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(54) **SYSTEM AND METHOD TO ALIGN VARIABLE DIFFUSER VANE WITH DIRECTION OF FLOW OF WORKING FLUID**

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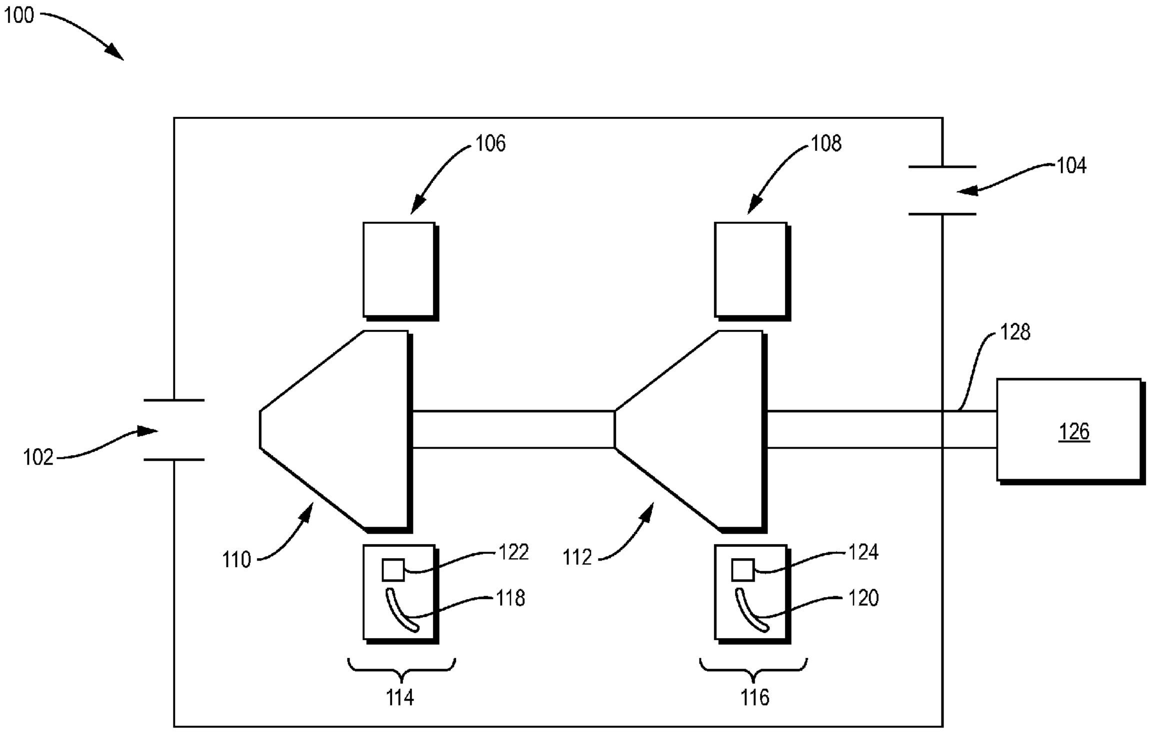
USPC **415/23**

(57) **ABSTRACT**

Embodiments of systems and methods permit use of variable diffuser vanes in multi-stage compressor devices. These embodiments deploy a flow sensor to identify the direction of flow for a working fluid that transits the stages of the compressor device. In one embodiment, the flow sensor generates a signal, which a controller processes to align a variable diffuser vane with the direction of flow of the working fluid. This configuration pre-empts the operational difficulties of previous designs by providing independent control over the diffuser vanes in the individual stages of the multi-stage compressor device.



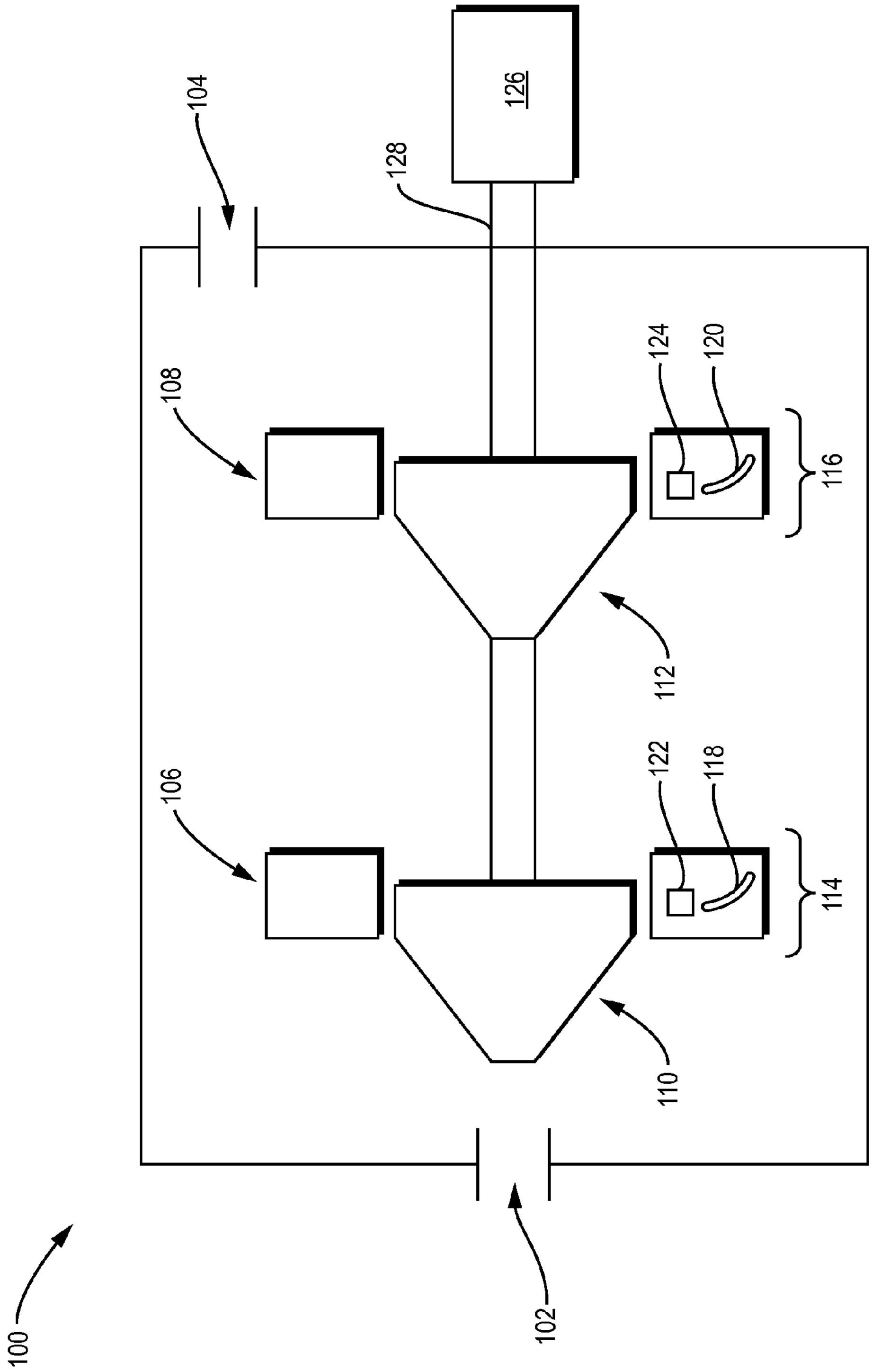


FIG. 1

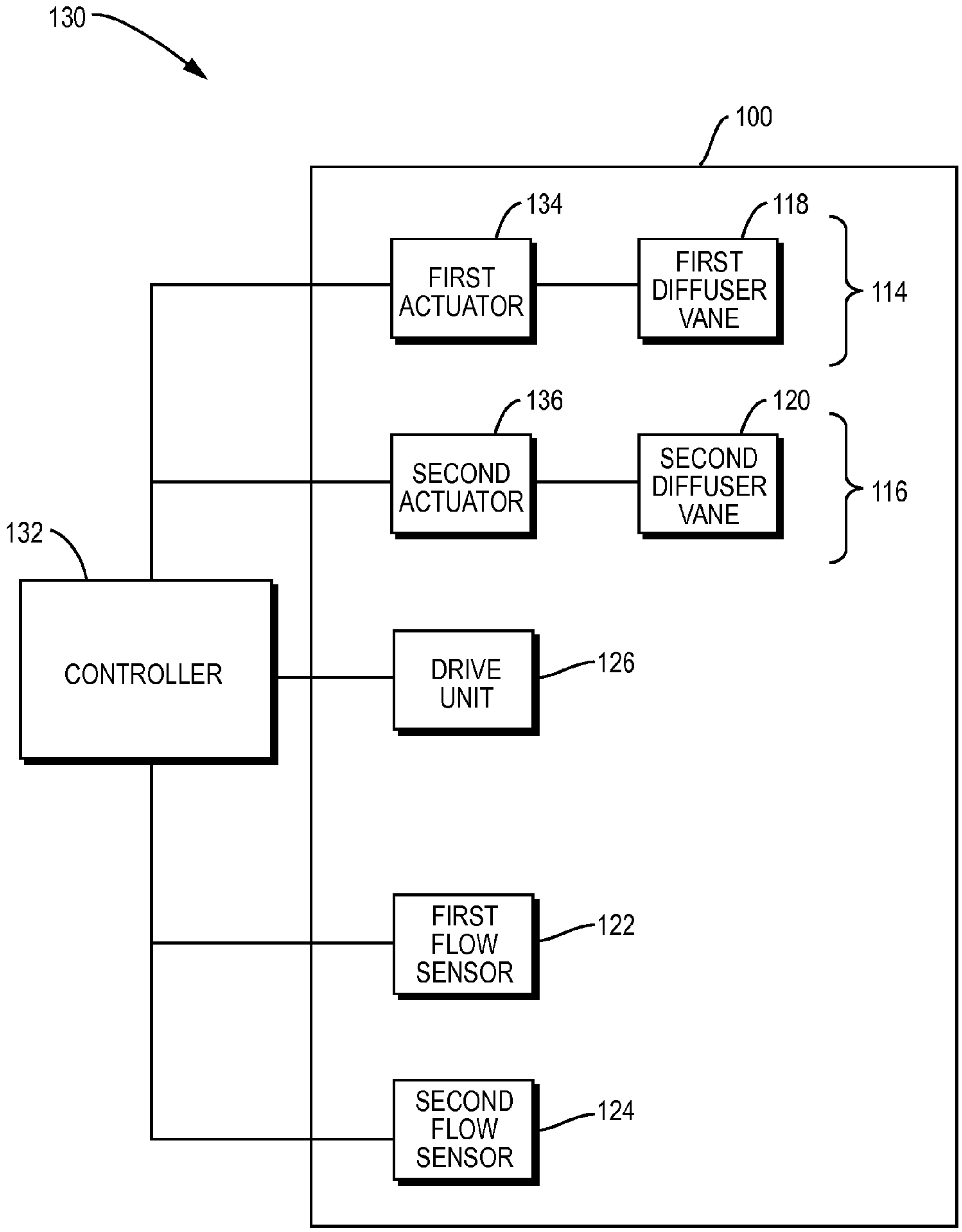

130
100
134
FIRST ACTUATOR
118
FIRST DIFFUSER VANE
114
136
SECOND ACTUATOR
120
SECOND DIFFUSER VANE
116
132
CONTROLLER
DRIVE UNIT
126
FIRST FLOW SENSOR
122
SECOND FLOW SENSOR
124

FIG. 2

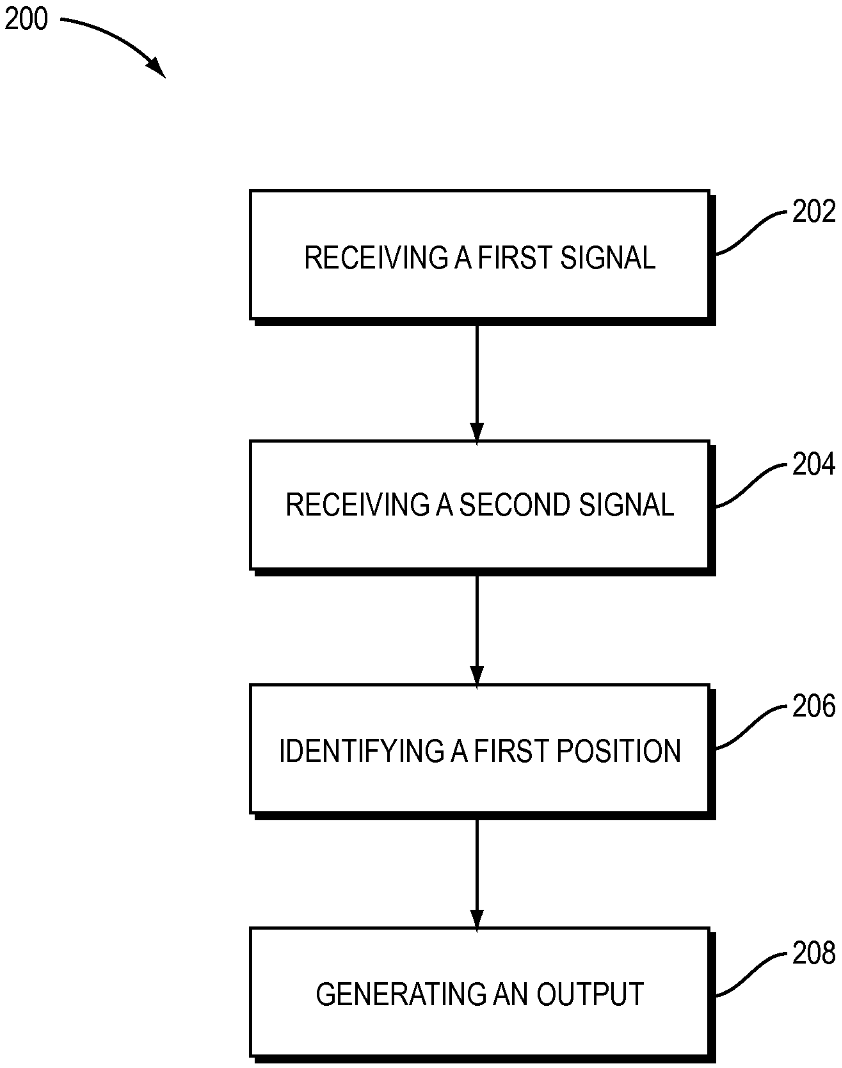

200
RECEIVING A FIRST SIGNAL
202
RECEIVING A SECOND SIGNAL
204
IDENTIFYING A FIRST POSITION
206
GENERATING AN OUTPUT
208

FIG. 3

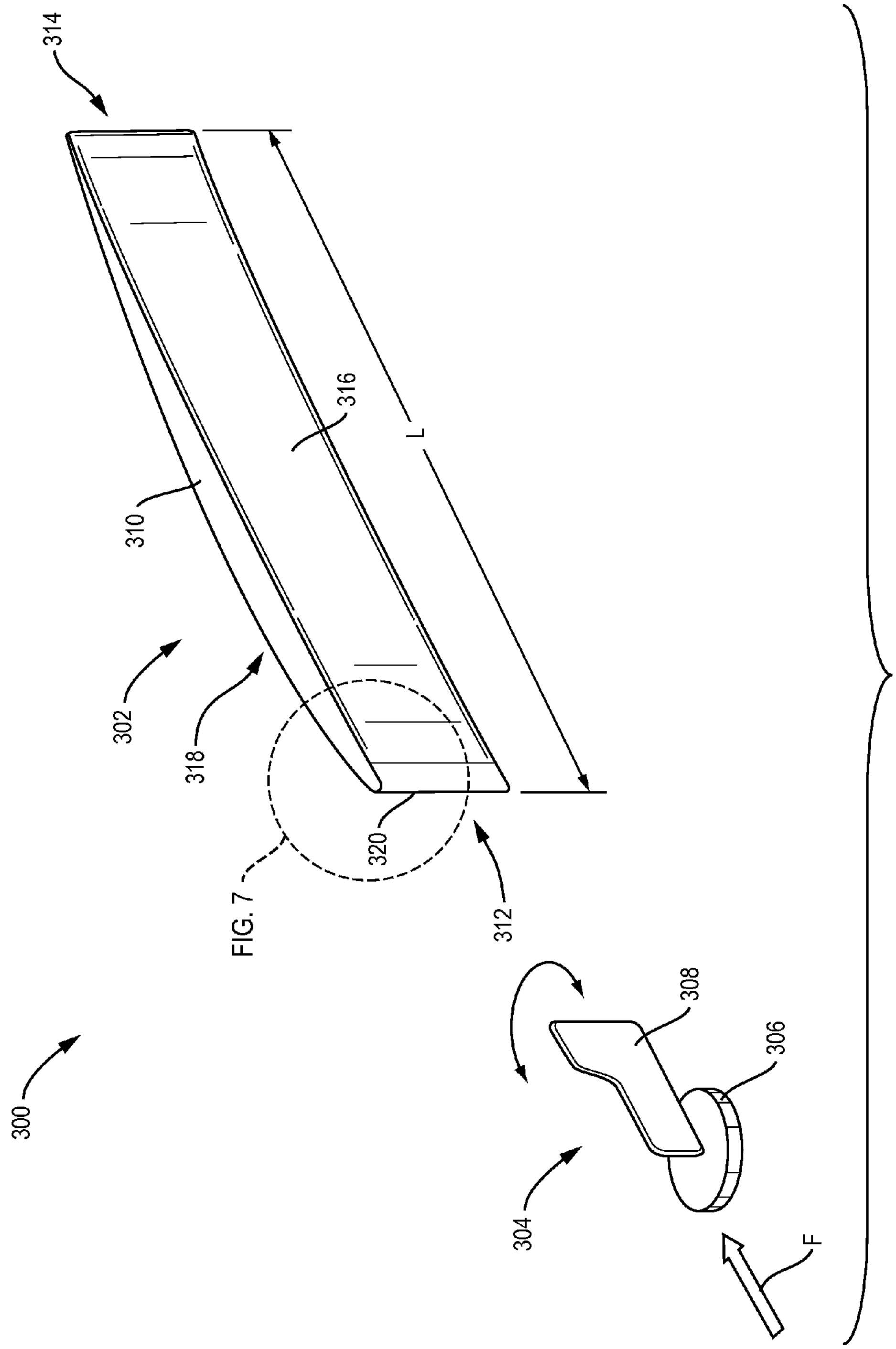


FIG. 4

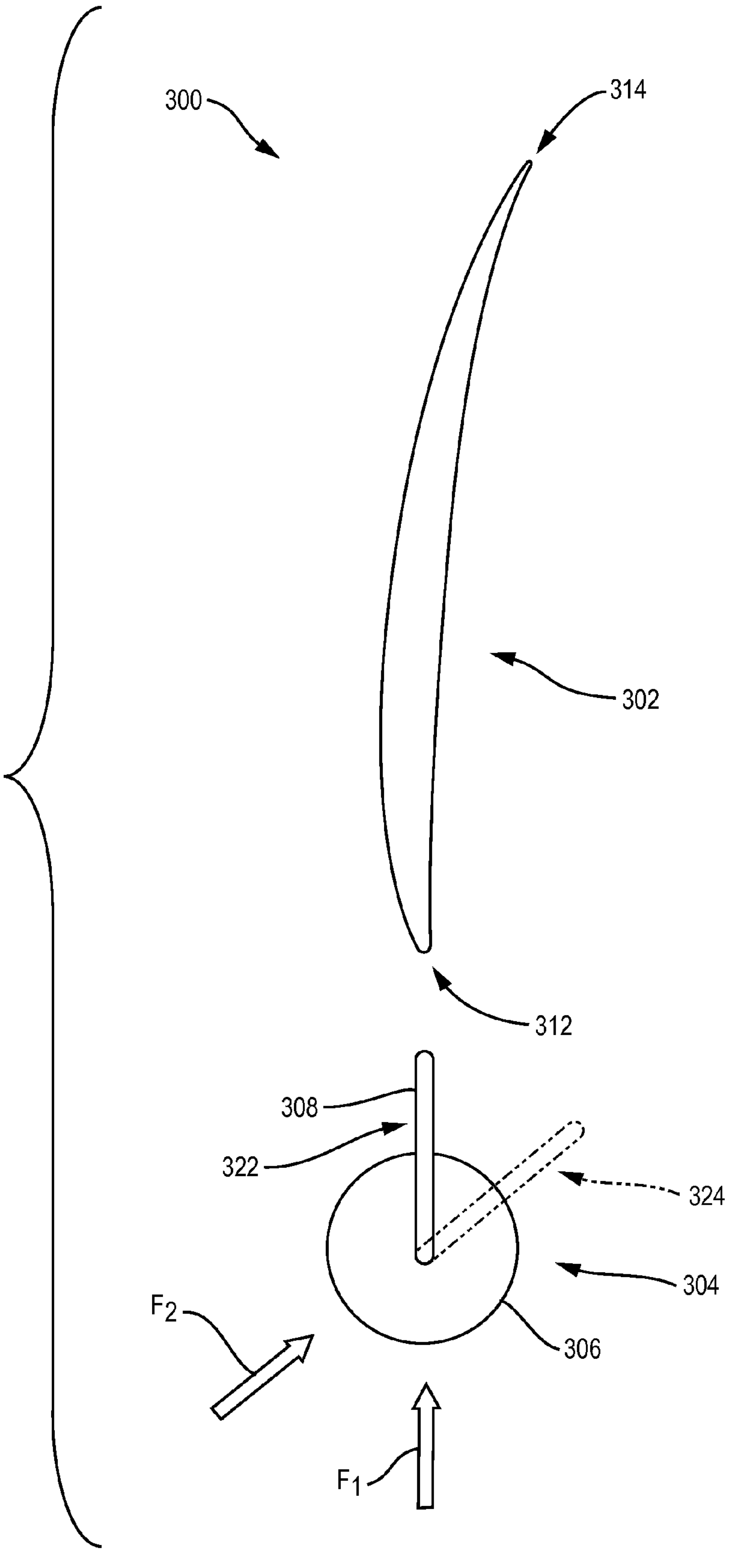


FIG. 5

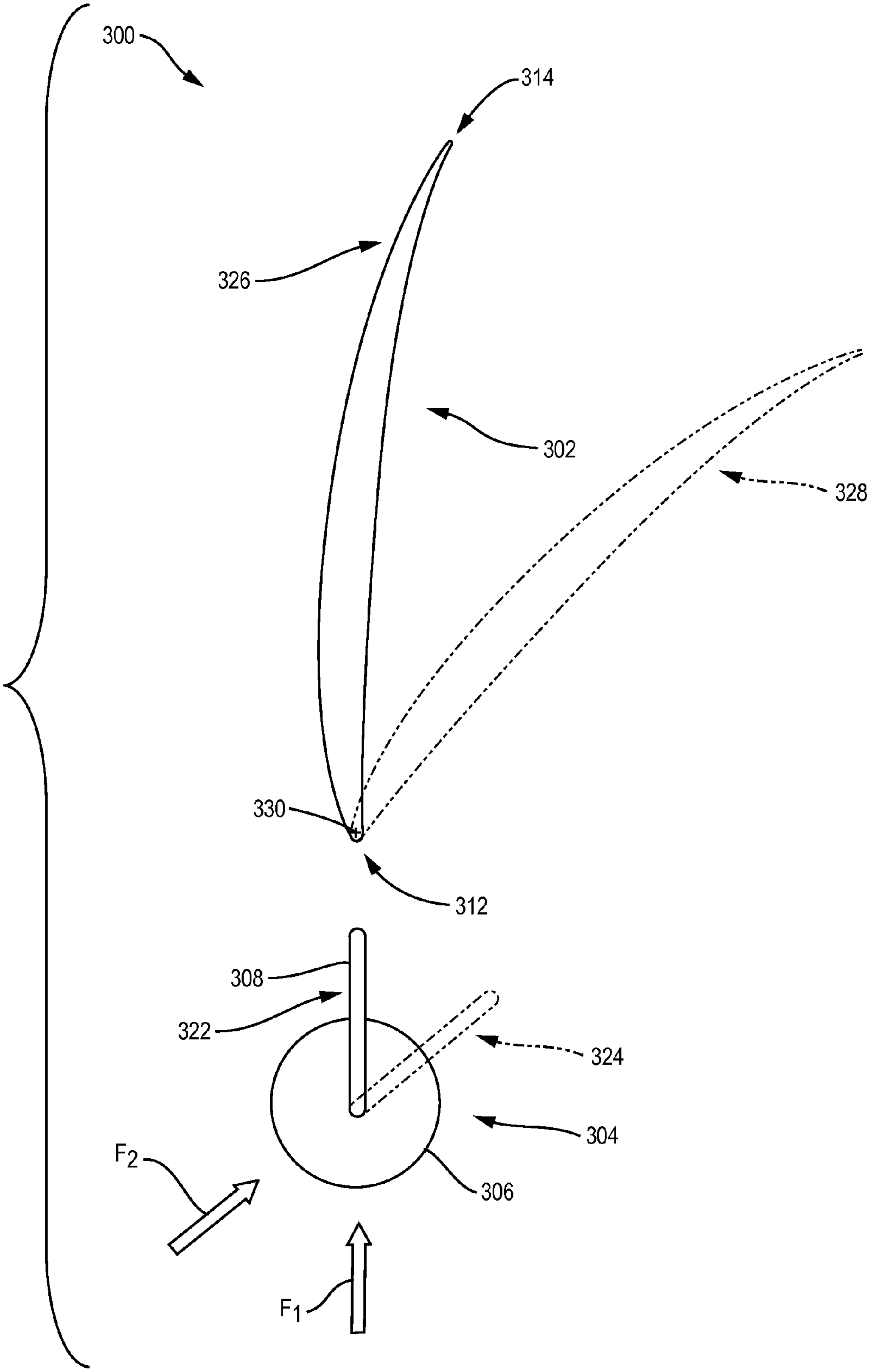


FIG. 6

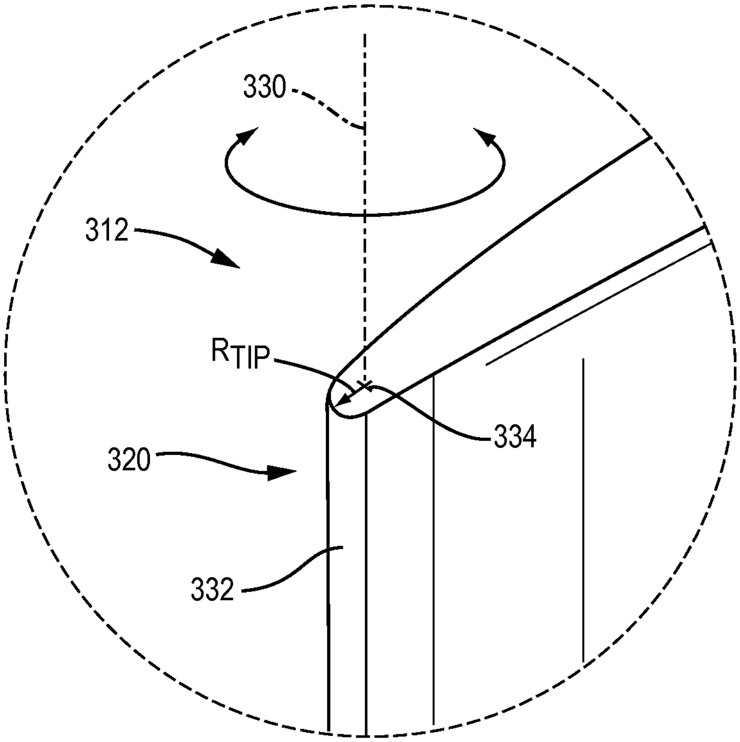


FIG. 7

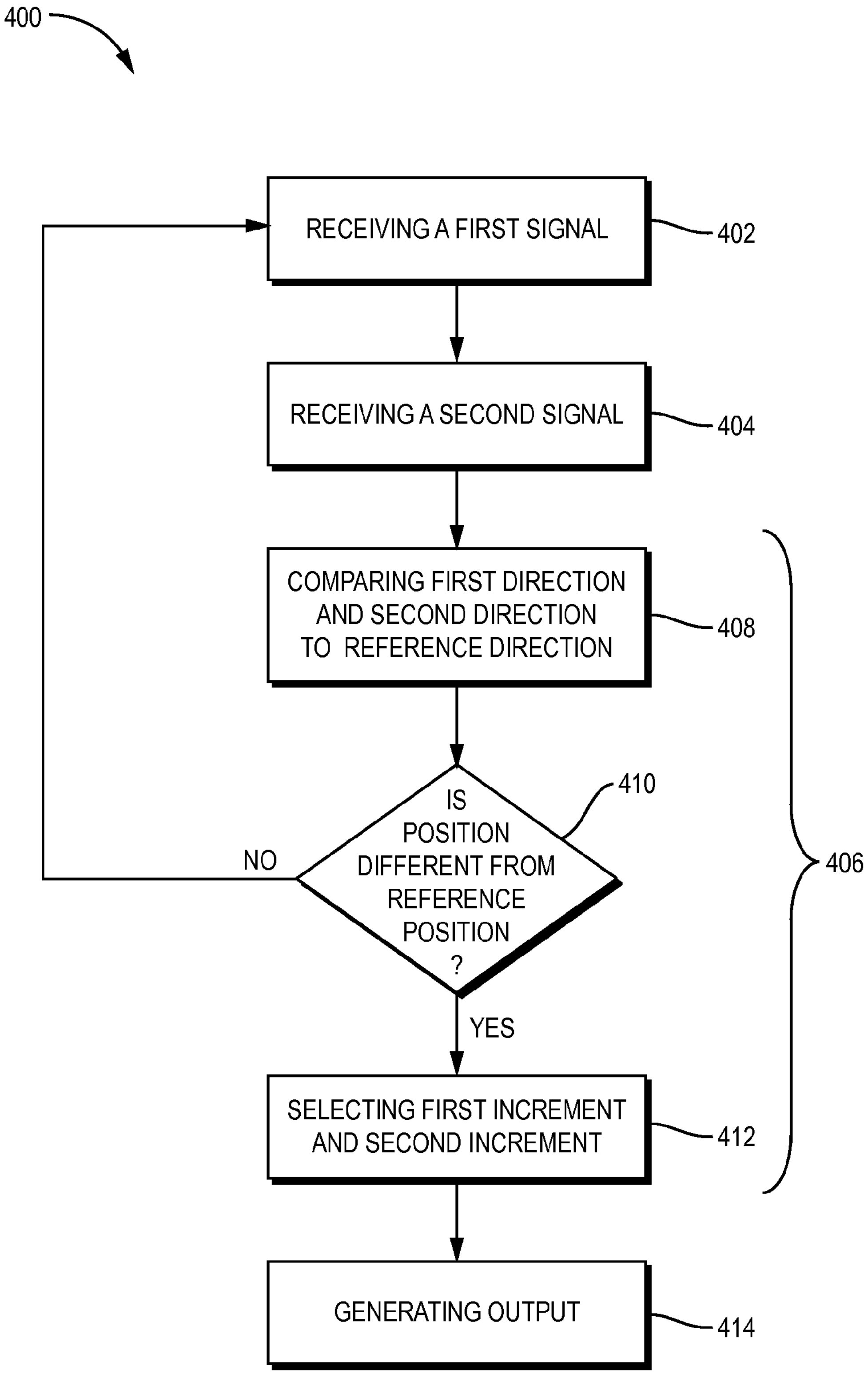

400
RECEIVING A FIRST SIGNAL
402
RECEIVING A SECOND SIGNAL
404
COMPARING FIRST DIRECTION AND SECOND DIRECTION TO REFERENCE DIRECTION
408
IS POSITION DIFFERENT FROM REFERENCE POSITION ?
410
NO
YES
SELECTING FIRST INCREMENT AND SECOND INCREMENT
412
406
GENERATING OUTPUT
414

FIG. 8

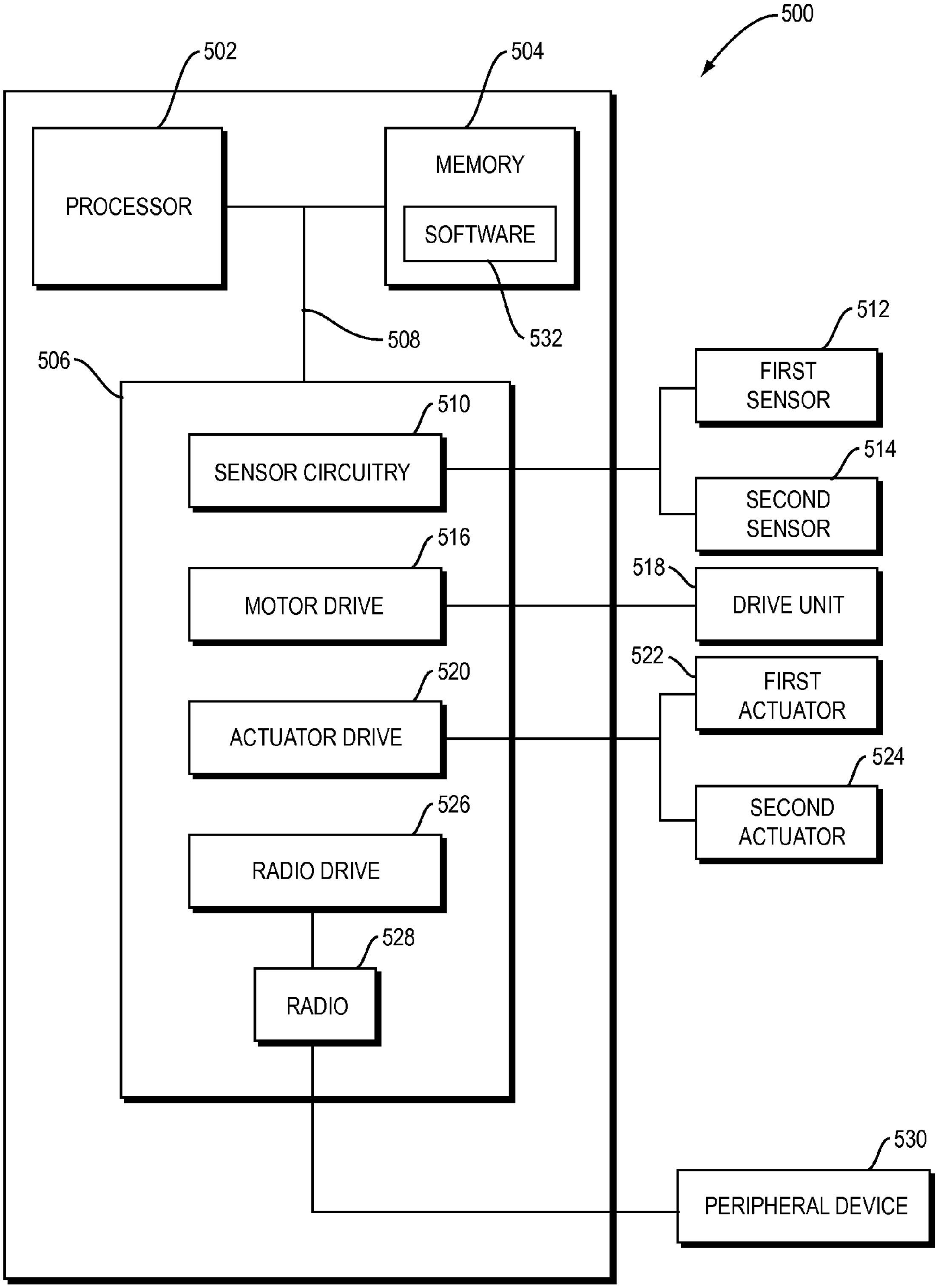

500
502
504
PROCESSOR
MEMORY
SOFTWARE
532
508
506
510
SENSOR CIRCUITRY
516
MOTOR DRIVE
520
ACTUATOR DRIVE
526
RADIO DRIVE
528
RADIO
512
FIRST SENSOR
514
SECOND SENSOR
518
DRIVE UNIT
522
FIRST ACTUATOR
524
SECOND ACTUATOR
530
PERIPHERAL DEVICE

FIG. 9

SYSTEM AND METHOD TO ALIGN VARIABLE DIFFUSER VANE WITH DIRECTION OF FLOW OF WORKING FLUID

BACKGROUND

[0001] The subject matter disclosed herein relates to compressor devices (e.g., centrifugal compressors) and, in particular, to diffusers and diffuser vanes for a compressor device.

[0002] Compressor devices (e.g., centrifugal compressors) use a diffuser assembly to convert kinetic energy of a working fluid into static pressure by slowing the velocity of the working fluid through an expanding volume region. An example of a diffuser assembly typically utilizes several diffuser vanes in circumferential arrangement about an impeller. The design (e.g., shapes and sizes) of the diffuser vanes, in combination with the preferred orientation of the leading edge and the trailing edge of the diffuser vanes with respect to the flow of the working fluid, often determine how the diffuser vanes are affixed in the diffuser assembly.

[0003] To add further improvement and flexibility to the design, some examples of a diffuser assembly incorporate variable diffuser vanes. These types of diffuser vanes move to change the orientation of the leading edge and the trailing edge. This feature helps to tune operation of the compressor device. Known designs for variable diffuser vanes rotate about an axis that resides in the lower half, i.e., closer to the leading edge than the trailing edge of the diffuser vanes.

[0004] Some configurations of compressor devices do not comport with use of variable diffuser vanes. Multi-stage compressors, for example, often forego use of variable diffuser vanes because of problems with maintaining desired flow and pressure rates for the working fluid; namely, that use of variable diffuser vanes can reduce the operating range of the multi-stage compressor device.

BRIEF DESCRIPTION OF THE INVENTION

[0005] This disclosure describes embodiments of systems and methods that permit use of variable diffuser vanes in multi-stage compressor devices. These embodiments deploy a flow sensor in combination with a variable diffuser vane to align the variable diffuser vane with the direction of flow of the working fluid. This configuration pre-empts the operational difficulties of previous designs by providing independent control over the diffuser vanes in the individual stages of the multi-stage compressor device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Reference is now made briefly to the accompanying drawings, in which:

[0007] FIG. **1** depicts a schematic view of an exemplary embodiment of a multi-stage compressor device;

[0008] FIG. **2** depicts a schematic view of an exemplary embodiment of a system for controller operation of a compressor device; e.g., the multi-stage compressor device of FIG. **1**;

[0009] FIG. **3** depicts a flow diagram of an exemplary embodiment of a method for operating a compressor device, e.g., the multi-stage compressor device of FIG. **1**;

[0010] FIG. **4** depicts a perspective view of an example of a diffuser assembly for use in a compressor device, e.g., the multi-stage compressor device of FIG. **1**;

[0011] FIG. **5** depicts a top view of the diffuser assembly of FIG. **4** with a flow sensor in a first sensor position and a second sensor position;

[0012] FIG. **6** depicts a top view of the diffuser assembly of FIG. **4** with the diffuser vane in a first vane position and a second vane position;

[0013] FIG. **7** depicts a detail view of the leading edge of the exemplary diffuser vane of FIG. **4**;

[0014] FIG. **8** depicts a flow diagram of an exemplary embodiment of a method for operating a compressor device, e.g., the multi-stage compressor device of FIG. **1**; and

[0015] FIG. **9** depicts a high-level wiring schematic of an example of a controller for use in a system, e.g., the system of FIG. **2**.

[0016] Where applicable like reference characters designate identical or corresponding components and units throughout the several views, which are not to scale unless otherwise indicated.

DETAILED DESCRIPTION OF THE INVENTION

[0017] FIG. **1** illustrates a schematic view of an exemplary embodiment of a compressor device **100**. The compressor device **100** includes an inlet **102**, an outlet **104**, and one or more stages (e.g., a first stage **106** and a second stage **108**) disposed in flow connection with the inlet **102** and the outlet **104**. The stages **106**, **108** include an impeller (e.g., a first impeller **110** and a second impeller **112**) and a diffuser assembly (e.g., a first diffuser assembly **114** and a second diffuser assembly **116**). The diffuser assemblies **114**, **116** include one or more diffuser vanes (e.g., a first diffuser vane **118** and a second diffuser vane **120**) and a flow sensor (e.g., a first flow sensor **122** and a second flow sensor **124**). The compressor device **100** also includes a drive unit **126** and a drive shaft **128**, which couples with the drive unit **126** and with one or more of the impellers **110**, **112**.

[0018] Embodiments of the compressor device **100** find use in a variety of settings and industries including automotive industries, electronics industries, aerospace industries, oil and gas industries, power generation industries, petrochemical industries, and the like. During one implementation, the shaft **128** transfers power from the drive unit **126** to rotate the first impeller **110** and the second impeller **112**. Rotation of the first impeller **110** draws a working fluid (e.g., air) through the inlet **102**. In the first stage **106**, the first impeller **110** compresses the working fluid. The compressed working fluid flows into the first diffuser assembly **114**, which allows the working fluid to expand before the working fluid enters the second stage **108**. In the second stage **108**, the working fluid undergoes compression and expansion by, respectively, the second impeller **112** and the second diffuser assembly **116**. In one embodiment, the compressor device **100** can couple at the outlet **104** with industrial piping to expel the working fluid under pressure and/or with certain designated flow parameters as desired.

[0019] Examples of the diffuser vanes **118**, **120** can move (e.g., rotate) from one position (e.g., a first position) to another position (e.g., a second position), and vice versa. Movement between the first position and the second position allows the diffuser vanes **118**, **120** to align with the direction of flow of the working fluid. This feature avoids flow separation of the working fluid from the surfaces of the diffuser vane **118**, **120**.

[0020] The flow sensors **122**, **124** monitor the direction of flow of the working fluid upstream of the diffuser vanes **118**,

120. As the direction of the flow changes, e.g., due to changes in operation of the compressor device **100**, the flow sensor **122** will generate a signal. Examples of the signal convey information to indicate the extent, direction, and other characteristics relevant to the direction of the flow. The controller **132** can process this signal and, in response, generate an output to impart changes to the position of the diffuser vanes **118**, **120**. In one example, the output encodes instructions to move the actuators **134**, **136** which in turn causes the diffuser vanes **118**, **120** to change position, e.g., from the first position to the second position.

[0021] As shown in FIG. **2**, the compressor device **100** can form part of a system **130** (also "control system **130**"), which can change operating settings for the first diffuser assembly **114** and the second diffuser assembly **116** independent of one another during operation of the compressor device **100**. The system **130** includes a controller **132**, which couples with the flow sensors **122**, **124** and with actuators (e.g., a first actuator **134** and a second actuator **136**). Examples of the actuators **134**, **136** change the position of, respectively, the first diffuser vane **118** and the second diffuser vane **120**. In one embodiment, the controller **132** (and/or one or more other devices in the system **130**) can communicate via a network **138** with a peripheral device **140** (e.g., a display, a computer, a smartphone, a laptop, a tablet, etc.) and/or an external server **142**.

[0022] The controller **132** can comprise computers and computing devices with processors and memory that can store and execute certain executable instructions, software programs, and the like. The controller **132** can be a separate unit, e.g., part of a control unit that operates the compressor device **100** and other equipment. In other examples, the controller **132** integrates with the compressor device **100**, e.g., as part of the hardware and/or software configured on such hardware. In still other examples, the controller **132** can be located remote from the compressor device **100**, e.g., in a separate location where the controller **132** can issue commands and instructions using wireless and wired communication, e.g., via the network **124**.

[0023] Examples of the system **130** orient one or both of the diffuser vanes **118**, **120** to modify flow and expansion that occurs as the working fluid transits the corresponding diffuser assemblies **114**, **116**. By utilizing separate flow sensors **122**, **124** to measure the direction of flow upstream of the respective diffuser vanes **118**, **120**, the system **130** can account for variations in flow that occur from stage to stage, e.g., from stage **106** to stage **108**. The system **130** can use the information about the direction of flow to instruct the actuators **134**, **136** to place the diffuser vanes **118**, **120** in different positions relative to one another. This feature effectively decouples operation of the compressor device **100** in the first stage **106** from the second stage **108**, which allows the diffuser vanes **118**, **120** to operate independent of one another and, in one example, independent of additional stages without having an adverse effect on overall performance of the compressor device **100**.

[0024] FIG. **3** depicts a flow diagram of an exemplary method **200** to improve performance of a compressor device (e.g., compressor device **100** of FIG. **1**). The method **200** includes, at step **202**, receiving a first signal from a first flow sensor and, at step **204**, receiving a second signal from a second flow sensor. In one embodiment, the first signal and the second signal encode information that identifies a first direction and a second direction of flow for a working fluid upstream of, respectively, a first diffuser vane and a second diffuser vane. The method **200** also includes, at step **206**, identifying a first position for the first diffuser vane and the second diffuser vane. In one example, the first position aligns the first diffuser vane and the second diffuser vane with the first direction of flow of the working fluid. The method **200** further includes, at step **208**, generating an output encoding instructions to move the first diffuser vane and the second diffuser vane to the first position.

[0025] In one embodiment, the first signal (e.g., at step **202**) and the second signal (e.g., at step **204**) indicate the position of the first flow sensor and the second flow sensor. To illustrate, FIG. **4** depicts a perspective view of an example of a diffuser assembly **300** for use in a compressor device (e.g., compressor device **100** (FIG. **1**)). The diffuser assembly **300** includes a diffuser vane **302** and a flow sensor **304** upstream of the diffuser vane **302**. In one example, the flow sensor **304** has a base element **306** and a directional element **308** disposed in the path of a flow F of a working fluid. The diffuser vane forms a vane body **310** with a leading edge **312** and a trailing edge **314**. A chord length L defines the straight-line distance between the leading edge **312** and the trailing edge **314**. The vane body **310** forms an aerodynamic shape (e.g., an airfoil) with a suction side surface **316** and a pressure side surface **318** identified relative to the orientation and angle of attack of the leading edge **312** relative to the flow F. At the leading edge **312**, the vane body **310** converges to a tip **320**.

[0026] The flow sensor **304** can move and, in one example, the directional element **308** rotates relative to the base element **306** to indicate the direction of flow F. Examples of the base element **306** can secure to components of the diffuser assembly **300**. These components can include wall members, frame member, and other structure (e.g., volute) that can position the flow sensor **304** in the flow of the working fluid. For example, the flow base element **306** can reside a bore and/or counter bore in such structure to position the directional element **308** in the flow path. Examples of the base element **306** can include a pin and/or other bearing element, which receives the directional element **308**. The pin acts as a pivot about which the directional element **308** can freely rotate. When placed in the path of flow F, the directional element **308** will align with the direction of the flow F. In one example, the base element **306** can comprise a rotary potentiometer and/or other like devices that can measure angular displacement. The rotary potentiometer can couple with the directional element **308** to register changes in the position of the directional element **308** in response to the direction of flow F.

[0027] With reference to FIG. **5**, during one implementation, a compressor device may operate in a manner that causes the flow F to flow in a number of different directions (e.g., a first flow direction F**1** and a second flow direction F**2**). The directional element **308** assumes one of a first sensor position **322** and a second sensor position **324**, which correspond to, respectively, the first flow direction F**1** and the second flow direction F**2**. In one example, the flow sensor **304** can register the change in the position of the directional element **308**, e.g., between the first sensor position **322** and the second sensor position **324**.

[0028] Examples of the first signal and/or the second signal can encode information to identify the position and/or the relative change in position of the directional element **308**. In one example, the first signal and the second signal may encode an angular position to each of the first sensor position **322** and the second sensor position **324**. Examples of the angular position can utilize a radial scale that covers 360°, wherein the first position **322** and the second position **324** assume different values on the radial scale, e.g., 0° for the first position **322** and 300° for the second position **324**. In other examples, the first signal and the second signal my encode an angular offset to each of the first sensor position **322** and the second sensor position **324**. The angular offset can define a value, e.g., a radial value, on the radial scale by which the first sensor position **322** and the second sensor position **324** deviate relative to a fixed or home position. For purposes of the present example of FIG. **5**, the radial value for the first sensor position **322** is 0 and or 0° and the radial value for the second sensor position **324** is −30 and/or −30°.

[0029] The steps for identifying a first position (e.g., at step **206**) for the diffuser vane **302** can use the information in the first signal and the second signal to align the diffuser vane **302** with the direction of flow F. In this connection, FIG. **6** illustrates an example of the diffuser vane **302** in a first vane position **326** and a second vane position, identified by phantom lines and the numeral **328**. In one example, the vane body **302** can rotate about a rotation axis **330**, which permits the position of the trailing edge **314** to change relative to, in one example, the leading edge **314**. This disclosure also contemplates configurations of the diffuser vane **302** in which the rotation axis **330** is located at various positions, e.g., in positions spaced apart from the leading edge **312** and the trailing edge **314** along the chord length L (FIGS. **4** and **5**). In these other configurations, both the leading edge **312** and the trailing edge **314** can rotate, e.g., about the rotation axis **330**.

[0030] Implementations in which the trailing edge **314** rotates the leading edge **312** are advantageous to accommodate the first flow direction F**1** and the second flow direction F**2**. As shown in the example of FIG. **6**, despite the relatively large angular displacement of the trailing edge **314** that occurs, the leading edge **312** is secured on the rotation axis **330** to limit changes to the position of the leading edge **312**, e.g., as the trailing edge **314** moves between the first vane position **326** and the second vane position **328**. This feature maintains the orientation of the leading edge **312** with the second flow direction F**2** to reduce the likelihood of flow separation, while providing adequate adjustment of the trailing edge **314** to dictate changes in the performance (e.g., of compressor device **100** of FIGS. **1** and **2**).

[0031] FIG. **7** illustrates a detail view of the diffuser vane **302**. The example of FIG. **7** shows that the tip **320** is round and/or has a curvilinear outer surface **332** defined by a radius R_{TIP} that extends from a center axis **334**. Other examples the tip **320** exhibit a shape (e.g., a point) that maintains the aerodynamics of the vane body **310**. This disclosure also contemplates configurations of the tip **320** having less than optimal aerodynamic shapes (e.g., blunt shapes) as desired.

[0032] In the example of FIG. **7** (and FIG. **6**), the rotation axis **330** resides proximate the leading edge **312** and, for example, within 5% or less of the chord length L (FIG. **4**) (as measured from the leading edge **312**). Depending on the size and shape of the tip **320**, the rotation axis **330** can also be found within an area that the radius R_{TIP} defines about the center axis **330**. In one example, the rotation axis **330** is coaxial with the center axis **334** of the tip **320**.

[0033] Examples of the diffuser vane **302** can comprise various materials and combinations, compositions, and derivations thereof. These materials include metals (e.g., steel, stainless steel, aluminum), metal alloys, high-strength plastics, composites, and the like. Material selection may depend on the type and composition of the working fluid. For example, working fluids with caustic properties may require that the diffuser vanes comprise relatively inert materials and/or materials that are chemically inactive with respect to the working fluid, and/or have one or more coatings and/or surface treatments that provide prevent corrosion, erosion, or other degradation of the surface of the diffuser vanes.

[0034] Geometry for the diffuser vane **302** is determined as part of the design, build, and fitting of the compressor device for the application. The geometry can include airfoil shapes, e.g., the shape shown in FIG. **4** for the vane body **310**, examples of which take the form of wings and blades and/or other forms that can generate lift. In one embodiment, the diffuser vane **302** can mount, e.g., to one of the wall members, using fasteners and fastening techniques that permit rotation of the diffuser vanes about the leading edge. Screws, bolts, pins, bearings, and like components can be used to maintain the position of the leading edge, while further allowing the trailing edge to change position as contemplated herein. These fasteners can secure to the wall members of the diffuser assembly, which can comprise pieces separate from the components of the compressor device or can integrate with existing hardware found in the compressor device.

[0035] Referring back to the method **200** of FIG. **3**, the steps for generating an output (e.g., at step **206**) can cause the diffuser vane **302** to move, e.g., as between the first position **326** and the second position **328**. The output can comprise any signal (e.g., analog and/or digital) that can encode instructs to operate a device. In the examples herein, the output can cause an actuator to move, which can facilitate movement either directly and/or indirectly of the diffuser vane **302** among and between one or more of the first position **326** and the second position **328**.

[0036] FIG. **8** illustrates another exemplary embodiment of a method **400** to operate a compressor device. The method **400** includes, at step **402**, receiving a first signal from the first flow sensor encoding information that identifies a first direction of flow for a working fluid upstream of the first diffuser vane. The method also includes, at step **404**, receiving a second signal from the second flow sensor encoding information that identifies a second direction of flow for the working fluid upstream of the second diffuser vane. The method further includes, at step **406**, comparing the first direction and the second direction to, respectively, a first reference direction and a second reference direction. In one example, the first reference direction and the second reference direction relate to a value for the first direction and the second direction. As shown in FIG. **8**, the method **400** also includes, at step **408**, identifying a first position for the first diffuser vane and the second diffuser vane aligning the first diffuser vane and the second diffuser vane with, respectively, the first direction and the second direction of the working fluid. In one embodiment, this step can include, at step **410**, determining whether the first position and the second position are different from the first reference position and the second reference position. If the first position and/or the second position are different, then the method **400** can include, at step **412**, selecting a first increment by which to move the first diffuser vane and/or a second increment by which to move the second diffuser vane. In one example, the first increment defines the relative position of the first direction with respect to the first reference direction and the second increment defining the relative position of the second direction with respect to the second reference direction. The method **400** can also include, at step **414**, generating an output encoding instructions to move the first diffuser vane and the second diffuser vane to the first position. In one example, the instructions cause the first diffuser vane and the second diffuser vane to move from the first position to a second position, wherein the second position is defined relative to the first position for the first diffuser vane by the first increment and for the second diffuser vane by the second increment.

[0037] In view of the foregoing discussion, one or more of the steps of the methods **200** and **400** can be coded as one or more executable instructions (e.g., hardware, firmware, software, software programs, etc.). These executable instructions can be part of a computer-implemented method and/or program, which can be executed by a processor and/or processing device. Examples of the controller **132** (FIG. **2**) can execute these executable instruction to generate certain outputs, e.g., a signal that encodes instructions to change the position of the diffuser vanes as suggested herein.

[0038] FIG. **9** depicts a schematic diagram that presents, at a high level, a wiring schematic for a controller **500** that can processing data (e.g., signals) to generate an output that instructs operation of a compressor device (e.g., compressor device **100** of FIGS. **1** and **2**). The controller **500** can be incorporated as part of compressor device to provide an integrated, effectively stand alone system. In other alternatives, the controller **500** can remain separate and/or as part of a control system, which can also monitor various operations of the compressor device as well as the systems coupled thereto.

[0039] In one embodiment, the controller **500** includes a processor **502**, memory **504**, and control circuitry **506**. Busses **508** couple the components of the controller **500** together to permit the exchange of signals, data, and information from one component of the controller **500** to another. In one example, the control circuitry **506** includes sensor driver circuitry **510** which couples with one or more sensors (e.g., first flow sensor **512** and second flow sensor **514**) and motor drive circuitry **516** that couples with a drive unit **518**. The control circuitry **506** also includes an actuator drive circuitry **520**, which couples with one or more actuators (e.g., first actuator **522** and second actuator **524**), and a radio circuitry **526** that couples to a radio **528**, e.g., a device that operates in accordance with one or more of the wireless and/or wired protocols for sending and/or receiving electronic messages to and from a peripheral device **530** (e.g., a smartphone). As also shown in FIG. **9**, memory **504** can include one or more software programs **532** in the form of software and/or firmware, each of which can comprise one or more executable instructions configured to be executed by the processor **502**.

[0040] This configuration of components can dictate operation of the controller **500** to analyze data, e.g., information encoded by the signals from sensors **512**, **514** and/or drive unit **518**, to identify appropriate changes to the diffuser vanes and/or other changes to other operating properties (e.g., motor speed) of the compressor device. For example, the controller **500** can provide signals (or inputs or outputs) to align diffuser vanes in various stages of the compressor device with the direction of flow, independent of the other stages and without disrupting operation (e.g., output pressure) of the compressor device.

[0041] The controller **500** and its constructive components can communicate amongst themselves and/or with other circuits (and/or devices), which execute high-level logic functions, algorithms, as well as executable instructions (e.g., firmware instructions, software instructions, software programs, etc.). Exemplary circuits of this type include discrete elements such as resistors, transistors, diodes, switches, and capacitors. Examples of the processor **502** include microprocessors and other logic devices such as field programmable gate arrays ("FPGAs") and application specific integrated circuits ("ASICs"). Although all of the discrete elements, circuits, and devices function individually in a manner that is generally understood by those artisans that have ordinary skill in the electrical arts, it is their combination and integration into functional electrical groups and circuits that generally provide for the concepts that are disclosed and described herein.

[0042] The structure of the components in the controller **500** can permit certain determinations as to selected configuration and desired operating characteristics that an end user convey via the graphical user interface or that are retrieved or need to be retrieved by the device. For example, the electrical circuits of the controller **500** can physically manifest theoretical analysis and logical operations and/or can replicate in physical form an algorithm, a comparative analysis, and/or a decisional logic tree, each of which operates to assign the output and/or a value to the output that correctly reflects one or more of the nature, content, and origin of the changes that occur and that are reflected by the inputs to the controller **500** as provided by the corresponding control circuitry, e.g., in the control circuitry **506**.

[0043] In one embodiment, the processor **502** is a central processing unit (CPU) such as an ASIC and/or an FPGA that is configured to instruct and/or control operation one or more devices. This processor can also include state machine circuitry or other suitable components capable of controlling operation of the components as described herein. The memory **504** includes volatile and non-volatile memory and can store executable instructions in the form of and/or including software (or firmware) instructions and configuration settings. Each of the control circuitry **506** can embody standalone devices such as solid-state devices. Examples of these devices can mount to substrates such as printed-circuit boards and semiconductors, which can accommodate various components including the processor **502**, the memory **504**, and other related circuitry to facilitate operation of the controller **500**.

[0044] However, although FIG. **9** shows the processor **502**, the memory **504**, and the components of the control circuitry **506** as discrete circuitry and combinations of discrete components, this need not be the case. For example, one or more of these components can comprise a single integrated circuit (IC) or other component. As another example, the processor **502** can include internal program memory such as RAM and/or ROM. Similarly, any one or more of functions of these components can be distributed across additional components (e.g., multiple processors or other components).

[0045] Moreover, as will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a system, method or computer program product. Accordingly, aspects of the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, aspects of the present invention may take the form of a computer program product embodied in one or more computer readable medium (s) having computer readable program code embodied thereon.

[0046] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. Examples of a computer readable storage medium include an electronic, magnetic, electromagnetic, and/or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0047] A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms and any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device.

[0048] Program code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

[0049] Computer program code for carrying out operations for aspects of the present invention may be written in any combination of one or more programming languages, including an object oriented programming language and conventional procedural programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0050] Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0051] These computer program instructions may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the flowchart and/or block diagram block or blocks.

[0052] The computer program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0053] Accordingly, a technical effect of embodiments of the systems and methods disclosed herein is to change the position of one or more diffuser vanes to align with the direction of flow of the working fluid.

[0054] As used herein, an element or function recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural said elements or functions, unless such exclusion is explicitly recited. Furthermore, references to "one embodiment" of the claimed invention should not be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0055] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A system, comprising:

a compressor device comprising a first diffuser vane, a second diffuser vane downstream of the first diffuser vane, and a flow sensor assembly comprising a first flow sensor upstream of the first diffuser vane and a second flow sensor upstream of the second diffuser vane; and

a controller coupled with the first flow sensor and the second flow sensor, the controller comprising a processor, memory, and one or more executable instructions stored on the memory and configured to be executed by the processor, the executable instructions comprising instructions for:

receiving a first signal from the first flow sensor encoding information that identifies a first direction of flow for a working fluid upstream of the first diffuser vane;

receiving a second signal from the second flow sensor encoding information that identifies a second direction of flow for the working fluid upstream of the second diffuser vane;

identifying a first position for the first diffuser vane and the second diffuser vane, the first position aligning the first diffuser vane and the second diffuser vane with, respectively, the first direction and the second direction of the working fluid; and

generating an output encoding instructions to move the first diffuser vane and the second diffuser vane to the first position.

2. The system of claim **1**, wherein the compressor device comprises a first actuator coupled with the first diffuser vane and a second actuator coupled with the second diffuser vane, and wherein the first actuator and the second actuator operate in response to the output.

3. The system of claim **1**, wherein the first flow sensor and the second flow sensor comprise a directional element and a base element coupled to the directional element, and wherein the information of the first signal and the second signal reflects an angular position of the directional element.

4. The system of claim **3**, wherein the base element comprises a rotary potentiometer that measures the angular position of the directional element.

5. The system of claim **1**, wherein the compressor device comprises a first impeller upstream of the first diffuser vane and a second impeller downstream of the first diffuser vane and upstream of the second diffuser vane.

6. The system of claim **1**, wherein the first diffuser vane and the second diffuser vane rotate in response to the output.

7. The system of claim **1**, wherein the first diffuser vane and the second diffuser vane have an airfoil shape that converges at the leading edge to a tip with a center axis, wherein the tip has a curvilinear outer surface defined by a radius from the center axis, and wherein the first diffuser vane and the second diffuser vane rotate about a rotation axis that is found within an area defined by the radius.

8. The system of claim **7**, wherein the rotation axis is coaxial with the center axis of the tip.

9. The system of claim **1**, wherein the executable instructions comprise instructions for:

comparing the first direction and the second direction to, respectively, a first reference direction and a second reference direction; and

selecting a first increment by which to move the first diffuser vane and a second increment by which to move the second diffuser vane, the first increment defining the relative position of the first direction with respect to the first reference direction and the second increment defining the relative position of the second direction with respect to the second reference direction,

wherein the instructions cause the first diffuser vane and the second diffuser vane to move from the first position to a second position, and wherein the second position is defined relative to the first position for the first diffuser vane by the first increment and for the second diffuser vane by the second increment.

10. A compressor device, comprising:

a first diffuser vane;

a second diffuser vane downstream of the first diffuser vane;

a flow sensor assembly comprising a first flow sensor upstream of the first diffuser vane and a second flow sensor downstream of the first diffuser vane and upstream of the second diffuser vane, the first flow sensor and the second flow sensor comprising a base element and a directional element coupled with the base element, wherein the directional element can move between a first position and a second position to align with a flow of a working fluid.

11. The compressor device of claim **10**, wherein the base element provides a pivot about which the directional element can rotate between the first position and the second position.

12. The compressor device of claim **10**, wherein the base element comprises a rotary potentiometer.

13. The compressor device of claim **10**, wherein the first diffuser vane and the second diffuser vane comprise a vane body with a leading edge and a trailing edge and a rotation axis spaced apart from the leading edge and the trailing edge along a chord length that defines the straight-line distance between the leading edge and the trailing edge

14. The compressor device of claim **10**, wherein the first diffuser vane and the second diffuser vane rotate about the leading edge.

15. The compressor device of claim **10**, wherein the vane body has an airfoil shape that converges at the leading edge to a tip with a center axis, wherein the tip has a curvilinear outer surface defined by a radius from the center axis, and wherein the first diffuser vane and the second diffuser vane rotate about a rotation axis that is found within an area defined by the radius.

16. The compressor device of claim **16**, wherein the rotation axis is coaxial with the center axis of the tip.

17. The compressor device of claim **10**, further comprising a controller coupled with the first flow sensor and the second flow sensor, the controller comprising a processor, memory, and one or more executable instructions stored on the memory and configured to be executed by the processor, the executable instructions comprising instructions for:

receiving a first signal from the first flow sensor encoding information that identifies a first direction of flow for a working fluid upstream of the first diffuser vane;

receiving a second signal from the second flow sensor encoding information that identifies a second direction of flow for the working fluid upstream of the second diffuser vane;

identifying a first position for the first diffuser vane and the second diffuser vane, the first position aligning the first diffuser vane and the second diffuser vane with, respectively, the first direction and the second direction of the working fluid; and

generating an output encoding instructions to move the first diffuser vane and the second diffuser vane to the first position.

18. The compressor device of claim **17**, wherein the executable instructions comprise instructions for:

comparing the first direction and the second direction to, respectively, a first reference direction and a second reference direction; and

selecting a first increment by which to move the first diffuser vane and a second increment by which to move the second diffuser vane, the first increment defining the relative position of the first direction with respect to the first reference direction and the second increment defining the relative position of the second direction with respect to the second reference direction,

wherein the instructions cause the first diffuser vane and the second diffuser vane to move from the first position to a second position, and wherein the second position is defined relative to the first position for the first diffuser vane by the first increment and for the second diffuser vane by the second increment.

19. A controller for operating a compressor device, said controller comprising:

a processor;

memory; and

executable instructions stored on the memory and configured to be executed by the processor, the executable instructions comprising instructions for:

receiving a first signal from the first flow sensor encoding information that identifies a first direction of flow for a working fluid upstream of the first diffuser vane;

receiving a second signal from the second flow sensor encoding information that identifies a second direction of flow for the working fluid upstream of the second diffuser vane;

identifying a first position for the first diffuser vane and the second diffuser vane, the first position aligning the first diffuser vane and the second diffuser vane with, respectively, the first direction and the second direction of the working fluid; and

generating an output encoding instructions to move the first diffuser vane and the second diffuser vane to the first position.

20. The controller of claim **19**, further comprising instructions for:

comparing the first direction and the second direction to, respectively, a first reference direction and a second reference direction, wherein the first reference direction and the second reference direction comprise a value for the first direction and the second direction at a time t, and wherein the first position; and

selecting a first increment by which to move the first diffuser vane and a second increment by which to move the second diffuser vane, the first increment defining the relative position of the first direction with respect to the first reference direction and the second increment defining the relative position of the second direction with respect to the second reference direction,

wherein the instructions cause the first diffuser vane and the second diffuser vane to move from the first position to a second position, and wherein the second position is defined relative to the first position for the first diffuser vane by the first increment and for the second diffuser vane by the second increment.

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