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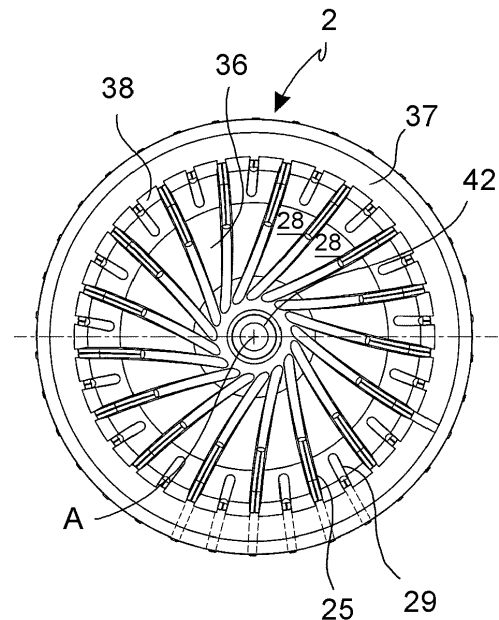
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(54) **A ROTOR FOR A RADIAL FAN AND A RADIAL FAN**

(57) A rotor (2) for a radial fan (1) comprises a plurality of main blades (25) positioned in sequence around a rotation axis (A) and a hub element (36) forming a guide surface (51) from which the main blades (25) project, wherein the guide surface (51) is a rotational surface with respect to the rotational axis (A) with a generatrix forming a convex radially inner portion (52), a concave intermediate portion (53), and, possibly, a substantially rectilinear radially outer portion (54) forming an outer ring that is planar and orthogonal to the rotational axis A.



**FIG. 2**

## Description

**[0001]** The present invention relates to a rotor for a radial fan and a radial fan provided with such rotor.

**[0002]** Radial fans, in particular fans intended to send air and/or gas (frequently in the form of a mixture thereof) to boilers, such as condensation boilers, comprise a housing provided with a suction aperture and a discharge aperture for the air. Inside the housing a rotor is arranged capable of rotating about an axis of rotation. The air enters the housing through the suction aperture in the axial direction, crosses the rotor and is discharged from it in the radial direction into a spiral portion of the housing, from which the air reaches the discharge aperture. To convey the air along said path, the rotor is provided with a plurality of blades arranged around the rotation axis of the rotor having an arched profile in the direction transverse to the rotation axis.

**[0003]** Radial fans must be able to provide adequate head in clearly defined flow intervals (so-called "working curves") to ensure the correct functioning for example of the condensing boiler to which they are connected.

**[0004]** Another deeply felt need, to which research in the field of radial fans devotes considerable efforts, is to achieve a reduction in dimensions without worsen performance. In other words, it is particularly desirable for radial fans to achieve efficient working curves while maintaining limited overall dimensions.

**[0005]** A further strongly felt need is to limit the energy consumption related to the operation of the rotor, usually set in motion by an electric motor.

**[0006]** To achieve the above objectives numerous solutions of radial fans have been proposed. In particular various configurations of the rotor blades as well as the housings suitable to receive them have been proposed. Some examples are provided by WO 2006/013067 A2 and EP 1744060 A2, in which rotors for radial fans and centrifugal fans are described in which some of the components have peculiar and advantageous geometric characteristics.

**[0007]** Yet a further specific need, closely linked to energy efficiency and the abatement of radial fan noise, is to further increase the fluid dynamic efficiency.

**[0008]** A further need felt is to be able to provide a fan which can achieve a high increase in static pressure of the conveyed air with a relatively small air flow. This is for example a key feature for making efficient heat exchangers of a compact size.

**[0009]** Lastly, modern radial fans are required to provide the aforesaid performance in a wide range of modulation of the flow of conveyed gas.

**[0010]** The purpose of the present invention is to make available a rotor for a radial fan and a radial fan which make it possible to achieve an efficient flow-head curve, in particular, appropriate to the operation of condensation boilers, such as not to requiring an excessive power consumption to drive the rotor, and to have overall limited dimensions.

**[0011]** These and other purposes are achieved by a rotor for a radial fan according to claim 1 and by a radial fan according to claim 10. The dependent claims refer to advantageous embodiments.

**[0012]** For a better understanding of the invention and its advantages some of its embodiments, made by way of non-limiting examples will be described below with reference to the appended drawings, wherein:

Figure 1 is an exploded perspective view of a radial fan according to the invention;

Figure 2 is a view in axial direction of a rotor according to the invention, in which a support ring is shown in transparency, to better highlight the position and the shape of the rotor blades;

Figure 3 is a partial view in radial cross-section of a rotor-housing group of the fan in figure 1;

Figure 4 is a view partially in radial cross-section of the rotor only of the fan in figure 1;

Figure 5 shows the geometry of a detail of the rotor according to one embodiment;

Figure 6 shows the geometry of a main blade of the rotor and of an auxiliary blade (split) of the rotor according to one embodiment;

Figures 7 and 8 are perspective views of a housing of the radial fan in Figure 1;

Figure 9 shows the geometry of a rotor space of a half-shell of the housing in figure 7 in an axial view;

Figure 10 shows the half-shell in cross-section along the plane X-X in figure 9;

Figures 11 and 12 show the geometry of a conveying tongue (nose) for the fan housing in figure 7, in two cross-section planes perpendicular to the rotation axis of the rotor;

Figure 13 shows the shape of the conveying tongue (nose) in figure 11 in an axial view and a radial view;

Figure 14 shows a fan housing according to one embodiment, in a side view;

Figure 15 shows a half-shell of the fan housing in figure 14, in an axial view;

Figure 16 shows a fan housing according to one embodiment, in a side view;

Figure 17 shows a half-shell of the fan housing in figure 16, in an axial view;

Figure 18 is a view in the axial direction of a rotor according to the invention, in which a support ring is shown in transparency, to better highlight the position and the shape of the rotor blades;

Figure 19 is a partial radial cross-section view of a rotor-housing group of the fan according to one embodiment;

Figure 20 is a partial view in radial cross-section of the rotor only of the rotor-housing group in figure 19;

Figure 21 shows the geometry of a detail of the rotor in figure 20,

**[0013]** With reference to the figures, a radial fan is globally denoted by reference numeral 1. The fan 1 is, for

example, suitable to convey air and/or gas (also in the form of a mixture thereof) towards a burner or a boiler or a general heating system. The fan 1 is particularly suitable to convey air and/or gas towards a condensation boiler.

**[0014]** The fan 1 comprises a rotor 2 able to rotate about a rotation axis A, in particular inside a housing 3 of the fan. In the present description and in the appended claims, the terms "axial" and "radial" refer to the rotation axis A of the rotor 2, unless otherwise specified.

**[0015]** The housing 3 preferably comprises two separate connectable parts, such as a half-shell 4 which defines a rotor space 6 suitable to receive within it the rotor 2 and a cover 5 suitable to close the rotor space 6. The half-shell 4 and the cover 5 can be connected to each other for example by means of threaded connection members 7. The cover 5 may further comprise a projecting portion 5' suitable to be inserted with a shaped coupling in the rotor space 6 delimited by the half-shell 4, advantageously substantially complementary to it.

**[0016]** The cover 5 is suitable to support a motor 8, preferably electric, intended to move the rotor 2 by means of its shaft 9 which, with the fan 1 assembled, is coaxial to the rotation axis A. The motor 8 may be connected to the cover 5 by means of an intermediate support 10 provided for connection to the cover 5, for example by means of screws 11 to be inserted in corresponding screw seats 12 of the cover 5. Preferably, the screw seats 12 are arranged along a circumference at constant angular distances. For example, the screw seats 12 may be three in number and spaced from each other by 120°. In order to permit the coupling of the screws 11 and the screw seats 12, the intermediate support 10 may be provided with as many radial brackets 15 correspondingly distributed to the screw seats 12 of the cover 5.

**[0017]** In order to limit the transmission of vibrations between the motor 8 and the cover 5, the fan 1 may comprise means for damping the vibrations. According to a possible embodiment, such damping means of the vibrations comprise first dampers 13 suitable to act between the intermediate support 10 and the cover 5, for example rubber elements provided with a through opening for the passage of the screws 11, so as to dampen the vibrations parallel to the rotation axis A. Alternatively, or in addition to the first dampers 13, the fan 1 may further comprise second dampers 14, acting between the intermediate support 10 and the cover 5 oriented and shaped so as to dampen the vibrations transmitted from the motor 8 to the housing 3 along radial directions. The second dampers 14, for example rubber elements, may be inserted in brackets 16 formed by or connected to the cover 5, and preferably arranged along an inner circumference to the circumference along which the screw seats 12 are arranged. Even more preferably such brackets 16 are three in number and arranged at 120° relative to one another. The second dampers 14 may for example be placed laterally in contact with the intermediate support 10, so as to act in the radial direction between the latter and the

brackets 16.

**[0018]** In order to ensure protection of the motor 8 during the operation of the fan 1, the latter may comprise a cover element 17 connected to the motor 8, for example by screws 18. Said cover element 17 is preferably cup-shaped, so as to make the motor 8 inaccessible once the fan 1 has been assembled. The cover element 17 may have the function of protecting, in addition to the motor 8, one or more further auxiliary elements 48, such as electronic control circuits of the motor 8.

**[0019]** Advantageously, to permit the passage of the shaft 9 of the motor 8 through the cover 5 and its connection with the rotor 2 housed in the rotor space 6, the cover 5 comprises a through aperture 19.

**[0020]** The fan 1 comprises a suction aperture 20 and a discharge aperture 21 for the air and/or gas. According to one embodiment, the suction aperture 20 and the discharge aperture 21 are made in the half-shell 4. In particular, the suction aperture 20 is preferably arranged laterally on the half-shell 4 and shaped so that the incoming air and/or gas enters the rotor space 6 and reaches the rotor 2 along a substantially axial direction. The discharge aperture 21 is preferably made at one end 23 of a discharge portion 22 of the half-shell 4 which extends in a direction substantially tangential to the housing 3 (figures 9, 15, 17), so that the air and/or gas discharged by the rotor 2 circulates in the rotor space 6 along substantially tangential flow lines and is discharged by the fan 1 through the discharge aperture 21 without undergoing excessive deviations in its motion.

**[0021]** At the end 23 of the discharge portion 22 a flange 24 may be provided suitable to connect the fan 1 to outer support elements (not shown in the figures), for example by means of threaded connection elements.

**[0022]** To ensure the movement of the air and/or gas in the fan 1, the rotor 2 comprises a plurality of main blades 25 arranged in succession around the rotation axis A (figures 2, 5, 20, 21). Each of the main blades 25 has a radially more inward leading end 32 and a radially more outward trailing end 33. The leading end 32 has the function of aspirating and capturing the air and/or gas coming in the axial direction from the suction aperture 20 and the trailing end 33 has the function of guiding the air and/or gas discharged by the rotor 2 into the rotor space 6 of the housing 3.

**[0023]** Each of the main blades 25 comprises a concave primary surface of the main blade 26 and a convex secondary surface of the main blade 27 opposite the primary surface of the main blade 26. This way, each of the main blades 25 has a substantially arched shape. Furthermore, the secondary surface of the main blade 27 of each of the main blades 25 faces toward the primary surface of the main blade 26 of the next main blade. This way, between two successive main blades of a pair of main blades a flow passage 28 is formed for conveying the air and/or gas between a radially inner position and a radially outer position of the rotor 2. In particular, in the assembled condition of the fan 1, the rotor 2, rotating as

a result of operation by the motor 8, aspirates the air and/or gas from the suction aperture 20 of the housing 3, coaxial to the rotor 2, and conveys it by effect of the rotation of the rotor into the flow passages 28 delimited by the main blades 25, lastly discharging it radially outside the rotor 2 in the rotor space 6.

**[0024]** The main blades 25 are shaped so as to optimise the fluid dynamics inside the rotor and thus the overall performance of the fan 1.

**[0025]** According to one embodiment (figures 2 - 6), the main blades 25 are free from twisting (i.e. the chord angle of the split is constant and the chord is parallel to the rotation axis A) and, in a cross-section plane perpendicular to the rotation axis A, extend along an arc of a circle with a substantially constant radius of curvature R1, preferably in the range from 140mm to 180mm, preferably from 150mm to 170mm, even more preferably about 159mm.

**[0026]** Of course, in the evaluation of the above dimensional parameters, the inevitable rounding of the decimal numbers should be borne in mind. This consideration may also be extended to the dimensional ratios and/or the dimensions described and claimed below, and will not therefore be repeated each time.

**[0027]** The rotor 2 further comprises a plurality of auxiliary blades 29 (so-called "splits") also arranged around the rotation axis of the rotor 2, and having a radial extension and length less than the radial extension and length of the main blades 25. The main blades 25 and the splits 29 alternate, so that in each of the flow passages 28 only one of the splits 29 is provided for.

**[0028]** Each of the splits 29 has a radially inner leading end 34 and a radially outer trailing end 35. Furthermore, each of the splits 29 comprises a concave split primary surface 30 and a convex split secondary surface 31 opposite the split primary surface 30 of said split 29 (figures 2, 5, 6). The split primary surface 30 of each of the splits 29 faces towards the secondary surface of the main blade 27 of a first of the main blades 25 between which the split 29 is positioned and the secondary split surface 31 of each of the auxiliary blades 29 faces toward the primary surface of the main blade 26 of a second of the main blades 25 between which is the split 29 is positioned.

**[0029]** According to one embodiment (figures 2 - 6), the splits 29 are free from twisting (i.e. the chord angle of the split is constant and the chord is parallel to the rotation axis A) and, in a cross-section plane perpendicular to the rotation axis A, extend along an arc of a circle with a substantially constant radius of curvature R2, preferably in the range from 140mm to 180mm, preferably from 150mm to 170mm, even more preferably about 159mm. Advantageously, the radius of curvature R2 of the splits 29 is substantially equal to the radius of curvature R1 of the main blades 25.

**[0030]** The main blades 25 and splits 29 thus preferably have the shape of cylindrical wall portions extending in a direction parallel to the rotation axis A and with a constant radius of curvature R1, R2 in the section planes

orthogonal to the rotation axis A.

**[0031]** To ensure an efficient flow of the air and/or gas through the rotor 2, as well as limited power absorptions by the motor 8 which drives the rotor 2, it is important that the blades, in addition to the shape described, have an adequate spatial arrangement inside the rotor as well as a suitable orientation at their leading and trailing ends where the air and/or gas are respectively suctioned and discharged.

**[0032]** With reference to the main blades (figures 5 and 6), at the trailing end 33 it is possible to draw a straight line  $T_{outpp}$  tangent to the arc of the main blade and a further radial straight line  $R_{outpp}$  which connects said trailing end 33 with the centre of the rotor, i.e. with the rotation axis A. Said two straight lines  $T_{outpp}$  and  $R_{outpp}$  identify a main blade output angle  $\beta_{outpp}$  which, advantageously, is between  $-5^\circ$  and  $+5^\circ$  and which preferably is approximately  $0^\circ$ . Therefore, according to a preferred embodiment, the trailing end of the main blade 33 is oriented exactly in a radial direction to the rotation axis A.

**[0033]** Also at the leading end 32 of the main blade 25 it is possible to draw a straight line  $T_{inpp}$  tangent to the arc of the main blade and a further radial straight line  $R_{inpp}$  which connects said leading end 32 to the rotation axis A. Said two straight lines  $T_{inpp}$  and  $R_{inpp}$  identify an input angle of the main blade  $\beta_{inpp}$  that is advantageously between  $45^\circ$  and  $55^\circ$  and which is preferably equal to about  $50.5^\circ$ .

**[0034]** The above-mentioned straight lines  $R_{outpp}$  and  $R_{inpp}$ , passing through the rotation axis A and, respectively, through the leading end 32 and the trailing end 33 of the main blade 25, form between them a wrap angle of the main blade  $\theta_{pp}$  which is advantageously between  $30^\circ$  and  $50^\circ$  and preferably is equal to approximately  $43^\circ$ .

**[0035]** With reference to the splits 29, with geometric constructions entirely analogous to those described for the main blades 25 it is possible to identify an output angle of the split  $\beta_{outps}$ , an input angle of the split  $\beta_{inps}$  and a wrap angle of the split  $\theta_{ps}$  (figures 5, 6).

**[0036]** The split output angle  $\beta_{outps}$  may be between  $-5^\circ$  and  $+5^\circ$  and is preferably equal to about  $0^\circ$ .

**[0037]** The split input angle  $\beta_{inps}$  may be between  $4^\circ$  and  $6^\circ$  and is preferably equal to about  $4.7^\circ$ .

**[0038]** The split wrap angle  $\theta_{ps}$  may be between  $7^\circ$  and  $-3^\circ$  and is preferably equal to about  $2^\circ$ .

**[0039]** The trailing ends 33 of the main blades 25 are arranged so as to define an outer rotor circumference which substantially delimits the maximum radial dimensions of the rotor. Similarly, the leading ends 32 of the main blades 25 are arranged so as to define an inner circumference of the main blades. The outer circumference of the rotor and the inner circumference of the main blades respectively have a rotor diameter  $D_{max}$  and an inner diameter of the main blades  $d_{ipp}$  (Figure 4) which, advantageously, have a dimensionless ratio  $D_{max} / d_{ipp}$  in the range between 5 and 7 and which is preferably approximately equal to 5.9.

**[0040]** At the outer circumference of the rotor, the rotor

2 has an axial rotor height  $h_{\text{ext}}$  (figure 4). According to one embodiment, the rotor diameter  $D_{\text{max}}$  and the axial rotor height  $h_{\text{ext}}$  have a ratio  $D_{\text{max}} / h_{\text{ext}}$  in the range from 4 to 5, and preferably equal to about 4.91.

**[0041]** Advantageously, the trailing ends 35 of the splits 29 are also arranged along the outer rotor circumference (figures 4, 5). Furthermore, their leading ends 34 are arranged so as to define a split inner circumference with a split blade inner diameter  $d_{\text{ips}}$ . Advantageously, the rotor diameter  $D_{\text{max}}$  and the split inner diameter  $D_{\text{ips}}$  have a ratio  $D_{\text{max}} / D_{\text{ips}}$  in the range from 1.55 to 1.65, preferably equal to about 1.59.

**[0042]** According to one embodiment, the ratio  $R1 / D_{\text{max}}$  between the radius of curvature  $R1$  of the main blades 25 and the outer diameter  $D_{\text{max}}$  of the rotor 2 is in the range from 1.55 to 2.0, preferably from 1.7 to 1.9, even more preferably of about  $R1 / D_{\text{max}} = 1.77$ .

**[0043]** Advantageously, the ratio  $R2 / D_{\text{max}}$  between the radius of curvature  $R2$  of the splits 29 and the outer diameter  $D_{\text{max}}$  of the rotor 2 is in the range from 1.55 to 2.0, preferably from 1.7 to 1.9, even more preferably approximately  $R2 / D_{\text{max}} = 1.77$ .

**[0044]** According to a preferred embodiment, the geometric parameters may be chosen as follows:

$$D_{\text{mas}} = 90 \text{ mm}$$

$$R1 = R2 = 159.1 \text{ mm}$$

$$d_{\text{ipp}} = 15.25 \text{ mm}$$

$$d_{\text{ips}} = 56.5 \text{ mm}$$

$$h_{\text{ext}} = 18.3 \text{ mm}.$$

**[0045]** According to one embodiment (figures 2, 4), the rotor 2 comprises a hub element 36 intended to be connected to the shaft 9 of the motor 8 to drive the rotor 2. The hub element 36 forms a guide surface 51 facing a front side 50 of the rotor 2 intended to face towards the suction aperture 20 of the housing 3. The main blades 25 and the splits 29 protrude from the guide surface 51 and, during the rotational movement of the rotor 2 inside the housing 3, the air and/or the gas is guided from the suction aperture 20 along the guide surface 51 in the flow passages 28 defined between the main blades 25. Along this path the air or gas is forced to change direction from a direction initially mainly axial (with respect to the rotation axis A) to a mainly radial and circumferential direction relative to the rotation axis A.

**[0046]** According to one relatively important aspect of the invention, the guide surface 51 is a rotation surface around the rotation axis A, preferably annular, or alternatively circular, with double curvature generatrix which forms a convex radially inner portion 52 to which an intermediate concave portion 53 connects (in a step or interruption free point of inversion). Of further advantage, the intermediate portion 53 connects to a substantially

rectilinear radially outer portion 54 which forms an outer ring that is planar and orthogonal to the rotational axis A.

**[0047]** This way, the guide surface 51 has the shape of an axially compressed or flattened bell, similar to a Gaussian bell, with the effect of reducing the transversal mixing, and turbulence effects between the molecules of the gas conveyed.

**[0048]** According to one embodiment, the radially inner 52 and intermediate 53 portions of the generatrix of the guide surface 51 are in the shape of an arc of a circle in which the curvature radius  $R52$  of the radially inner portion 52 is less than the curvature radius  $R53$  of the intermediate portion 53, preferably  $R52 < 0.7 \cdot R53$ , even more preferably  $R52$  is about  $0.5 \cdot R53$ .

**[0049]** In addition, the ratio  $D54_{\text{ex}} / D_{\text{max}}$  between an outer diameter  $D54_{\text{ex}}$  of the guide surface 51 and an outer diameter  $D_{\text{max}}$  of the rotor 2 is advantageously in the range from 0.7 to 0.85, preferably about 0.76.

**[0050]** In addition, the ratio  $D53_{\text{ex}} / D54_{\text{ex}}$  between an outer diameter  $D53_{\text{ex}}$  of the concave intermediate portion 53 of the generatrix of the guide surface 51 and an outer diameter  $D54_{\text{ex}}$  of the guide surface 51 is advantageously in the range from 0.75 to 0.89, preferably about 0.83.

**[0051]** By way of example of an advantageous embodiment, the aforementioned geometrical parameters may be chosen as follows:

$$R52 = 8 \text{ mm} \dots 10 \text{ mm} \dots 12 \text{ mm},$$

$$R53 = 16 \text{ mm} \dots 20 \text{ mm} \dots 24 \text{ mm},$$

$$D54_{\text{ex}} = 65 \text{ mm} \dots 68 \text{ mm} \dots 73 \text{ mm},$$

$$D53_{\text{ex}} = 54 \text{ mm} \dots 56.5 \text{ mm} \dots 59 \text{ mm},$$

**[0052]** The rotor 2 may also comprise a peripheral support ring 37, placed in a position axially opposite the hub element 36 and which forms an aperture 38 overlapping in the axial direction (relative to the rotation axis A) with the hub element 36. With the fan assembled, the support ring 37 is positioned around the suction aperture 20 of the housing 3. This way, during the rotational movement of the rotor 2, the air and/or the gas is guided from the suction aperture 20 through the aperture 38 along the guide surface 51 and along an inner surface 56 of the support ring 37 which partially close on two axially opposite sides the flow passages 28 delimited by the blades 25, 29, thereby imposing on the air and/or gas to transit inside them.

**[0053]** The support ring 37 is connected to all the main blades 25 and splits 29 on a front side thereof axially opposite the guide surface 51 of the hub element 36.

**[0054]** According to one embodiment, the hub element 36, support ring 37 and the main and secondary blades are made in one piece, e.g. using a moulding process, preferably in plastic material.

**[0055]** In order to permit the moulding operation of the rotor 2 in a single piece, the hub element 36 and the support ring 37 are arranged so that the projection of the hub element 36 on the support ring 37 along the rotation

axis of the rotor A is at or inside the aperture 38 of the support ring 37. In particular, the aperture 38 is circular in shape and the hub element 36 has also a circular shape with dimensions equal or inferior (preferably slightly smaller) to those of the aperture 38.

**[0056]** Advantageously, the hub element 36 and the support ring 37 are mutually connected both by means of the main blades 25 and the splits 29 (figure 4), which have their leading ends 32, 34 on the hub element 36 and comprise connection portions 40 in which their height (in the axial direction A of the rotor) increases gradually from such leading ends 32, 34 radially outwardly until reaching the maximum value in a radially inner area with respect to the support ring 37. Starting from the radial position corresponding to the support ring 37, the main blades 25 and splits 29 extend radially (but not in a perfectly radial direction, but with the curvature described above) outwardly along the support ring 37 up to their trailing ends 33, 35 (figures 3, 5, 19, 20). Preferably, the trailing ends 33 of the main blades 25 and the splits 29, which define the rotor circumference of diameter  $D_{\max}$ , end exactly flush with an outer circumference of the support ring 37 (figure 4).

**[0057]** In one embodiment, the outer diameter  $D_{37\text{ex}}$  of the support ring 37 corresponds exactly with the outer diameter  $D_{\max}$  of the rotor 2 and the ratio  $D_{\max}/D_{37\text{int}}$  between the outer diameter  $D_{\max}$  of the rotor 2 and an inner diameter  $D_{37\text{int}}$  of the support ring 37 is in the range 1.1 to 1.3, preferably about 1.22.

**[0058]** By way of example,  $D_{37\text{int}}$  may be chosen in the range of 73mm ... 73.9mm ... 75mm.

**[0059]** As illustrated for example in figures 3 and 4, a front edge of the main blades 25 forms the aforementioned substantially straight connection portion 40 seen in a circumferential direction relative to the axis of rotation A, to which an outer continuously convex portion connects, for example formed of an intermediate arc of circle portion 57 having a radius of curvature  $R_{57}$  and a radially outer portion 58 of an arc of circle having a radius of curvature  $R_{58}$  (at the support ring 37), wherein the ratio  $R_{57}/R_{58}$  of the two curvatures may advantageously be in the range from 0.18 to 0.22, preferably about 0.2.

**[0060]** By way of example of an advantageous embodiment, the aforementioned geometrical parameters may be chosen as follows:

$$\begin{aligned} R_{57} &= 17\text{mm} \dots \underline{20\text{mm}} \dots 24\text{mm}, \\ R_{58} &= 92\text{mm} \dots \underline{100\text{mm}} \dots 110\text{mm}. \end{aligned}$$

**[0061]** The ratio  $D_{25\text{alt}}/D_{\max}$  between a diameter  $D_{25\text{alt}}$  of the point of maximum axial height of the main blade 25 and the outer diameter  $D_{\max}$  of the rotor 2 may advantageously be in the range from 0.45 to 0.6, preferably about 0.52.

**[0062]** To permit the connection of the rotor 2 to the motor 8, the hub element 36 advantageously comprises a tubular portion 42 suitable to receive the shaft 9 of the motor 8 and which preferably extends parallel to the ro-

tation axis A of the rotor 2. The shaft 9 may be connected to the tubular portion 42 by means of locking means (not shown in the figures) suitable to connect the latter integrally in rotation and in translation along the rotation axis A.

**[0063]** In this tubular attachment area of the motor shaft to the hub element 36, the hub element 36 may form a discontinuity with respect to the curvature of the guide surface 51 described (figures 4, 20).

**[0064]** In a preferred embodiment, the number of main blades 25 is seventeen and the number of splits 29 is seventeen.

**[0065]** The main blades 25 and the splits 29 may have a substantially constant thickness  $s_{\text{pp}}$  and  $s_{\text{ps}}$  equal to about 1.15mm (at the slimmer end) ... 1.8mm.

**[0066]** The rotor space 6 of the housing 3 in the axial direction has a housing axial height  $H_{\text{all}}$  (figures 3, 19) which, advantageously, has with the axial height of the rotor  $h_{\text{ext}}$  a ratio in the range  $H_{\text{all}} / H_{\text{ext}} = 1.0 \dots 1.15$ , preferably equal to about  $H_{\text{all}} / H_{\text{ext}} = 1.08$ .

**[0067]** By way of an example of a preferred embodiment, the axial height of the housing  $H_{\text{all}}$  may be 19.2mm ... 19.8mm ... 20.3mm.

**[0068]** Furthermore, the rotor space 6 of the housing 3, transversally to its height  $H_{\text{all}}$ , and thus transversely to the rotation axis A of the impeller 2, is delimited by a transversal profile which comprises a main section 45 advantageously shaped as a plurality of successive housing circular arcs (figures 9, 15, 17). The transversal profile of the rotor space 6 may further comprise a discharge portion 46, in which the housing 3 extends into the discharge portion 22, identified by a reference angle  $\alpha$ .

**[0069]** According to one embodiment, the main section 45 comprises four of the aforesaid successive housing circular arcs, in particular a first CC1, a second CC2, a third CC3, and a fourth CC4 arc of a circle of housing respectively having a first housing radius of curvature  $RC_1$ , a second housing radius of curvature  $RC_2$ , a third housing radius of curvature  $RC_3$ , and a fourth housing radius of curvature  $RC_4$ . These arcs of circles of housing are disposed in an order, preferably starting more or less from the discharge portion 46, with a direction opposite to that of rotation of the rotor 2. In particular, with reference to figure 9, the arcs of circles of housing are arranged counter-clockwise, while the rotor is intended to rotate clockwise.

**[0070]** Advantageously, such housing radii of curvature have ratios in the following ranges and preferred values (underlined):  $RC_1/RC_2 = 1.25 \dots \underline{1.27} \dots 1.3$ ;  $RC_1/RC_3 = 1.37 \dots \underline{1.4} \dots 1.43$ ;  $RC_1/RC_4 = 1.45 \dots \underline{1.49} \dots 1.53$ .

**[0071]** By way of example of an advantageous embodiment, the aforementioned geometrical parameters may be chosen as follows:

$$\begin{aligned} RC_1 &= 67\text{mm} \dots \underline{70\text{mm}} \dots 73\text{mm}, \\ RC_2 &= 52\text{mm} \dots \underline{55\text{mm}} \dots 58\text{mm}, \end{aligned}$$

RC3 = 47mm ... 50mm ... 53mm,  
RC4 = 44mm ... 47mm ... 50mm,

**[0072]** provided that the radii of curvature of housing RC1, RC2, RC3, RC4 are decreasing from RC1 to RC4, namely counter-clockwise in figure 9.

**[0073]** According to one embodiment, the first radius of curvature of housing RC1 and the rotor diameter  $D_{\max}$  have a ratio within the following range and preferred value (underlined):  $D_{\max}/RC1 = 1.2 \dots \underline{1.29} \dots 1.4$ .

**[0074]** The housing arcs of circle are advantageously connected so that the main section 45 of the transversal profile of the rotor space 6 is substantially free of discontinuities.

**[0075]** The discharge portion 46 may have a width  $\alpha$  between  $60^\circ$  and  $80^\circ$ , preferably equal to about  $70^\circ$ .

**[0076]** Advantageously, the housing 3 comprises a guide tongue 47 suitable to convey the air and/or gas discharged radially by the rotor 2 towards the discharge portion 22 and from there towards the discharge aperture 21 (figures 9, 11- 13, 15, 17). This guide tongue 47, preferably cantilevered formed in a single piece with the half-shell 4 of the housing 3, is placed in the rotor space 6 at the discharge portion 46.

**[0077]** The guide tongue 47 forms a curved radially inner surface 59 (facing the rotor space 6) substantially with said fourth radius of curvature of housing RC4, and a radially outer surface 60 with a double curvature with a convex portion remote from the discharge aperture 21 and a concave portion next to the discharge aperture 21.

**[0078]** To further advantage, the guide tongue 47 has a cross-section that increases gradually in the direction of the rotation axis A towards the discharge aperture 21 (figure 13), so as to force the air and/or gas discharged by the rotor to follow a circumferential path along the entire rotor space before reaching the discharge portion 22. Moreover, the guide tongue 47 has a cross-section which gradually increases in a direction radial to the rotation axis A towards the discharge aperture 21 (figure 13).

**[0079]** The housing 3, in particular the half-shell 4 and the cover 5, are preferably made of aluminium or aluminium alloy.

**[0080]** The fan 1 thus configured is able to guarantee high head values and that do not undergo excessive variations as the flow rates dispensed vary. It has also been verified that the power absorbed by the electric motor for operating the fan at the working pressures and flow rates is maintained at sufficiently low levels.

**[0081]** The overall dimensions of the fan, due essentially to the axial and radial dimensions of the rotor, which determine the axial and radial dimensions of the housing, are suitable for applications for which the fans according to the invention are intended, in particular for the supply of air and/or gas to condensing boilers.

**[0082]** From the description given above a person skilled in the art may thus appreciate how the rotor and fan according to the invention permit the achievement of

efficient flow rate-head working curves for limited energy consumption and overall dimensions.

**[0083]** Figures 21, 22, 23 illustrate an embodiment of a rotor and a fan which have several features in common with the fan described so far, but which differ in some details that will emerge from the following brief description:

**[0084]** The main blades 25 are free of twisting, and in a cross-section plane perpendicular to the rotation axis A, extend along an arc of a circle with a substantially constant radius of curvature R1, preferably in the range from 575mm to 625mm, preferably approximately 599mm.

**[0085]** The splits 29 are free of twisting, and in a cross-section plane perpendicular to the rotation axis A, extend along an arc of a circle with a substantially constant radius of curvature R2, preferably in the range from 575mm to 625mm, preferably approximately 599mm.

**[0086]** Advantageously, the radius of curvature R2 of the splits 29 is substantially equal to the radius of curvature R1 of the main blades 25.

**[0087]** The ratio  $D_{\max} / D_{\text{ipp}}$  between the outer rotor circumference  $D_{\max}$  and the inner circumference of the main blades  $d_{\text{ipp}}$  is in the range from 3.5 to 5.5, preferably about 4.6 .

**[0088]** The rotor diameter  $D_{\max}$  and the axial rotor height  $h_{\text{ext}}$  have a ratio  $D_{\max} / H_{\text{ext}}$  in the range from 7 to 7.5, and which is preferably equal to about 7.27.

**[0089]** The rotor diameter  $D_{\max}$  and the split inner diameter  $D_{\text{ips}}$  have a ratio  $D_{\max} / D_{\text{ips}}$  in the range from 1 to 2, preferably equal to about 1.5.

**[0090]** According to one embodiment, the ratio R1 /  $D_{\max}$  between the radius of curvature R1 of the main blades 25 and the outer diameter  $D_{\max}$  of the rotor 2

**[0091]** (embodiment in figures 21-23) is in the range from 4.5 to 5.5 preferably about R1 /  $D_{\max} = 4.99$ .

**[0092]** Advantageously, the ratio R2 /  $D_{\max}$  between the radius of curvature R2 of the splits 29 and the outer diameter  $D_{\max}$  of the rotor 2 is in the range from 4.5 to 5.5, preferably approximately R2 /  $D_{\max} = 4.99$ .

**[0093]** By way of example, the geometric parameters may be chosen as follows:

$D_{\max} = 120\text{mm}$   
 $R1 = R2 = 599.1 \text{ mm}$   
 $d_{\text{ipp}} = 26.2\text{mm}$   
 $d_{\text{ips}} = 78\text{mm}$   
 $h_{\text{ext}} = 16.5\text{mm}.$

**[0094]** In the embodiments in figures 21-23 also, the hub element 36 forms a guide surface 51 from which the main blades 25 and the splits 29 protrude and which is a rotation surface with respect to the rotation axis A, preferably annular or alternatively circular, with double curvature generatrix which forms a convex radially inner portion 52 to which an intermediate concave portion 53 connects (in a stepless or interruption-free point of inversion). Of further advantage, the intermediate portion 53 con-

nects to a substantially rectilinear radially outer portion 54 which forms an outer ring that is planar and orthogonal to the rotational axis A.

**[0095]** This way, here too the guide surface 51 has the shape of an axially compressed or flattened bell, similar to a Gaussian bell, with the effect of reducing the transversal mixing, and turbulence effects between the molecules of the gas conveyed.

**[0096]** The radially inner 52 and intermediate 53 portions of the generatrix of the guide surface 51 are composed of series of arcs of a circle in which the curvature radius R52 of the radially inner portion 52 is less than the curvature radius R53 of the intermediate portion 53.

**[0097]** In addition, the ratio D54ex/Dmax between an outer diameter D54ex of the guide surface 51 and an outer diameter Dmax of the rotor 2 is advantageously in the range from 0.7 to 0.75, preferably about 0.72.

**[0098]** In addition, the ratio D53ex/D54ex between an outer diameter D53ex of the concave intermediate portion 53 of the generatrix of the guide surface 51 and an outer diameter D54ex of the guide surface 51 is advantageously in the range from 0.85 to 0.95, preferably about 0.9.

**[0099]** Contrary to the embodiment of figures 2 and 3, in the embodiment of figures 21-23 the outer diameter D37ex of the support ring 37 is inferior to the outer diameter Dmax of the rotor 2. The ratio Dmax/D37int between the outer diameter Dmax of the rotor 2 and an inner diameter D37int of the support ring 37 is in the range from 1.2 to 1.3, preferably about 1.25.

**[0100]** The ratio Dmax/D37ext between the outer diameter Dmax of the rotor 2 and the outer diameter D37ext of the support ring 37 is in the range from 1.02 to 1.1, preferably about 1.04.

**[0101]** By way of example, D37int may be chosen in the range of 92mm ... 96mm ... 100mm and D37ext may be chosen in the range 113mm.. 115.3 mm ... 117mm.

**[0102]** A person skilled in the art may make numerous modifications and variations to the embodiments described of the rotor and of the radial fan, replacing elements with others functionally equivalent so as to satisfy specific contingent requirements while remaining within the sphere of protection of the following claims.

## Claims

1. A rotor (2) for a radial fan (1), which is suitable to rotate about a rotational axis (A) and comprising a plurality of main blades (25) arranged in sequence about said rotational axis (A) and having radially inner leading ends (32) and radially outer trailing ends (33), wherein the rotor (2) comprises a hub member (36) forming a guide surface (51) from which the main blades (25) project, **characterised in that** the guide surface (51) is a rotational surface with respect to the rotational axis (A) with a generatrix forming a

convex radially inner portion (52), a concave intermediate portion (53), and, possibly, a substantially rectilinear radially outer portion (54) forming an outer ring that is planar and orthogonal to the rotational axis A.

2. The rotor (2) according to claim 1, wherein the guide surface (51) has substantially the shape of a Gaussian bell that is flattened in the direction of the rotational axis (A).
3. The rotor (2) according to claim 1, wherein said radially inner (52) and intermediate (53) portions of the generatrix of the guide surface (51) are in the shape of an arc of a circle, and a curvature radius (R52) of the radially inner portion (52) is less than a curvature radius (R53) of the intermediate portion (53), preferably  $R52 < 0.7 \cdot R53$ , still more preferably R52 is about  $0.5 \cdot R53$ .
4. The rotor (2) according to one of the preceding claims, wherein a ratio (D54ex/Dmax) between an outer diameter (D54ex) of the guide surface (51) and an outer diameter (Dmax) of the rotor (2) ranges from 0.7 to 0.85, preferably it is about 0.76.
5. The rotor (2) according to one of the preceding claims, wherein a ratio (D53ex/D54ex) between an outer diameter (D53ex) of the concave intermediate portion (53) of the generatrix of the guide surface (51) and an outer diameter (D54ex) of the guide surface (51) ranges from 0.75 to 0.89, preferably it is about 0.83.
6. The rotor (2) according to one of the preceding claims, wherein the main blades (25) are free from twisting and extend along an arc of a circle with a substantially constant curvature radius (R1), ranging from 140mm to 180mm, wherein the rotor (2) further comprises a plurality of auxiliary blades (29) having a radially inner leading end (34) and a radially outer trailing end (35), and having a radial extent that is less than a radial extent of the main blades (25), wherein the main blades (25) and the auxiliary blades (29) are mutually alternated, wherein the auxiliary blades (29) are free from twisting and extend along an arc of a circle with a curvature radius (R2) substantially equal to the curvature radius (R1) of the main blades 25.
7. The rotor (2) according to claim 6, wherein a main blade output angle ( $\beta_{outpp}$ ) ranges between  $-5^\circ$  and  $+5^\circ$ , and a main blade input angle ( $\beta_{inpp}$ ) ranges between  $45^\circ$  and  $55^\circ$ , wherein a main blade wrap angle ( $\theta_{pp}$ ) ranges between  $30^\circ$  and  $50^\circ$ .
8. The rotor (2) according to claim 6 or 7, wherein an

auxiliary blade output angle ( $\beta_{outps}$ ) ranges between  $-5^\circ$  and  $+5^\circ$ , and an auxiliary blade input angle ( $\beta_{inps}$ ) ranges between  $4^\circ$  and  $6^\circ$ , wherein an auxiliary blade wrap angle ( $\theta_{ps}$ ) ranges between  $7^\circ$  and  $-3^\circ$ .

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9. The rotor (2) according to one of the claims 6 to 8, comprising a peripheral support ring (37), arranged in a position axially opposite with respect to the hub member (36) and connected to all the main (25) and auxiliary (29) blades, wherein a ratio ( $D_{max}/D_{37int}$ ) between the outer diameter  $D_{max}$  of the rotor (2) and an inner diameter ( $D_{37int}$ ) of the support ring (37) ranges from 1.1 to 1.3.
10. A fan (1), comprising a housing (3) defining a rotor space (6) that receives a rotor (2) according to any of the preceding claims, wherein a ratio ( $H_{all}/h_{ext}$ ) between an axial height of the rotor space (6) and an axial height ( $h_{ext}$ ) of the rotor (2) at an outer perimeter thereof ranges between  $= 1.0 \dots 1.15$ , wherein the rotor space (6) is circumferentially defined by a transversal profile comprising a main length (45) composed of a first housing arc of a circle (CC1), a second housing arc of a circle (CC2), a third housing arc of a circle (CC3), and a fourth housing arc of a circle (CC4), respectively having a first housing curvature radius (RC1), a second housing curvature radius (RC2), a third housing curvature radius (RC3), and a fourth housing curvature radius (RC4), and being arranged in sequence with a direction that is opposite the rotation direction of the rotor (2), wherein said housing curvature radii have ratios in the following ranges:
- $RC1/RC2 = 1.25 \dots \underline{1.27} \dots 1.3$ ;  
 $RC1/RC3 = 1.37 \dots \underline{1.4} \dots 1.43$ ;  
 $RC1/RC4 = 1.45 \dots \underline{1.49} \dots 1.53$ .

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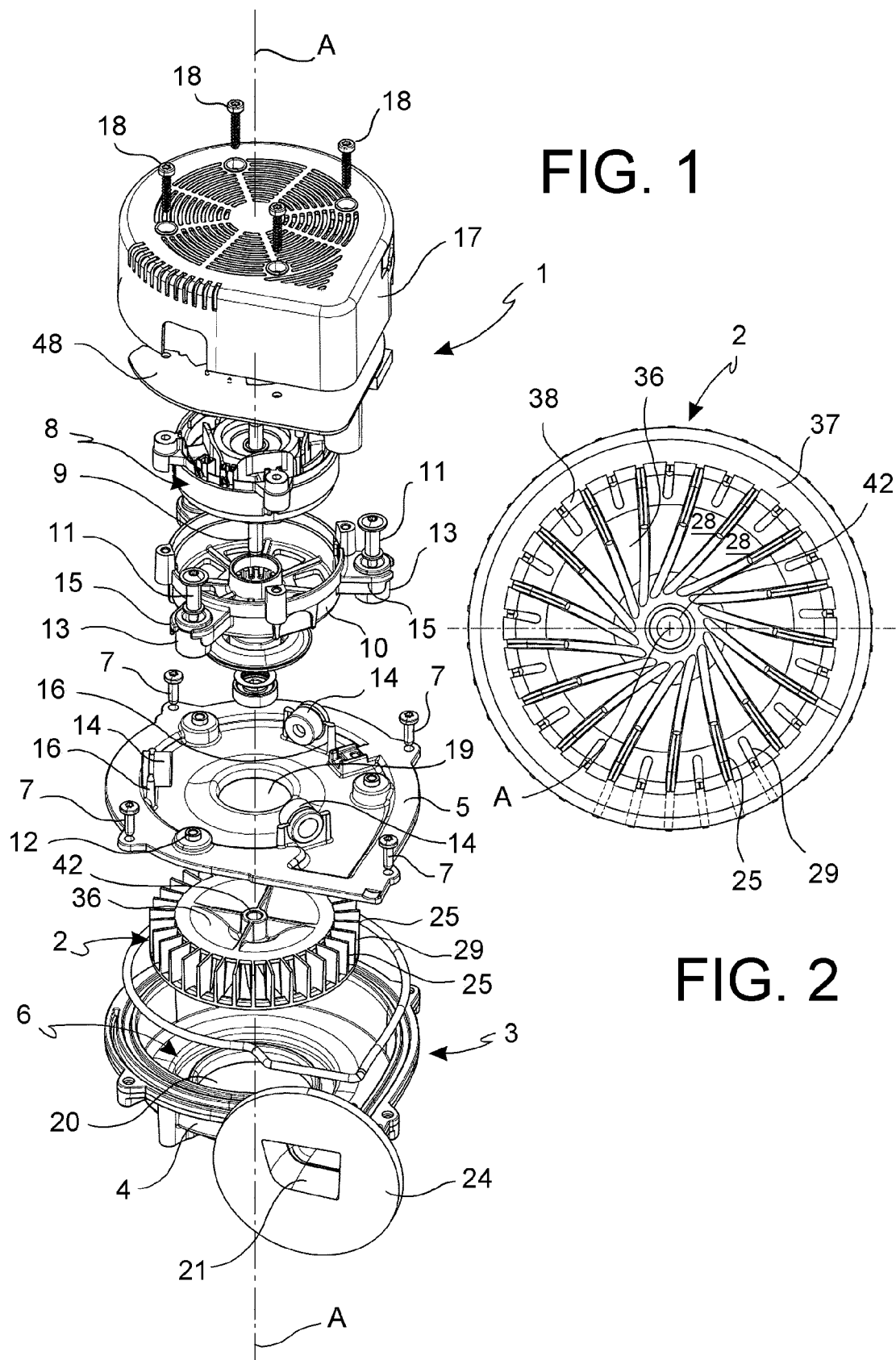
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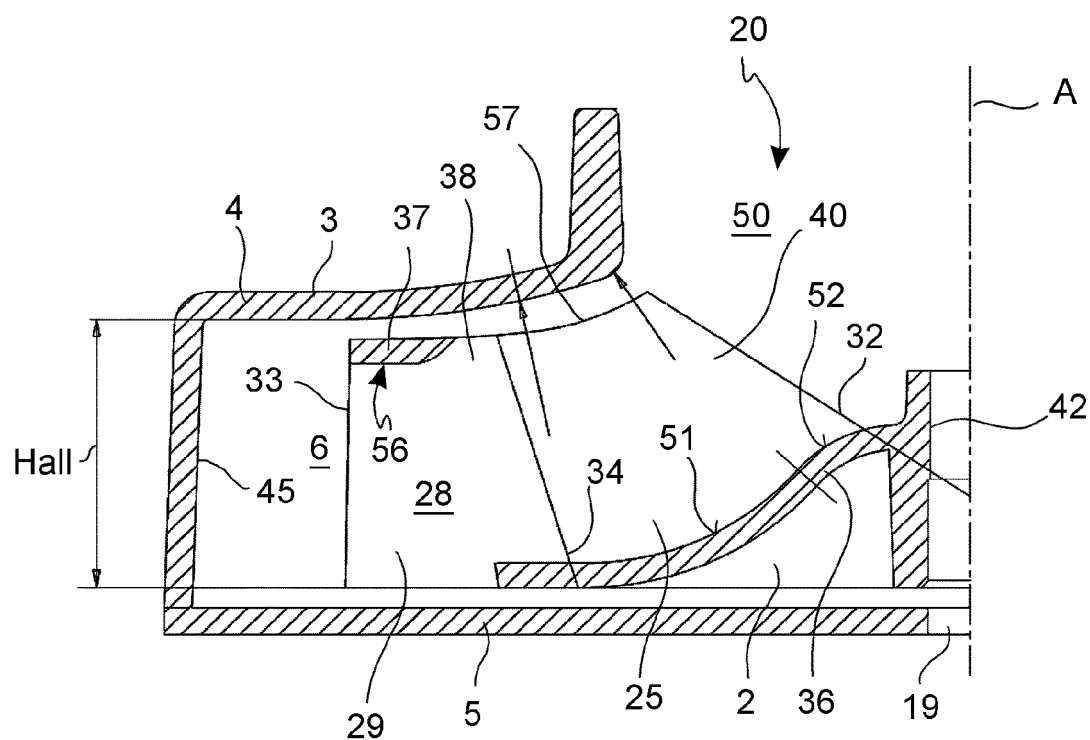


FIG. 3

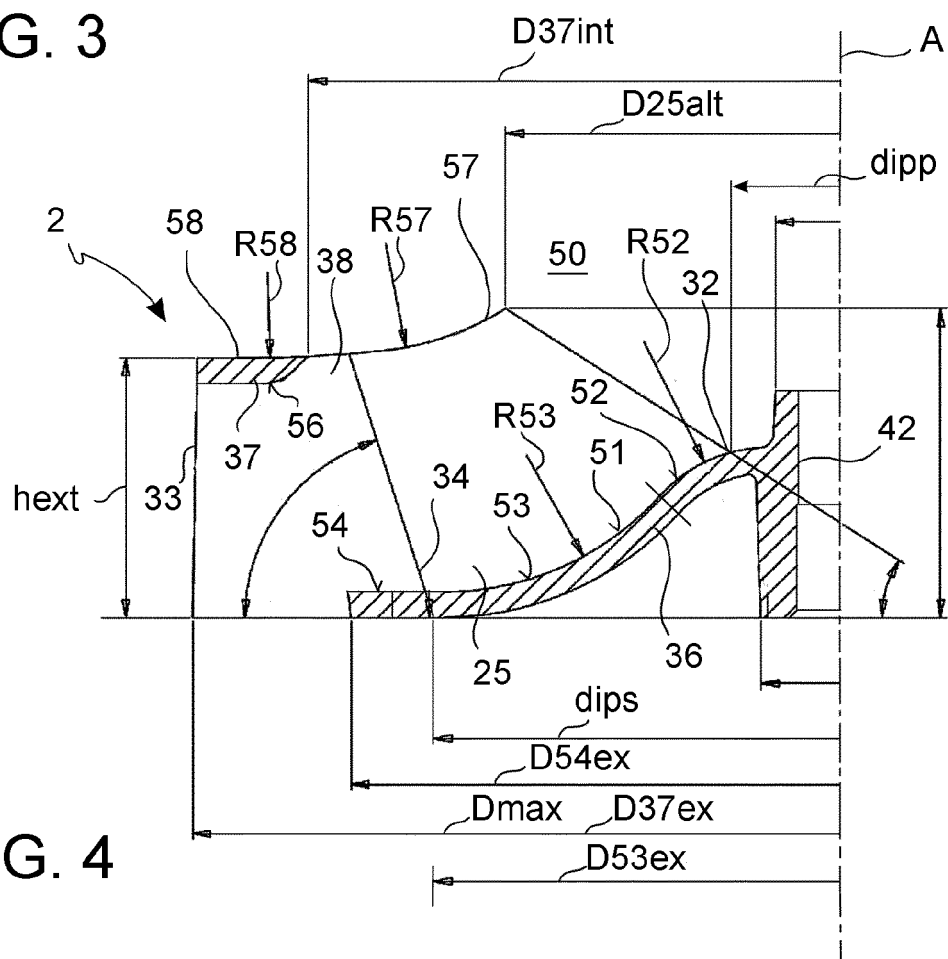


FIG. 4

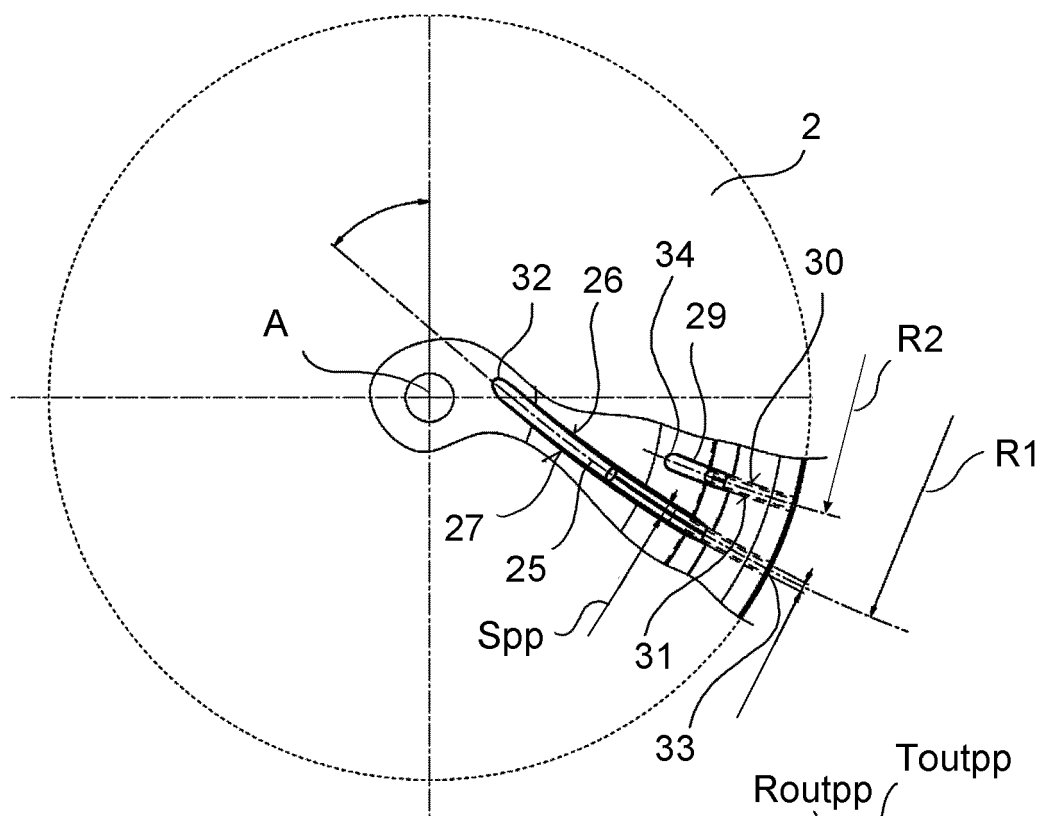


FIG. 5

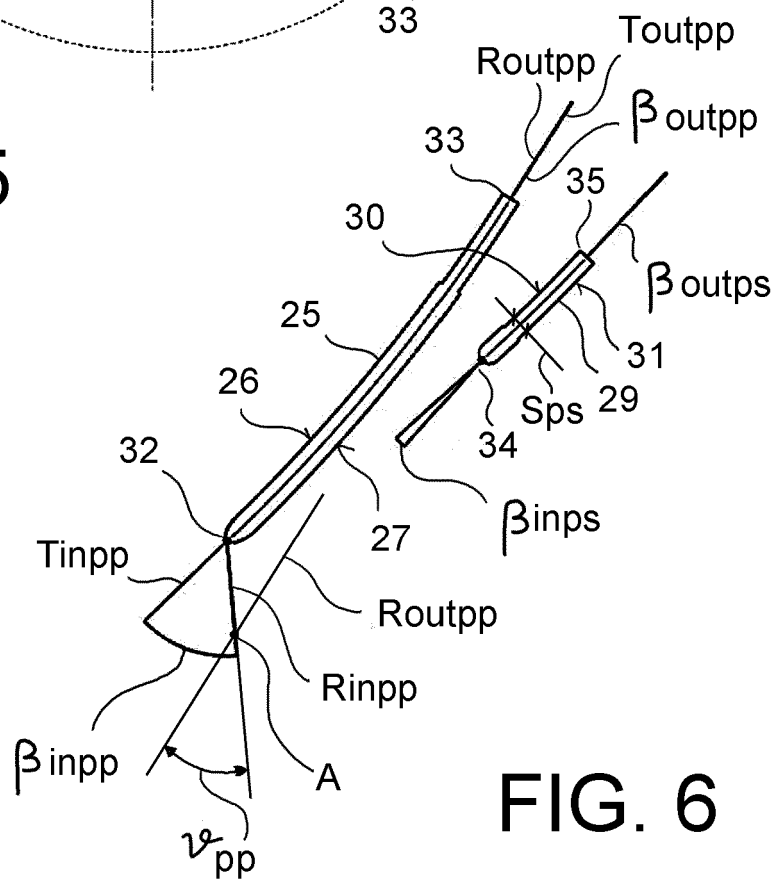


FIG. 6

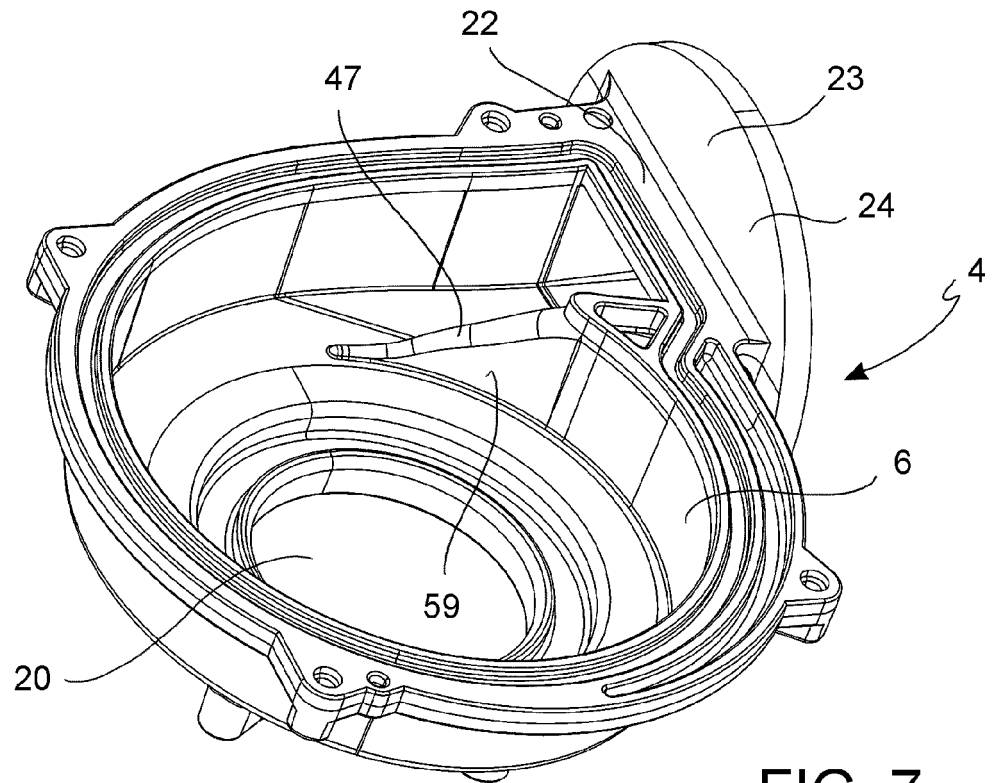


FIG. 7

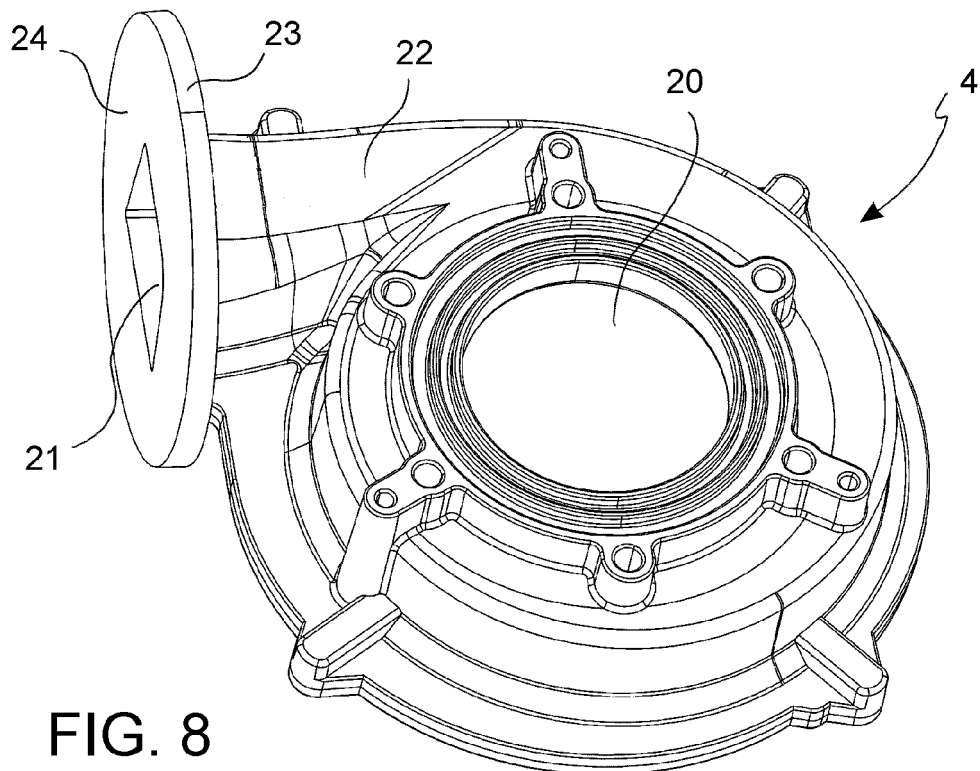


FIG. 8

FIG. 9

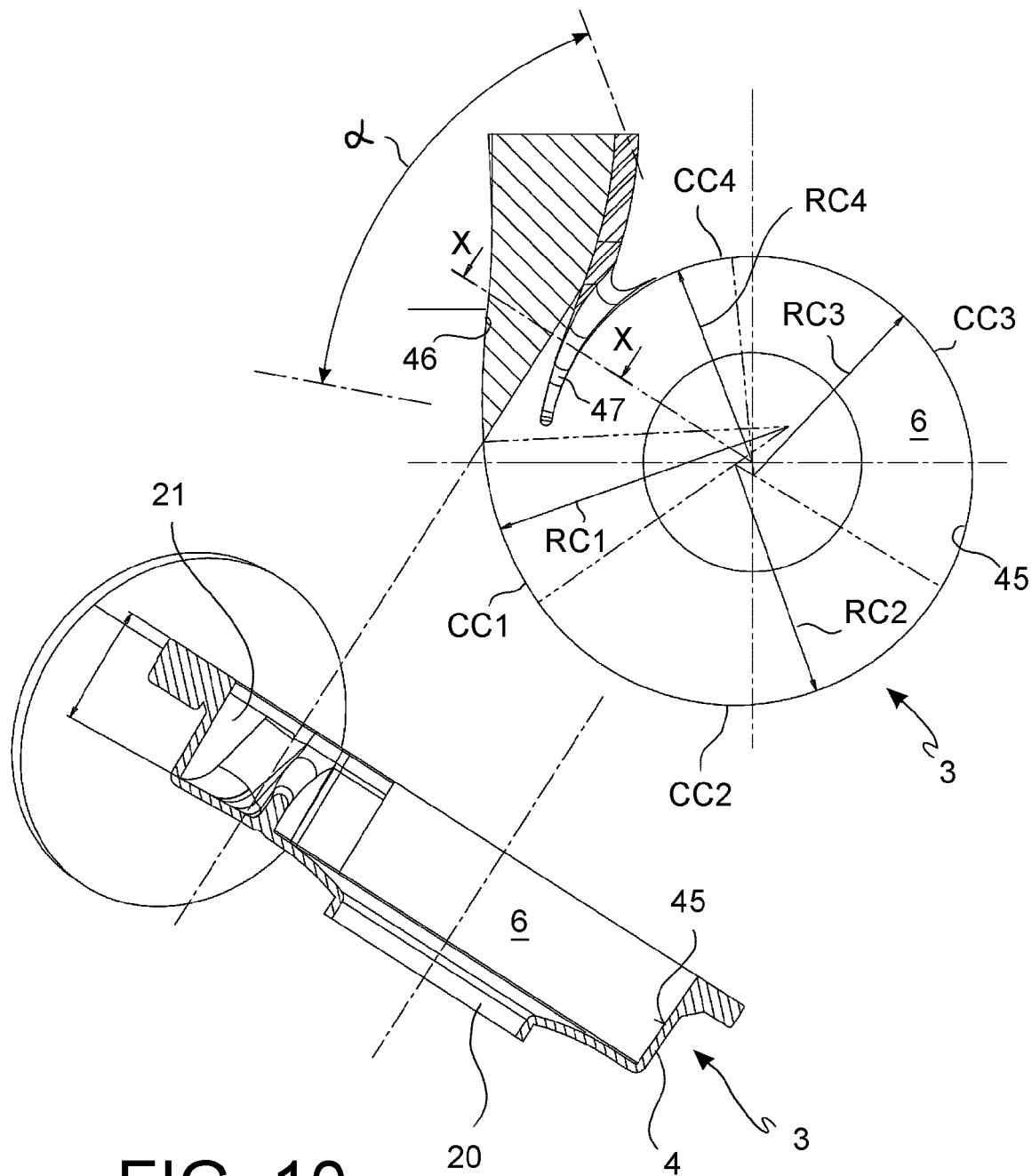
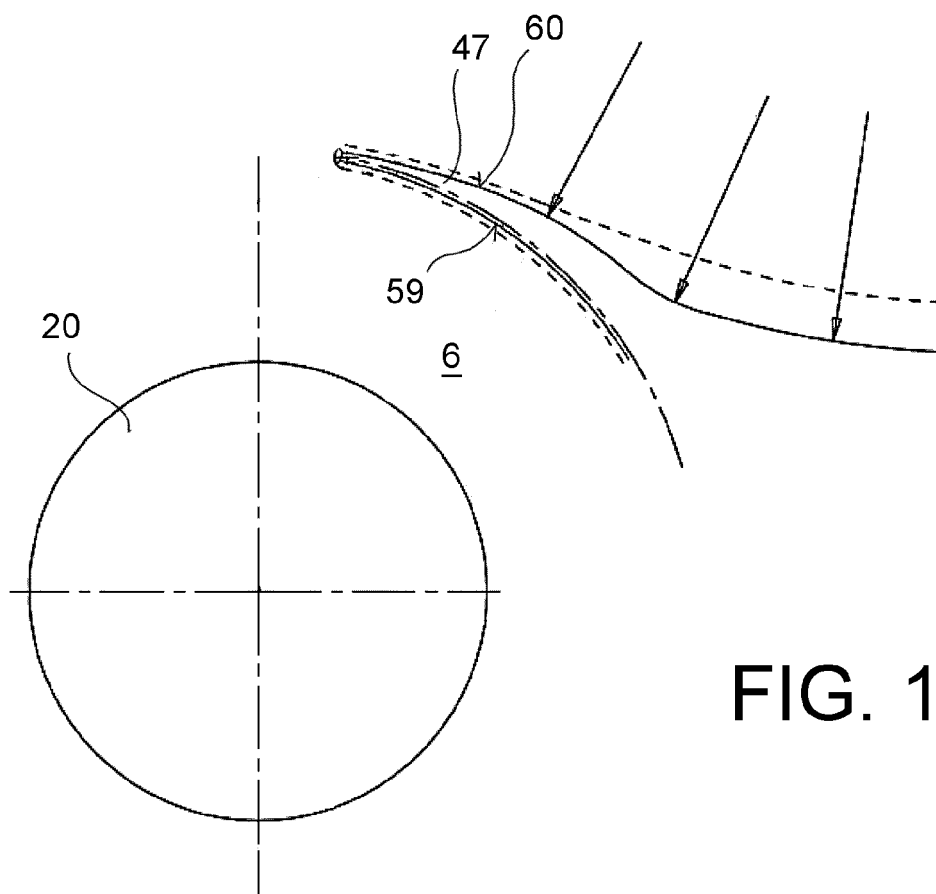
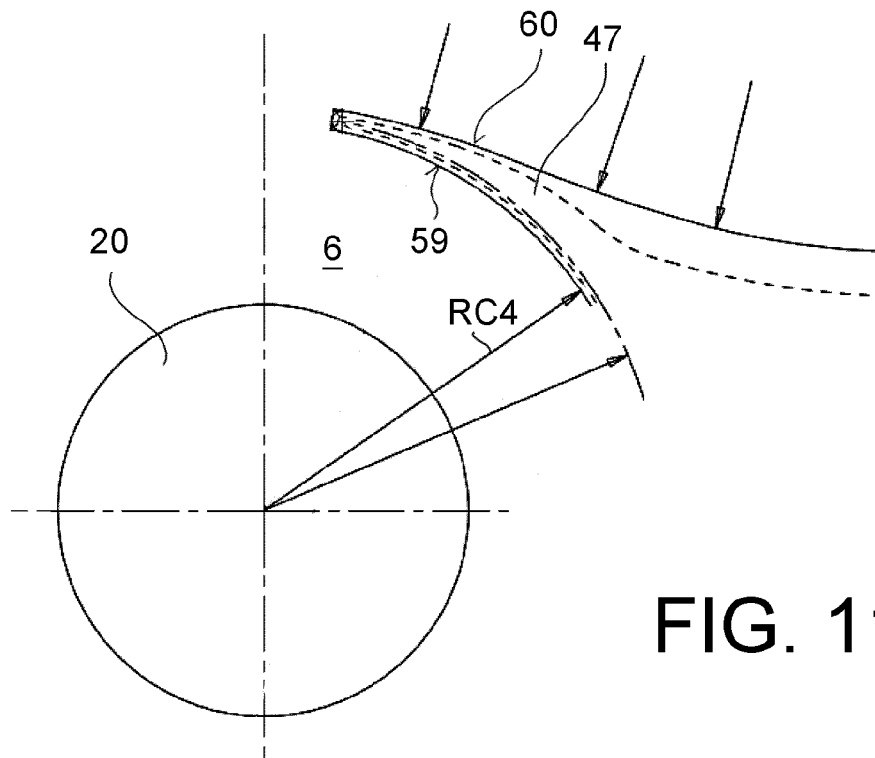
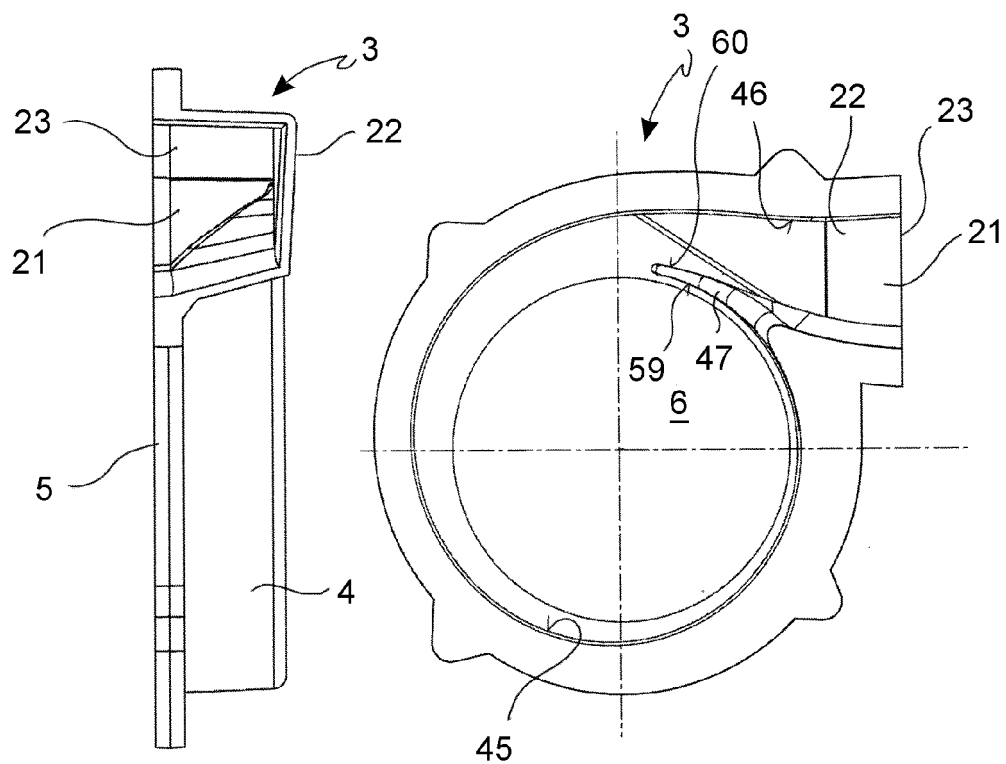
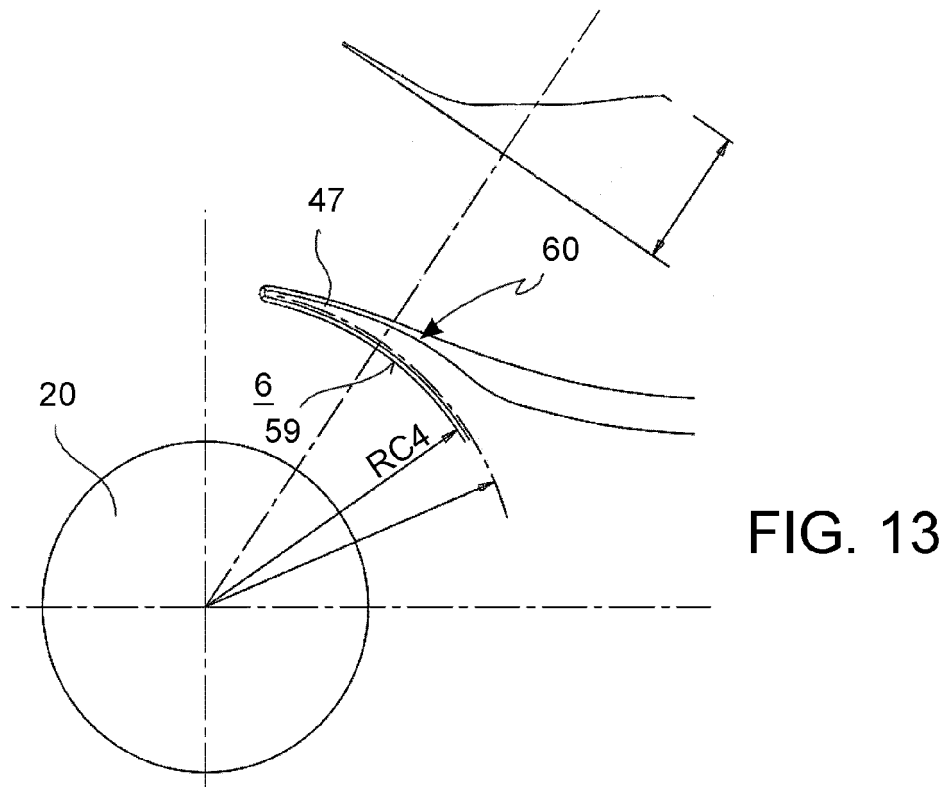
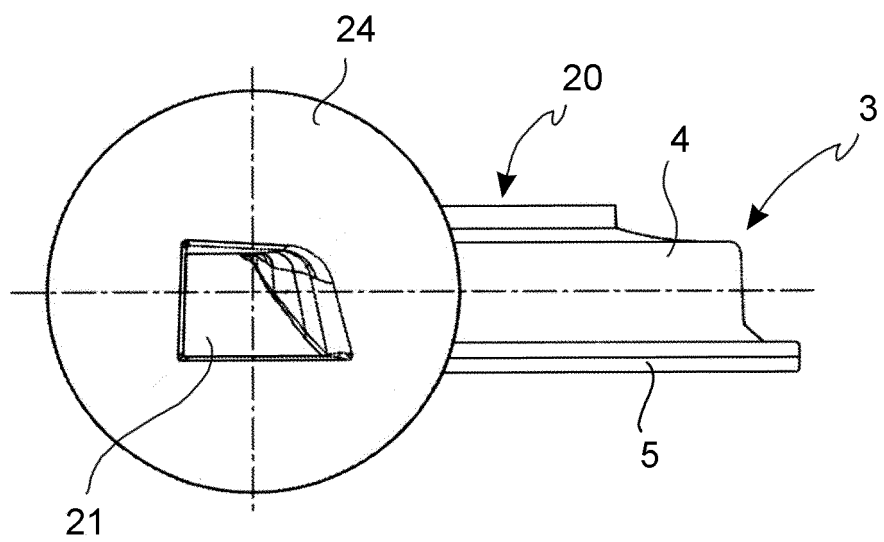
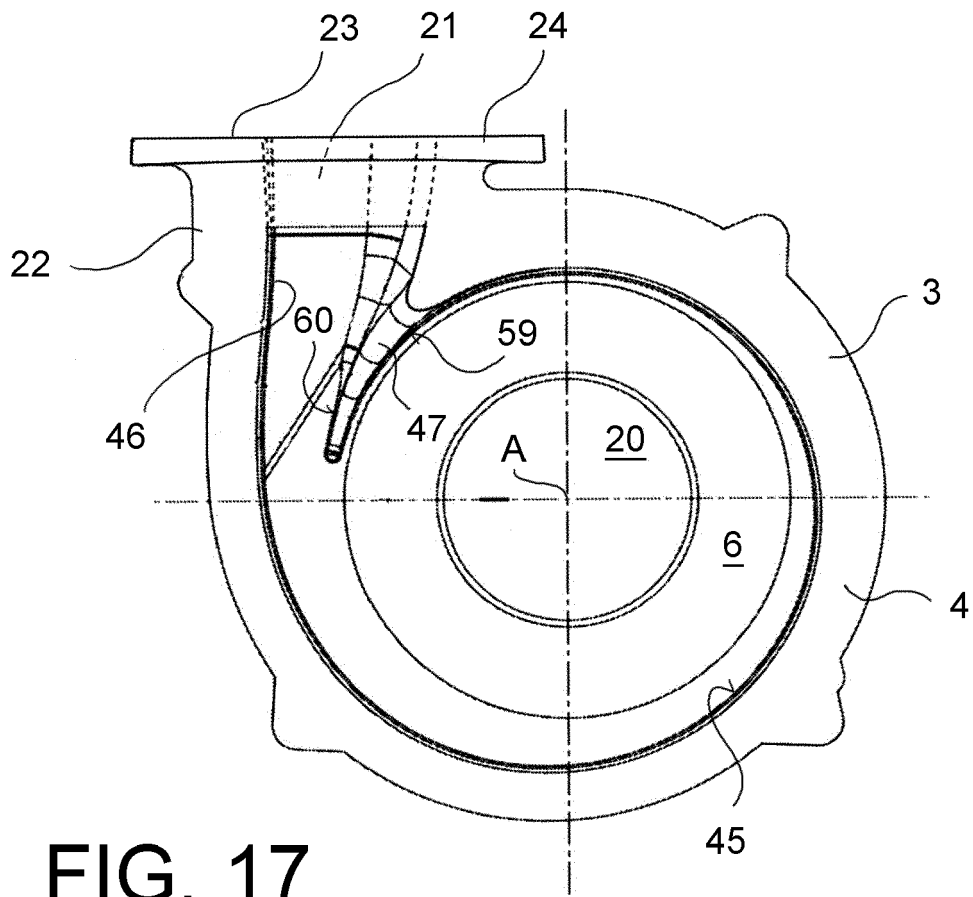


FIG. 10







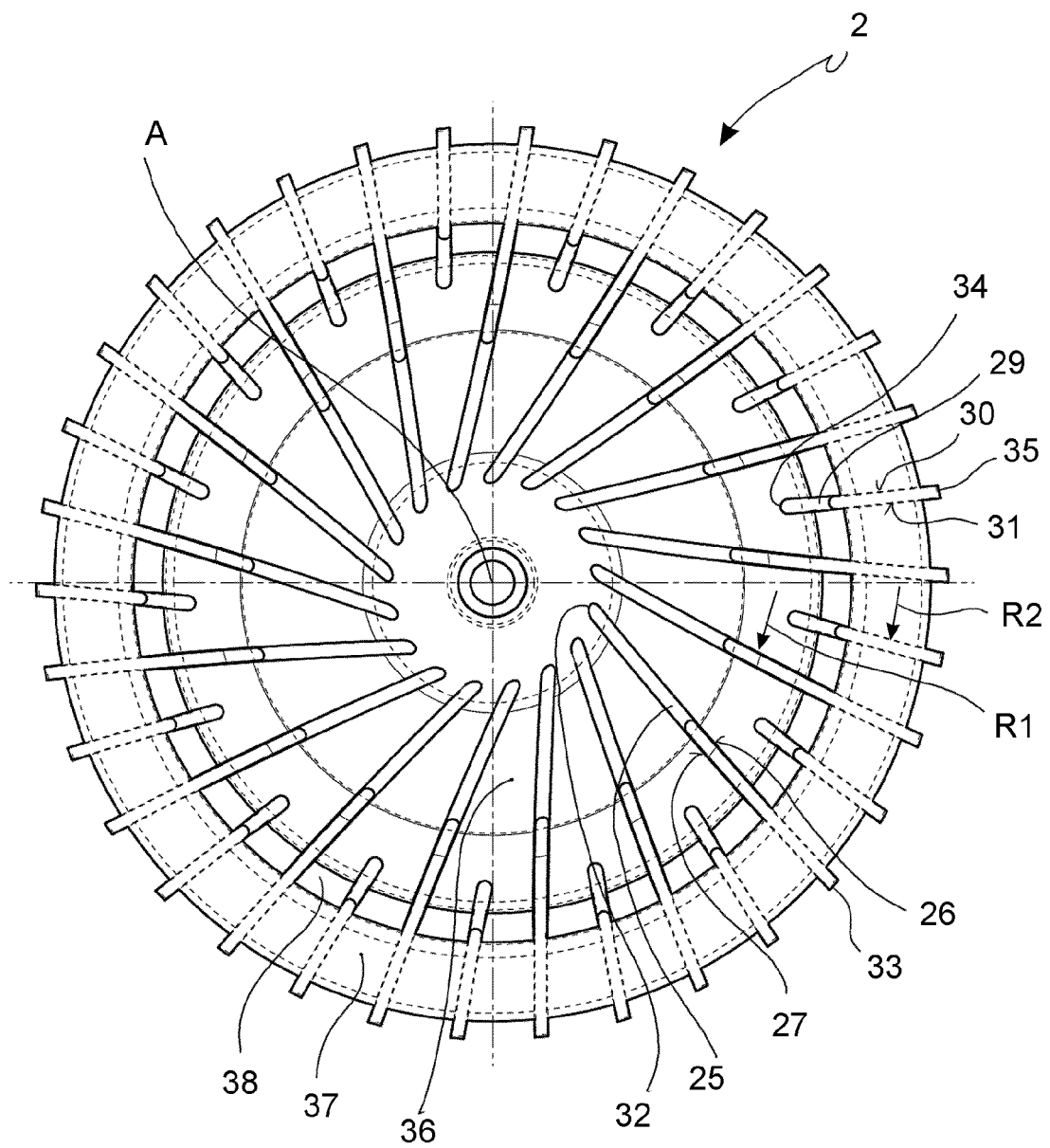


FIG. 18

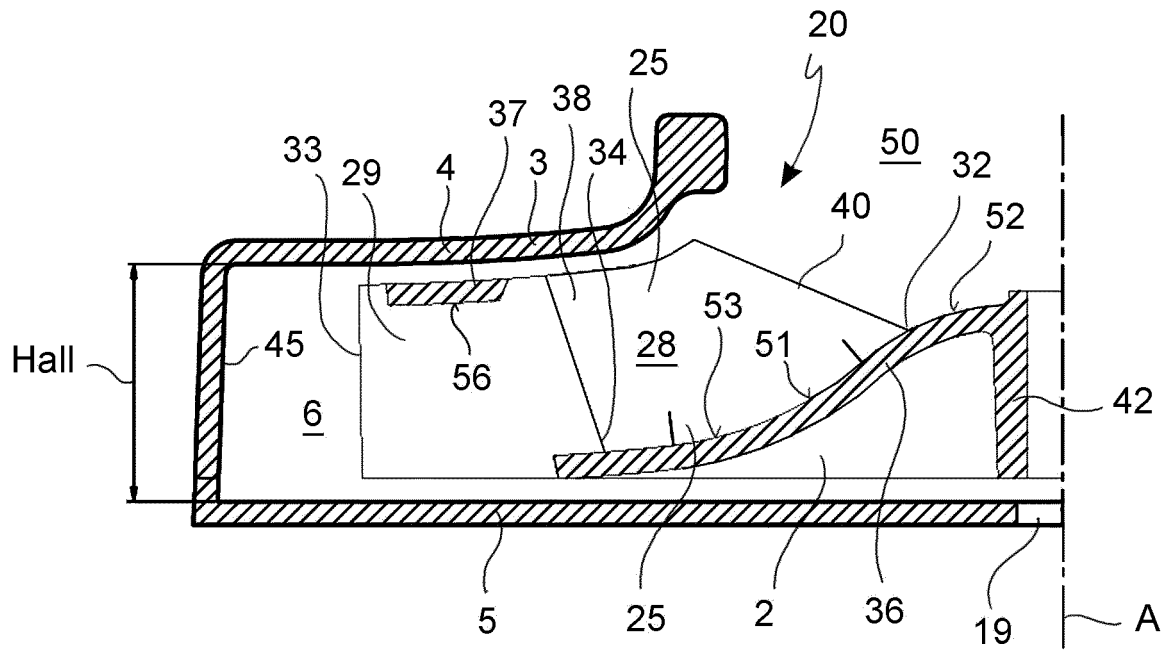


FIG. 19

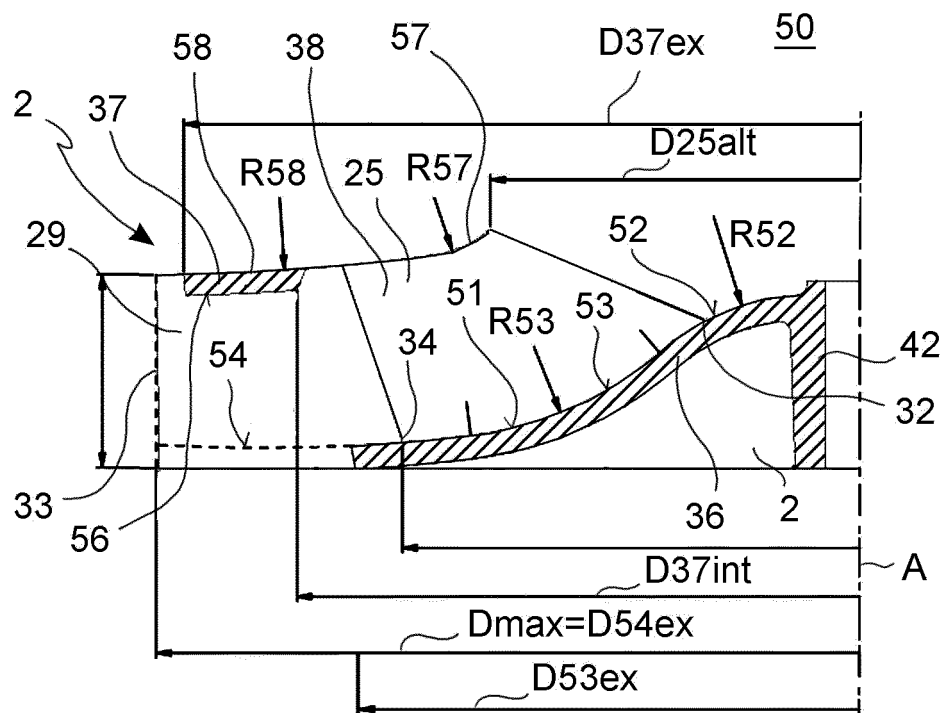


FIG. 20

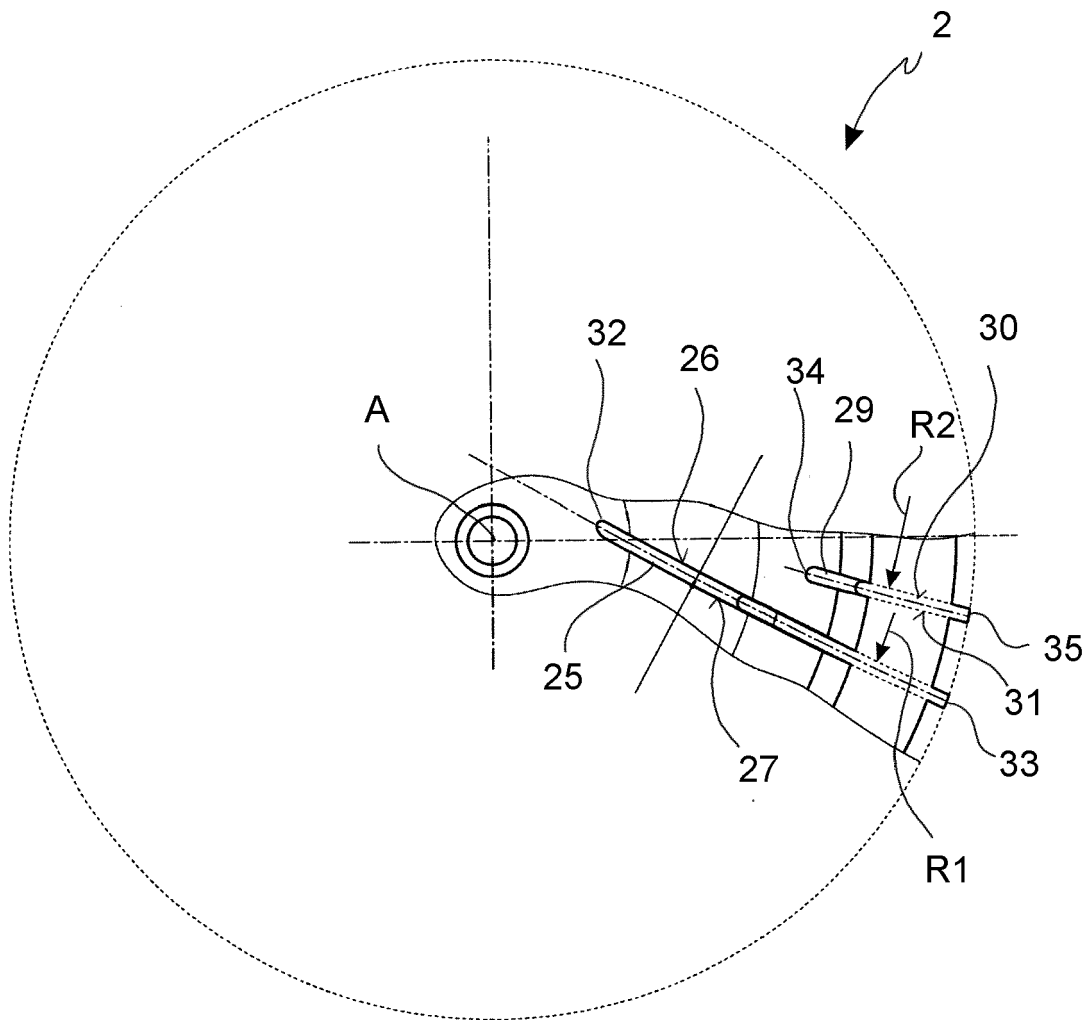


FIG. 21



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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                             |                                                         |                                                |
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