluid passage respectively; and a diffusion chamber downstream of the mixing chamber; wherein the high-pressure fluid nozzle includes a constricted segment, a throat portion, and a diffusion segment in sequence, a distal end of the diffusion segment defines a high-pressure fluid outlet, and a peripheral wall of the diffusion segment has a convex arc shape in a longitudinal section.

[0006] Optionally, in the ejector for the heat recovery or work recovery system, a diffusion angle at the high-pressure fluid outlet at the distal end of the diffusion segment is in a range of 0° to 10°, preferably in a range of 0° to 5°, more preferably in a range of 0° to 3°, for example, the diffusion angle is equal to 0°.

[0007] Optionally, in the ejector for the heat recovery or work recovery system, the peripheral wall of the diffusion segment is composed of a convex arc-shaped segment having a gradually decreasing diffusion angle.

[0008] Optionally, in the ejector for the heat recovery or work recovery system, the peripheral wall of the diffusion segment is composed of a convex arc-shaped segment having a parabolic shape.

[0009] Optionally, in the ejector for the heat recovery or work recovery system, the peripheral wall of the diffusion segment is composed of a convex circular arc-shaped segment with a consistent radius of curvature.

[0010] Optionally, in the ejector for the heat recovery or work recovery system, the peripheral wall of the diffusion segment satisfies the following in a longitudinal section: a perpendicular line is drawn from a tangent line at end point P2 of the diffusion segment, and on the perpendicular line, there is an outer point P3 located inwardly of the peripheral wall and having a distance R from the end point P2, wherein $R=0.5L/(\sin\theta * \cos\theta)$, where L is a total length of the diffusion segment, θ is a net diffusion angle of the diffusion segment, and a line connecting the outer point P3 and a starting point P1 of the peripheral wall of the diffusion segment is perpendicular to a tangent line at the starting point P1.

[0011] Optionally, in the ejector for the heat recovery or work recovery system, the high-pressure fluid outlet of the high-pressure fluid nozzle faces the mixing chamber, and a center line of the high-pressure fluid nozzle is collinear with a center line of the mixing chamber.

[0012] Optionally, in the ejector for the heat recovery or work recovery system, the suction chamber is in communication with the mixing chamber, and a transition segment having a tapered structure is located between the suction chamber and the mixing chamber.

[0013] Optionally, in the ejector for the heat recovery or work recovery system, the constricted segment of the high-pressure fluid nozzle is composed of a straight segment having a constant constriction angle or an arc segment having a convex or concave shape.

[0014] In another aspect, a heat recovery or work recovery system is provided, which includes the ejector according to the first aspect and, optionally, in accordance with any of the optional features thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The contents of the present disclosure will become easier to understand in light of the following description, which describes exemplary embodiments of the invention, and with reference to the accompanying drawings. It can be easily understood by those skilled in the art that the following description and accompanying drawings are merely used for illustration and are provided by way of example only, and are not intended to limit the scope of protection. In addition, like parts are denoted by like numerals in the drawings, wherein:

FIG. 1 shows an illustrative schematic view of a work recovery system to which an ejector may be applied;

FIG. 2 shows a longitudinal sectional view of an ejector;

FIG. 3 shows a flow simulation diagram in a longitudinal section of an ejector;

FIG. 4 shows a schematic view of a partial design of an ejector;

FIG. 5 shows a schematic view of a partial design of an ejector; and

FIG. 6 shows a schematic view of a partial design of an ejector.

DETAILED DESCRIPTION OF THE EMBODIMENT(S) OF THE INVENTION

[0016] Referring to FIG. 1, a work recovery system to which an ejector is applied will be described. An example will be used in which the work recovery system is a cooling device. The work recovery system may include a compressor 83, an outlet of the compressor 83 is connected to an inlet of a condenser 82 downstream of the compressor 83, and an outlet of the condenser 82 is connected to a high-pressure fluid inlet 11 of an ejector 80. A fluid outlet 43 of the ejector 80 is connected to a separator 84. A fluid flowing out of the fluid outlet 43 of the ejector 80 is separated in the separator, wherein a gas phase returns to an inlet of the compressor 83, and a liquid phase passes through a valve 85 and an evaporator 86 and then enter into a low-pressure fluid inlet 21 of the ejector 80. The ejector 80 is used in the work recovery system as shown in FIG. 1. Alternatively, the ejector 80 may also be applied to other types of more complicated work recovery systems. In addition, the ejector 80 may also be applied to a heat recovery system, such as a heat recovery system including a generator. The work recovery system of Figure 1 includes only one ejector, but alternative systems may include a plurality of ejectors. Therefore, the ejector may be applied to various types of heat recovery or work recovery systems.

[0017] With reference to FIG. 2, an ejector will be described. The ejector includes: a high-pressure fluid passage 1; a low-pressure fluid passage 2; a mixing chamber 3 in fluid communication with the high-pressure fluid passage 1 and the low-pressure fluid passage 2 respectively; and a diffusion chamber 4 downstream of the mixing chamber 3. More specifically, the high-pressure fluid passage 1 may include a high-pressure fluid inlet 11 and a high-pressure fluid nozzle 12. The high-pressure fluid nozzle includes a constricted segment 13, a throat portion 14, and a diffusion segment 15 in sequence. A distal end of the diffusion segment 15 defines a high-pressure fluid outlet 16. The high-pressure fluid outlet 16 may face the mixing chamber 3. For example, a center line of the high-pressure fluid nozzle 16 may be collinear with a center line of the mixing chamber 3. The low-pressure fluid passage 2 may include a low-pressure fluid inlet 21, and a suction chamber 22 surrounding the high-pressure fluid nozzle 12. The suction chamber 22 is in communication with the mixing chamber 3. A transition segment 23 between the suction chamber 22 and the mixing chamber 3 has a tapered structure. That is, the cross section thereof gradually decreases. The mixing chamber 3 may have a cylindrical shape having a constant cross-sectional area. In the mixing chamber 3, a high-pressure fluid MF entering through the high-pressure fluid passage 1 and a low-pressure fluid SF suctioned in through the low-pressure fluid passage 2 are sufficiently mixed so that a supersonic fluid transitions to a subsonic fluid which diffuses in the diffusion chamber 4 to restore the kinetic energy therein to a pressure, thereby forming an output flow EF of a medium-pressure fluid at the outlet 43 of the ejector, which is supplied to, for example, the inlet of the compressor. In the design of the diffusion chamber 4, a diffusion angle thereof needs to ensure full restoration of the fluid pressure and avoid the occurrence of flow separation.

[0018] With reference to FIG. 3, a flow simulation diagram in the ejector shown in FIG. 2 is illustrated. The high-pressure fluid MF entering from the high-pressure fluid inlet is ejected from the ejector and forms a high-pressure flow core 91. There is a fictive throat 92 between the high-pressure flow core 91 and a peripheral wall where the suction chamber and the mixing chamber 3 meet. The low-pressure fluid SF needs to be sufficiently mixed with the high-pressure fluid MF in a potential mixed shock region 93 after passing through the fictive throat 92. If the fictive throat 92 is blocked (the high-pressure flow core 91 is too large and therefore blocks the low-pressure fluid SF from passing through the fictive throat 92), then the entrainment ratio (which is defined as a mass flow ratio of the low-pressure fluid SF to the high-pressure fluid MF, and which is an important parameter affecting the performance of the ejector) will no longer increase, that is, the performance of the ejector can no longer be improved.

[0019] Referring to FIG. 4, a partial longitudinal sectional view of an example design of a high-pressure fluid nozzle is shown. A peripheral wall of the high-pressure fluid nozzle includes a constricted segment 13, a throat portion 14, and a diffusion segment 15 in sequence. The peripheral wall of the diffusion segment 15 of the nozzle extends straight at a constant diffusion angle θ from a starting point P1 of the diffusion segment 15 to an end point P2 of the diffusion segment 15, and a total length of the diffusion segment 15 is L. At the end point P2 of the diffusion segment 15 at the high-pressure fluid outlet 16, an angle θ is between a tangent line at that point and a horizontal line, that is, the high-pressure fluid is ejected from the high-pressure fluid nozzle at a diffusion angle θ. If the diffusion angle θ is too large, the fictive throat is prone to early blockage.

[0020] With reference to FIG. 5, a partial longitudinal sectional view of a high-pressure nozzle is shown. In this high-pressure fluid nozzle, the peripheral wall of the diffusion segment 15 has a convex arc shape. The so-called convex arc shape means that in the section shown in FIG. 5, the peripheral wall is raised relative to a line C connecting the starting point P1 and the end point P2 of the diffusion segment 15 and has an arc shape. The center of curvature at any point of the peripheral wall is located inwardly of the peripheral wall. With this arrangement, the high-pressure fluid nozzle has an increased internal space 49 as compared to the design of FIG. 4, which allows for more phase changes in the high-pressure fluid nozzle; that is, more liquid evaporates into vapor, resulting in higher nozzle ejection velocity and enabling a higher efficiency of the ejector.

[0021] In some embodiments, the diffusion angle of the diffusion segment 15 at the high-pressure fluid outlet 16 (at the end point P2 of the diffusion segment) is in a range of 0° to 10°, preferably in a range of 0° to 5°, more preferably in a range of 0° to 3°, for example, the diffusion angle is equal to 0°, that is, the high-pressure fluid leaving the high-pressure fluid nozzle is ejected substantially horizontally. With this arrangement and in combination with the convex arc-shaped side wall, the position of the fictive throat 92 related to the diffusion angle of the high-pressure fluid ejected from the high-pressure fluid nozzle is more rearward (more downstream), so that the system can operate in a larger range of operating parameters without early blockage of the fictive throat. In combination with an adaptive design of the downstream mixing chamber, a higher efficiency of the ejector can be achieved and the operating efficiency of the entire system can be improved.

[0022] In some embodiments, the peripheral wall of the diffusion segment 15 is composed of a convex arc-shaped segment having a gradually decreasing diffusion angle; that is, in the diffusion segment 15, the diffusion angle of any further downstream point on the peripheral wall is less than that of an upstream point. The diffusion angle may be defined as an angle between a tangent line at a point on the peripheral wall and the horizontal line or a centerline of the ejector. For example, the diffusion angle at the starting point P1 of the diffusion segment 15 is larger than the diffusion angle at a first intermediate point P4, the diffusion angle at the first intermediate point P4 is larger than the diffusion angle at a second intermediate point P5 downstream of the first intermediate point P4, and the diffusion angle at the second intermediate point P5 is larger than the diffusion angle at the end point P2 of the diffusion segment, which is located downstream of the second intermediate point P5. For example, the diffusion angle at the end point P2 of the diffusion segment may substantially be 0°. In some embodiments, the peripheral wall of the diffusion segment 15 may be composed of a convex arc-shaped segment having a parabolic shape. In some other embodiments, the peripheral wall of the diffusion segment 15 may be composed of a convex circular arc-shaped segment with a consistent radius of curvature.

[0023] In any of the embodiments, the constricted segment 13 of the high-pressure fluid nozzle may be composed of a straight segment having a constant constriction angle; alternatively, the constricted segment 13 may be composed of a convex arc-shaped segment or a concave arc-shaped segment.

[0024] In some embodiments, the high-pressure fluid outlet 16 of the high-pressure fluid nozzle 12 faces the mixing chamber 3, and the center line of the high-pressure fluid nozzle 12 is collinear with the center line of the mixing chamber 3.

[0025] In some embodiments, as shown in FIG. 6, the peripheral wall of the diffusion segment 15 may be designed to satisfy the following: a perpendicular line "a" is drawn from the end point P2 of the peripheral wall of the diffusion segment 15 (the perpendicular line being perpendicular to a tangent line at the end point P2), and on the perpendicular line "a", there is an outer point P3 located inwardly of the peripheral wall and having a distance R from the end point P2, wherein $R=0.5L/(\sin\theta^*\cos\theta)$, where L is a total length of the diffusion segment 15, θ is a net diffusion angle of the diffusion segment (i.e., an angle between a line connecting the starting point P1 and the end point P2 of the diffusion segment 15 and the horizontal direction), and a line "b" connecting the outer point P3 and the starting point P1 of the peripheral wall of the diffusion segment 15 is perpendicular to a tangent line at the starting point P1. The segment between the point P1 and the point P2 may be formed by a convex arc-shaped segment as described above or in other various suitable forms. This design can improve the efficiency of the ejector.

[0026] A heat recovery or work recovery system may include an ejector as described above.

[0027] The specific embodiments described above are merely for describing the principle of the present disclosure more clearly, and various components are clearly illustrated or depicted to make it easier to understand the principle of the present disclosure. Those skilled in the art can readily make various modifications or changes to the present disclosure without departing from the scope of the claims. Therefore, it should be understood that these modifications or changes should be included within the scope of protection as defined by the claims.

Claims

1. An ejector (80) for a heat recovery or work recovery system, comprising:

    a high-pressure fluid passage (1) comprising a high-pressure fluid inlet (11) and a high-pressure fluid nozzle (16);
    a low-pressure fluid passage (2) comprising a low-pressure fluid inlet (21) and a suction cham-

ber (22) surrounding the high-pressure fluid nozzle;
a mixing chamber (3) in fluid communication with the high-pressure fluid passage and the low-pressure fluid passage respectively; and
a diffusion chamber (4) downstream of the mixing chamber;
wherein the high-pressure fluid nozzle comprises a constricted segment (13), a throat portion (14), and a diffusion segment (15) in sequence, a distal end of the diffusion segment defines a high-pressure fluid outlet, and a peripheral wall of the diffusion segment has a convex arc shape in a longitudinal section.

2. The ejector (80) for the heat recovery or work recovery system according to claim 1, wherein a diffusion angle (θ) at the high-pressure fluid outlet at the distal end of the diffusion segment (15) is in a range of 0° to 10°, preferably in a range of 0° to 5°, more preferably in a range of 0° to 3° for example, the diffusion angle is equal to 0°.

3. The ejector (80) for the heat recovery or work recovery system according to claim 1 or 2, wherein the peripheral wall of the diffusion segment (15) is composed of a convex arc-shaped segment having a gradually decreasing diffusion angle.

4. The ejector (80) for the heat recovery or work recovery system according to claim 1 or 2, wherein the peripheral wall of the diffusion segment (15) is composed of a convex arc-shaped segment having a parabolic shape.

5. The ejector (80) for the heat recovery or work recovery system according to claim 1 or 2, wherein the peripheral wall of the diffusion segment (15) is composed of a convex circular arc-shaped segment with a consistent radius of curvature.

6. The ejector (80) for the heat recovery or work recovery system according to any one of claims 1 to 5, wherein the peripheral wall of the diffusion segment (15) satisfies the following in a longitudinal section: a perpendicular line (a) is drawn from a tangent line at an end point (P2) of the diffusion segment (15), and on the perpendicular line, there is an outer point (P3) located inwardly of the peripheral wall and having a distance, R, from the end point (P2), wherein $R=0.5L/(\sin\theta*\cos\theta)$, where L is a total length of the diffusion segment (15), θ is a net diffusion angle of the diffusion segment, and a line connecting the outer point (P3) and a starting point (P1) of the peripheral wall of the diffusion segment (15) is perpendicular to a tangent line at the starting point (P1).

7. The ejector (80) for the heat recovery or work recovery system according to any preceding claim, wherein the high-pressure fluid outlet of the high-pressure fluid nozzle (16) faces the mixing chamber (3), and a center line of the high-pressure fluid nozzle is collinear with a center line of the mixing chamber.

8. The ejector (80) for the heat recovery or work recovery system according to any preceding claim, wherein the suction chamber (22) is in communication with the mixing chamber (3), and a transition segment (23) having a tapered structure is located between the suction chamber and the mixing chamber.

9. The ejector (80) for the heat recovery or work recovery system according to any preceding claim, wherein the constricted segment (13) of the high-pressure fluid nozzle (16) is composed of a straight segment having a constant constriction angle or an arc segment having a convex or concave shape.

10. A heat recovery or work recovery system, comprising the ejector (80) according to any one of claims 1 to 9.

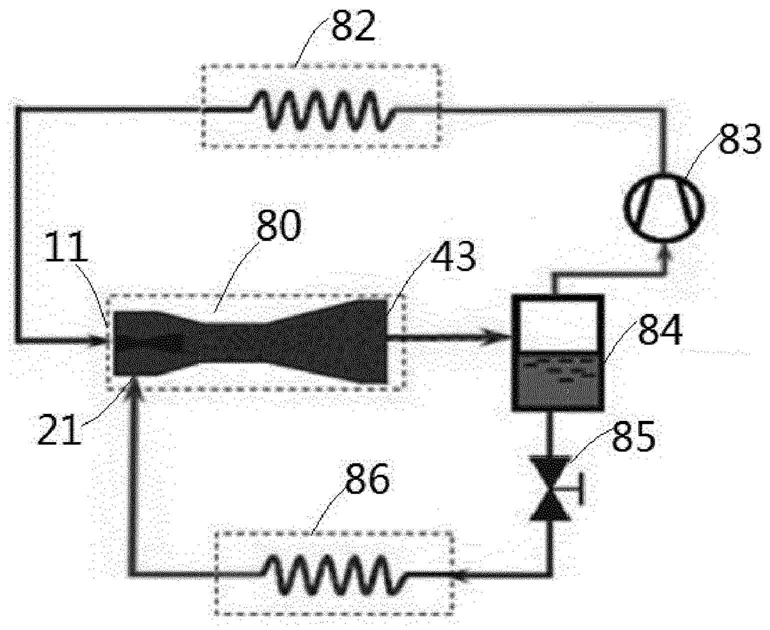

Fig.1

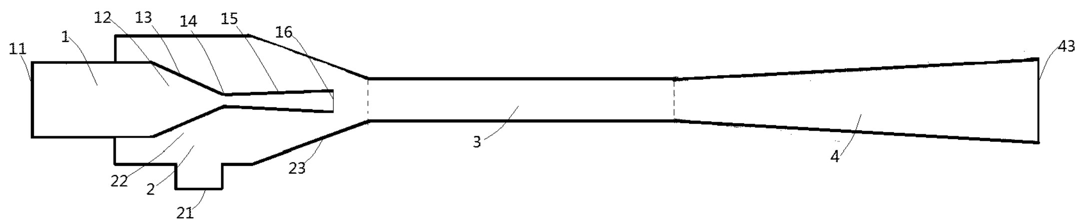

Fig.2

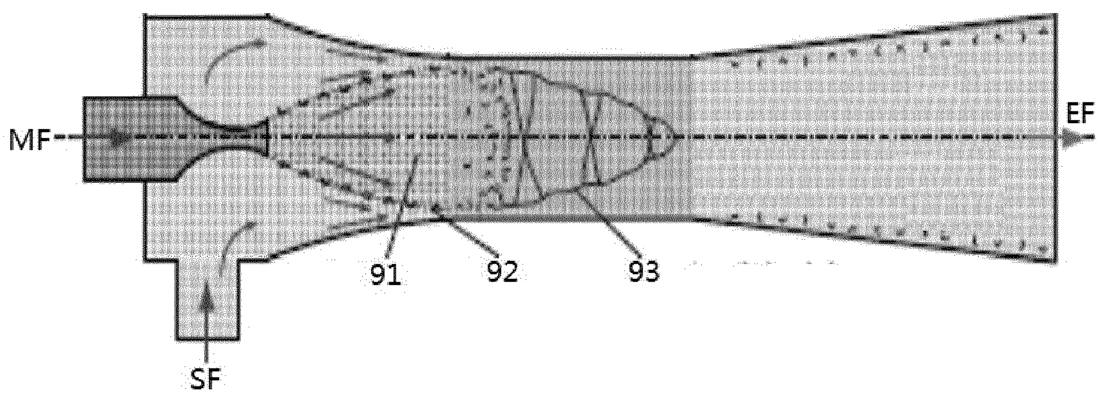

Fig.3

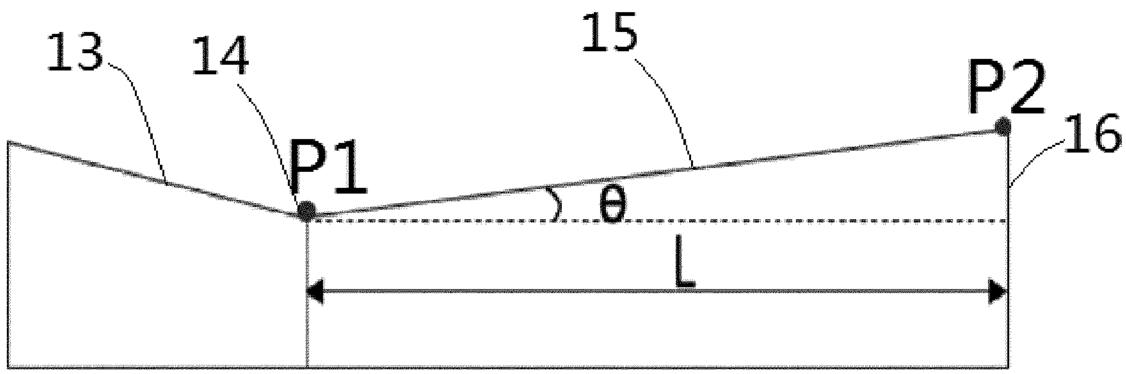

Fig.4

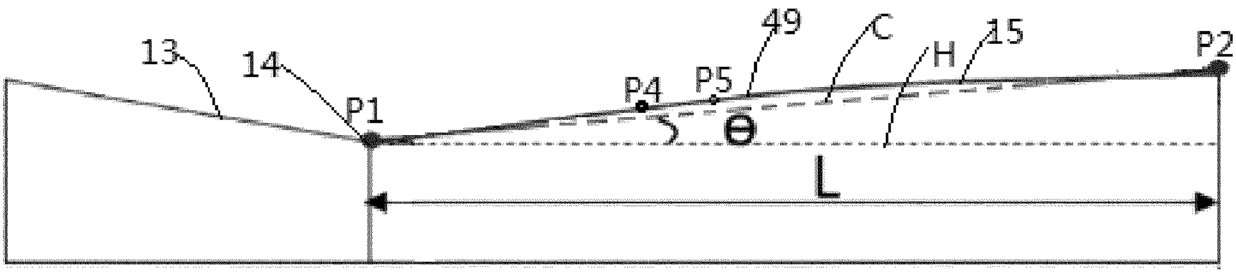

Fig.5

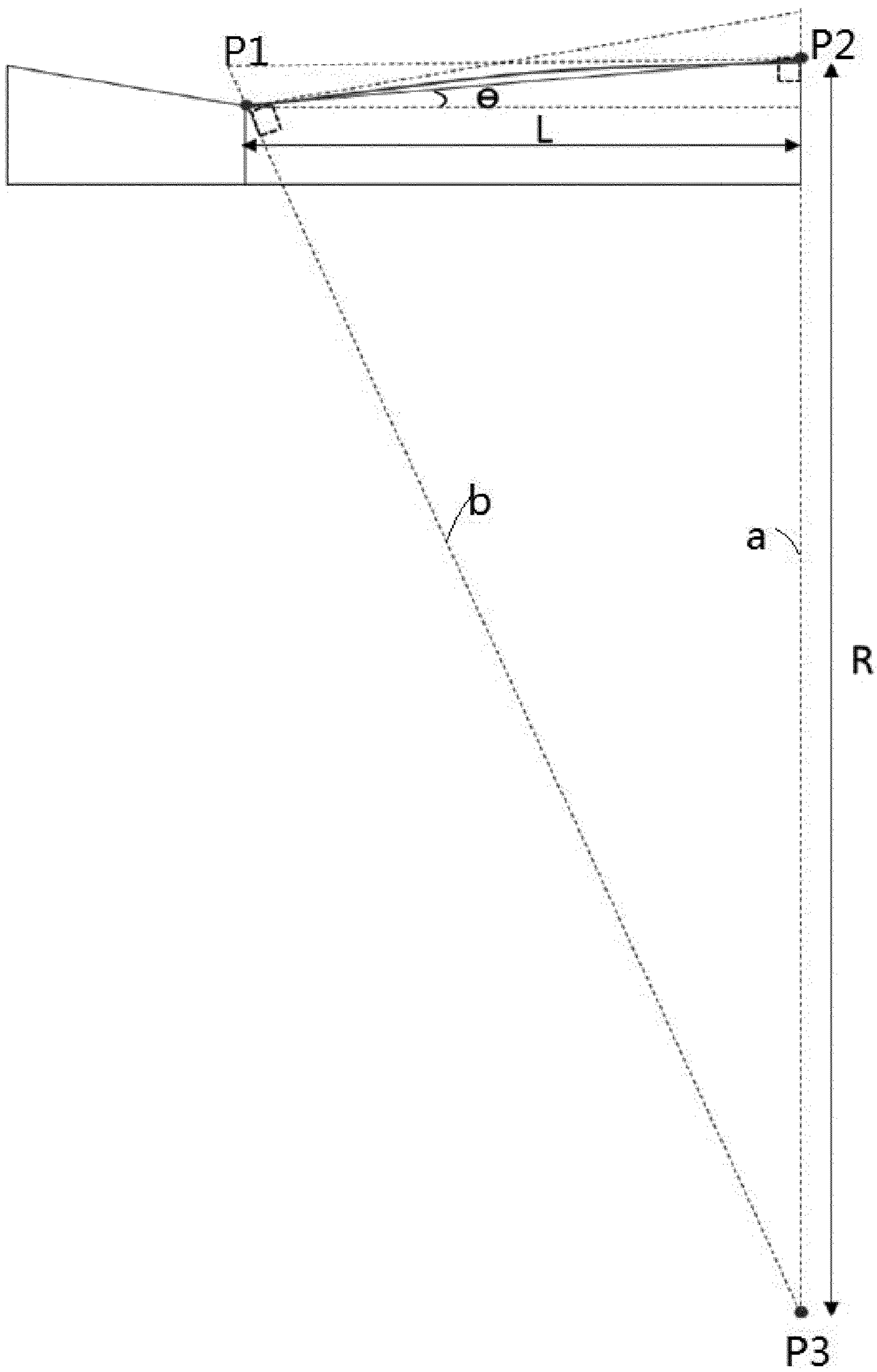

Fig.6

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EUROPEAN SEARCH REPORT

Application Number
EP 20 21 3788

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	FR 960 172 A (SOCIÉTÉ DES CONDENSEURS DELAS) 14 April 1950 (1950-04-14) * page 2, line 37 - page 3, line 92; figures 5,3,6 *	1-10	INV. F04F5/24 F04F5/46 F04F5/54
X	EP 3 093 585 A1 (CARRIER CORP [US]) 16 November 2016 (2016-11-16) * paragraphs [0031] - [0042]; figures 1,3,4 *	1-10	
X	DE 662 250 C (GERHARD FEHST DIPL ING) 9 July 1938 (1938-07-09) * page 1 - page 2; figures 1,2 *	1-10	
A	CN 106 391 341 A (CHINA SHENHUA ENERGY CO LTD; BEIJING GUOHUA ELECTRIC POWER ET AL.) 15 February 2017 (2017-02-15) * paragraphs [0040] - [0042]; figure 3 *	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

F04F
F25B
B05B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	1 March 2021	Jurado Orenes, A

CATEGORY OF CITED DOCUMENTS

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01-03-2021

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