



(51) International Patent Classification:

*F04D 13/06* (2006.01) *F04D 29/60* (2006.01)  
*F04D 13/02* (2006.01) *F04D 29/42* (2006.01)

(21) International Application Number:

PCT/US2018/012548

(22) International Filing Date:

05 January 2018 (05.01.2018)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/443,295 06 January 2017 (06.01.2017) US

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: ADAPTABLE THIN SECTION LIQUID PUMP FOR ELECTRONICS COOLING SYSTEMS OR OTHER SYSTEMS

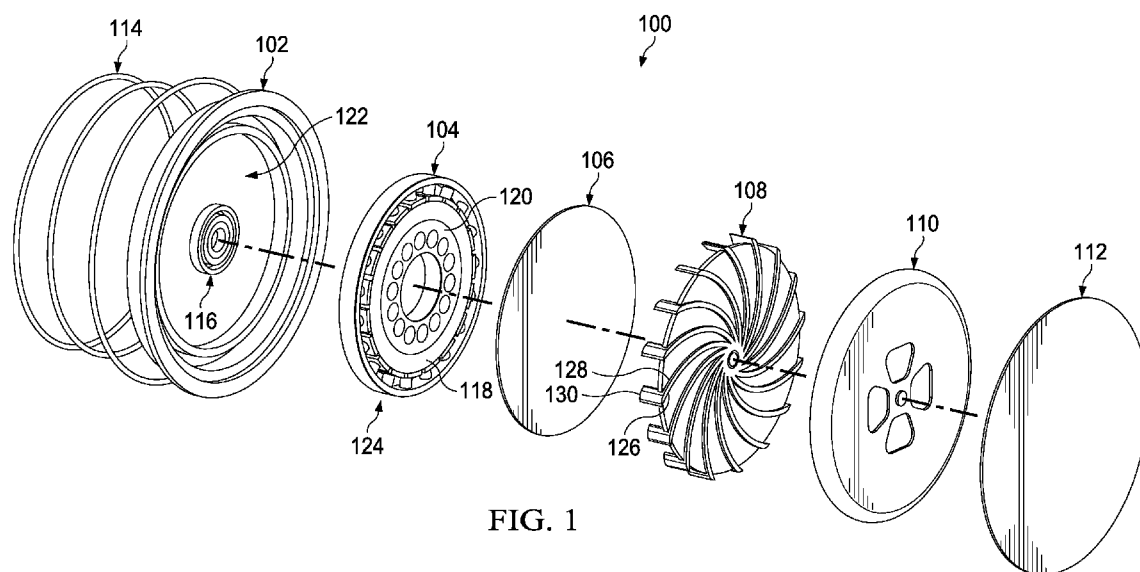


FIG. 1

(57) Abstract: A pump (100) includes a circular housing (102) having a thin profile, a brushless open frame motor (124), and a centrifugal impeller (108). The pump is configured to transport a fluid to transfer thermal energy to or from one or more external components.



## ADAPTABLE THIN SECTION LIQUID PUMP FOR ELECTRONICS COOLING SYSTEMS OR OTHER SYSTEMS

### TECHNICAL FIELD

5 [0001] This disclosure is generally directed to electronics cooling systems. More specifically, this disclosure is directed to an adaptable thin section liquid pump for electronics cooling systems or other systems.

### BACKGROUND

10 [0002] In many industries, including commercial and military radio frequency (RF) and electronics industries, a method to minimize junction temperatures and ensure system reliability includes liquid cooling directly in thermal contact with a mounting base of active electronic components to be cooled. Miniature brushless motor pumps designed to be mounted directly on circuit card assembly (CCA) heat producing components, such as  
15 computer processors, are available from multiple sources. However, these are not typically capable of being integrated internally into thin structures and providing volume flow rates and pressures that a large-diameter torque motor can produce. Thermal conduction paths that use dry contact clamping, such as wedge locks, also typically compromise thermal designs.

### SUMMARY

20 [0003] This disclosure provides an adaptable thin section liquid pump for electronics cooling systems or other systems.

[0004] In a first embodiment, a pump includes a circular housing having a thin profile, a brushless open frame motor, and a centrifugal impeller. The pump is configured to  
25 transport a fluid to transfer thermal energy to or from one or more external components.

[0005] In a second embodiment, a system includes one or more electronic components and a pump. The pump includes a circular housing having a thin profile, a brushless open frame motor, and a centrifugal impeller. The pump is configured to transport coolant in a closed loop to transfer thermal energy away from the one or more electronic  
30 components.

[0006] Other technical features may be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a more complete understanding of this disclosure, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

5 [0008] FIGURE 1 illustrates an exploded view of an example fluid pump according to this disclosure;

[0009] FIGURES 2A through 2F illustrate examples of different systems that incorporate one or more fluid pumps according to this disclosure;

[0010] FIGURE 3 illustrates a cross-sectional view of the fluid pump of FIGURE 1 according to this disclosure; and

10 [0011] FIGURE 4 illustrates an assembly sequence for the fluid pump of FIGURE 1 according to this disclosure.

## DETAILED DESCRIPTION

15 [0012] FIGURES 1 through 4, discussed below, and the various embodiments used to describe the principles of the present invention in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the invention. Those skilled in the art will understand that the principles of the invention may be implemented in any type of suitably arranged device or system.

20 [0013] For simplicity and clarity, some features and components are not explicitly shown in every figure, including those illustrated in connection with other figures. It will be understood that all features illustrated in the figures may be employed in any of the embodiments described. Omission of a feature or component from a particular figure is for purposes of simplicity and clarity and is not meant to imply that the feature or component cannot be employed in the embodiments described in connection with that figure.

25 [0014] As noted above, many industries desire a method to minimize junction temperatures and ensure system reliability. Some systems use forced-air cooling, which can be adequate for low thermal loads. However, some heat-generating components, such as RF electronics and microwave arrays, have very high density thermal loads. In such cases, forced-air cooling systems may not support sufficient thermal transfer. To address these and  
30 other issues, embodiments of this disclosure provide a scalable, thin-section coolant pump that can be incorporated into various structures, such as distributed line-replaceable unit (LRU) housings and array structures for thermal control of high density RF or other electronics. The disclosed embodiments avoid the use of large-scale plumbing and piping

systems.

[0015] The disclosed embodiments provide a low cost, thin profile (such as less than 0.5" thick) centrifugal pump providing closed-loop coolant flow at high flow rates (e.g., 1.5 – 3 gallons/minute) and pressure heads (e.g., 20-50 PSI), which can be suitable for localized thermal control of high-density RF or other electronic components. The pump can be also referred to a "cool puck" due to its cooling function and its similarity in overall size and shape to a hockey puck. A synchronous, brushless open-frame motor (such as with a separate stator and rotor) can be installed in a circular (e.g., >3.5" dia.) housing of the fluid pump with a magnetically-coupled centrifugal impeller achieving maximum flow rate and pressure head. The fluid pump can be easily integrated into electronic structures or housings for heat removal. In some embodiments, the fluid pump can use an open-frame torque motor and magnetic coupling to drive a wrap-around impeller, providing a thin profile cooling system adaptable to many structures.

[0016] Some existing open-frame brushless motors are used in various industries, but they are highly integrated into specialized machines, such as in robotics. These types of motors are extremely quiet (such as less than 26dBA) and highly reliable (such as more than 50,000 hours). Using an open-frame brushless motor to rotate a large-diameter centrifugal impeller-type pump provides for high discharge rates and pressure heads directly under RF or other electronics and power subsystems. Integrating single-motor or dual-motor pumps into structural cold plates and electronics housings can significantly lower junction component temperatures using high-pressure micro-channels and/or high-density fin stocks. Centrifugal pumps can provide lower noise and vibration compared to gear, piston, or diaphragm type pumps.

[0017] Liquid transport systems in direct contact with high-power or other components can help to reduce or minimize size and increase or maximize system performance. Developing structures using the disclosed pumps that can be integrated within existing structures can advance and greatly benefit existing power systems, data processing systems, array sensor technologies, or other systems.

[0018] In some embodiments, additive manufacturing can be used to generate components of the fluid pump, including the impeller. The disclosed pumps are easily adaptable to multiple types of structures. Among other things, the disclosed pumps enable an increase in RF or other electronic power and component packaging densities.

[0019] Additional details regarding embodiments of this disclosure are provided

below. Note that while embodiments of this disclosure describe the use of one or more pumps with electronics cooling systems, the pump(s) could be used in any other suitable device or system. Also note that while various embodiments provide specific dimensions for example implementations of the pump(s), these dimensions are examples only, and other dimensions could be used as needed or desired.

[0020] FIGURE 1 illustrates an exploded view of an example fluid pump 100 according to this disclosure. As shown in FIGURE 1, the fluid pump 100 includes a housing 102, a brushless stator 104, a fluid shield 106, an impeller 108, an impeller shield 110, a cover 112, one or more seals 114, a bearing 116, a rotor 118, and a magnetic coupling 120.

[0021] The housing 102 houses most of the other components of the fluid pump 100. The housing 102 is generally circular and, in some embodiments, has a diameter of approximately 3.5 inches. The housing 102 includes a recess 122 in which other components are arranged. The housing 102 is low profile, having a depth (in the axial direction) of approximately 0.7 inch or less in some embodiments. In some particular embodiments, the profile depth is 0.5 inch or less. This depth represents most of the thickness of the pump 100 (other than the thickness of the cover 112). Thus, in some embodiments, the diameter of the housing 102 can be at least seven times as large as a thickness of the pump 100. The housing 102 can be formed of a metal, such as anodized aluminum, or of any other suitable material.

[0022] The brushless stator 104, the bearing 116, and the rotor 118 form a synchronous, brushless open-frame motor 124 that drives the impeller 108. The brushless stator 104 can be formed of stainless steel or any other suitable material. The bearing 116 can be a ball bearing. The rotor 118 can be a rare earth rotor. In some embodiments, the motor 124 is a synchronous, brushless open-frame motor. The magnetic coupling 120 serves to couple the motor 124 and the impeller 108.

[0023] The impeller 108 is a two-stage impeller that includes a plurality of blades 126 that extend radially from a central axis. The blades 126 are two-stage blades that include a planar portion 128 and an axial portion 130. The planar portions 128 of the blades 126 include ridges that project from a planar surface of the impeller 108. In some embodiments, the ridges extend out from the central axis in an arc, as shown in FIGURE 1. At the end of the planar portion 128 of each blade 126, the axial portion 130 extends perpendicular to the planar portion 128 (and parallel to the central axis), thereby covering a portion of the motor 124.

[0024] Together, the planar portions 128 of the blades 126 generate radial movement

of the coolant fluid toward the axial portions 130, while the axial portions 130 result in circumferential movement of the coolant fluid toward one or more fluid outlets (shown in FIGURE 3).

5 [0025] Because of the axial portions 130 of the blades 126, the impeller 108 essentially wraps around edges of the motor 124, as more clearly illustrated in FIGURE 3. Driven by the motor 124, the impeller 108 rotates, during standard fluid throughput, at 400-600rpm. In other embodiments, the rotation may be faster or slower, but typically will be less than 1000rpm. The impeller 108 can be formed of brass, bronze, or another suitable metallic material.

10 [0026] The fluid shield 106 is plastic and protects the motor 124 from the fluid. The impeller shield 110 is disposed closely over the impeller 108 and acts to reduce fluid turbulence in the pump 100. The impeller shield 110 can be formed of stainless steel. The cover 112 covers and protects the components inside the housing 102 and, together with the housing 102, creates a hermetic environment for the coolant to flow through. Like the  
15 housing 102, the cover 112 can be formed from a metal, such as anodized aluminum.

[0027] The seals 114 extend circumferentially around an exterior surface of the housing 102 and are used to ensure a sealed connection once the fluid pump 100 is installed in a system or device. The seals 114 are formed of elastomers, such as plastic or rubber. In some embodiments, the seals 114 are “O” rings.

20 [0028] While FIGURE 1 illustrates one example of the pump 100, various changes may be made to FIGURE 1. For example, the example dimensions of the pump 100 described herein are scalable to other values to accommodate different flow volumes and delivery pressures.

[0029] FIGURES 2A through 2F illustrate examples of different systems 201-206 that  
25 incorporate one or more fluid pumps 100 according to this disclosure. These systems 201-206 illustrate that the fluid pump 100 can provide cooling in many types of applications.

[0030] FIGURE 2A illustrates a system 201 that includes a fluid pump 100 with a cold plate 210. The cold plate 210 includes one or more pump inlets 212 and one or more pump outlets 214. Each pump inlet 212 is an interface for fluid flowing from the cold plate  
30 210 into the housing 102 of the pump 100. Each pump outlet 214 is an interface for fluid flowing from the pump 100 back into the cold plate 210. The cold plate 210 also includes a fluid inlet 216 and a fluid outlet 218. These may be hydraulically coupled to a radiator, evaporator, or other components (not shown) in a closed-loop cooling system.

[0031] The fluid pump 100 can be installed (“plugged”) directly into a recess of the cold plate 210, and the seals 114 ensure a sealed connection once the fluid pump 100 is installed. When the pump 100 is installed in the cold plate 210, the pump 100 and cold plate 210 are hydraulically connected. Input and output openings in the pump housing 102 (shown in FIGURE 3) align with corresponding ones of the pump inlet(s) 212 and pump outlet(s) 214. The cold plate 210 can be formed of aluminum or another suitable material. In some embodiments, the cold plate 210 can include a configurable plate adapter that can accommodate different sizes of fluid pumps 100.

[0032] In one aspect of operation, operation of the pump 100 causes coolant fluid to flow into the fluid inlet 216, through the pump inlet 212, and into the pump 100. The fluid then moves through the pump 100, out of the pump 100 back into the cold plate through the pump outlet 214, and then out of the cold plate 210 through the fluid outlet 218. The cold plate 210 may have one or more fluid channels (not shown) that allow for the fluid to circulate within portions of the cold plate 210 before and/or after passing through the pump 100. While the fluid is circulating through the pump 100 and the cold plate 210, thermal energy can be transferred through the cover 112 of the pump 100, through exterior surfaces of the cold plate 210, or a combination of these.

[0033] FIGURE 2B illustrates a system 202 that is similar to the system 201 of FIGURE 2A, and includes a fluid pump 100 and a cold plate 210. The system 202 also includes a controller 220 that controls operation of the pump 100. The controller 220 can be programmable, and can include any suitable combination of hardware, firmware, and software for controlling operation of the pump 100. In some embodiments, the controller 220 is an integrated gate bipolar transistor (IGBT) controller. In some embodiments, the controller 220 also provides power to operate the pump 100.

[0034] FIGURE 2C illustrates a system 203 that is similar to the system 201 of FIGURE 2A, and includes a fluid pump 100 and a cold plate 210. The system 203 provides thermal control to a connected power supply component 230, such as a high power DC to DC converter. In one aspect of operation, the power supply component 230 generates waste heat, and the coolant fluid circulating through the fluid pump 100 and cold plate 210 absorb portions of the waste heat, which is conductively transferred through the pump cover 112 and surfaces of the cold plate 210.

[0035] FIGURES 2D and 2E illustrate systems 204-205 that are similar to the system 201 of FIGURE 2A, and include a fluid pump 100 and a cold plate 210. Both systems 204-

205 provide thermal control to a connected heat-generating component. In FIGURE 2D, the heat-generating component is a solid state module 240 of a ultra-high frequency (UHF) phased array antenna. In FIGURE 2E, the heat-generating component is a digital receiver exciter (DREX) or synthesizer 250.

5 [0036] FIGURE 2F illustrates a system 206 that includes a heating or cooling array with multiple fluid pumps 100. The system also includes an array plate 260, one or more array plate stiffeners 262, and one or more heating or cooling lines 264. The array plate 260 includes a generally planar surface through which thermal transfer can occur with an object to be heated or cooled. The array plate stiffeners 262 are generally perpendicular to the array  
10 plate 260 and help to prevent bending or flexing of the array plate 260. The array plate 260 and array plate stiffeners 262 can be formed of a metal, such as aluminum, or any other suitable material.

[0037] The heating or cooling lines 264 are disposed on a back surface of the array plate 260 and are configured to transport heating or coolant fluid for thermal transfer  
15 throughout the array plate 260. While various embodiments disclosed herein have been described with coolant for transferring thermal energy away from a heat generating body, it will be understood that these embodiments are also suitable for use with a heating fluid for transferring thermal energy to a cooler body.

[0038] The heating or cooling lines 264 are hydraulically connected to the multiple  
20 fluid pumps 100, which can operate together in parallel to increase the total fluid flow through the heating or cooling lines 264. The array plate stiffeners 262 could be fitted with openings and adapters (similar to those of the cold plate 210 shown in FIGURE 2A) configured to accept a fluid pump 100 and provide a sealed connection once each fluid pump 100 is installed.

25 [0039] FIGURE 3 illustrates a cross-sectional view of the fluid pump 100 according to this disclosure. As shown in FIGURE 3, the fluid pump 100 includes the housing 102, the stator 104, the fluid shield 106, the centrifugal impeller 108, the impeller shield 110, the cover 112, seals 114, the bearing 116, the rotor 118, and the magnetic coupling 120.

[0040] FIGURE 3 also shows one or more pump inlets 302 disposed  
30 circumferentially around the housing 102. The pump inlets 302 are where low pressure coolant fluid enters the pump 100. Each pump inlet 302 can align with a corresponding pump inlet of a cold plate, such as the pump inlet 212 of FIGURE 2A. The fluid then flows from the pump inlet(s) 302 into the cavity around the impeller 108 through one or more orifices

304. The planar portions 128 of the blades 126 generate radial movement of the coolant fluid toward the axial portions 130, while the axial portions 130 result in circumferential movement of the coolant fluid toward one or more pump outlets 306 disposed circumferentially around the housing 102 near the axial portions 130 of the impeller 108. The pump outlets 306 are where high pressure fluid leaves the pump. Each pump outlet 306 can align with a corresponding pump outlet of a cold plate, such as the pump outlet 214 of FIGURE 2A.

[0041] FIGURE 4 illustrates an assembly sequence for the fluid pump 100 according to this disclosure. As shown in FIGURE 4, operation 401 includes positioning the motor 124 within the recess of the housing 102. At operation 402, the fluid shield 106 is positioned over the motor 124. At operation 403, the impeller 108 is installed over the fluid shield 106. At operation 404, the impeller shield 110 is added over the impeller 108. At operation 405, the cover 112 is installed over and fastened to the housing 102. Any suitable fastening technique can be used to fasten the cover 112 to the housing 102, including adhesives, welding, or fasteners (e.g., screws). Although not specifically shown in FIGURE 4, one or more seals 114 can be positioned around a circumferential exterior surface of the housing 102.

[0042] It may be advantageous to set forth definitions of certain words and phrases used throughout this patent document. The terms “include” and “comprise,” as well as derivatives thereof, mean inclusion without limitation. The term “or” is inclusive, meaning and/or. The phrase “associated with,” as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, have a relationship to or with, or the like. The phrase “at least one of,” when used with a list of items, means that different combinations of one or more of the listed items may be used, and only one item in the list may be needed. For example, “at least one of: A, B, and C” includes any of the following combinations: A, B, C, A and B, A and C, B and C, and A and B and C.

[0043] The description in this patent document should not be read as implying that any particular element, step, or function is an essential or critical element that must be included in the claim scope. Also, none of the claims is intended to invoke 35 U.S.C. § 112(f) with respect to any of the appended claims or claim elements unless the exact words “means for” or “step for” are explicitly used in the particular claim, followed by a participle phrase identifying a function. Use of terms such as (but not limited to) “mechanism,” “module,”

“device,” “unit,” “component,” “element,” “member,” “apparatus,” “machine,” and “system” within a claim is understood and intended to refer to structures known to those skilled in the relevant art, as further modified or enhanced by the features of the claims themselves, and is not intended to invoke 35 U.S.C. § 112(f).

5       [0044] While this disclosure has described certain embodiments and generally associated methods, alterations and permutations of these embodiments and methods will be apparent to those skilled in the art. Accordingly, the above description of example embodiments does not define or constrain this disclosure. Other changes, substitutions, and alterations are also possible without departing from the scope of this disclosure, as defined by  
10       the following claims.

## WHAT IS CLAIMED IS:

1. A pump comprising:

a circular housing having a thin profile;

a brushless open frame motor; and

5 a centrifugal impeller,

wherein the pump is configured to transport a fluid to transfer thermal energy to or from one or more external components.

2. The pump of Claim 1, wherein the circular housing has a thickness of less than

10 0.5 inches.

3. The pump of Claim 2, wherein the circular housing has a diameter at least seven times as large as a thickness of the pump.

15 4. The pump of Claim 1, wherein the centrifugal impeller comprises a plurality of two-stage blades, each blade comprising a planar portion and an axial portion.

5. The pump of Claim 4, wherein:

the planar portion of each blade includes ridges that project from a planar surface of  
20 the centrifugal impeller, the planar portions of the blades configured to generate radial movement of the fluid toward the axial portions, and

the axial portion of each blade extends perpendicular to the planar portion, the axial portions configured to generate circumferential movement of the fluid toward at least one pump outlet.

25 6. The pump of Claim 1, further comprising:

at least one pump inlet configured to receive the fluid at a first pressure; and

at least one pump outlet configured to output the fluid at a second pressure higher than the first pressure.

30 7. The pump of Claim 6, further comprising:

one or more orifices configured to transport the fluid from the at least one pump inlet into a cavity around the centrifugal impeller.

8. The pump of Claim 1, wherein the centrifugal impeller is magnetically coupled to the motor.

9. The pump of Claim 1, wherein the impeller wraps around edges of the motor.

5

10. A system comprising:  
one or more electronic components; and  
a pump comprising:

10

a circular housing having a thin profile;  
a brushless open frame motor; and  
a centrifugal impeller,

wherein the pump is configured to transport coolant in a closed loop to transfer thermal energy away from the one or more electronic components.

15

11. The system of Claim 10, wherein the circular housing has a thickness of less than 0.5 inches.

12. The system of Claim 11, wherein the circular housing has a diameter at least seven times as large as a thickness of the pump.

20

13. The system of Claim 10, wherein the centrifugal impeller comprises a plurality of two-stage blades, each blade comprising a planar portion and an axial portion.

14. The system of Claim 13, wherein:

25

the planar portion of each blade includes ridges that project from a planar surface of the centrifugal impeller, the planar portions of the blades configured to generate radial movement of the coolant toward the axial portions, and

the axial portion of each blade extends perpendicular to the planar portion, the axial portions configured to generate circumferential movement of the coolant toward at least one pump outlet.

30

15. The system of Claim 10, further comprising:  
at least one pump inlet configured to receive the coolant at a first pressure; and

at least one pump outlet configured to output the coolant at a second pressure higher than the first pressure.

16. The system of Claim 15, further comprising:  
5 one or more orifices configured to transport the coolant from the at least one pump inlet into a cavity around the centrifugal impeller.

17. The system of Claim 10, wherein the centrifugal impeller is magnetically coupled to the motor.  
10

18. The system of Claim 10, wherein the impeller wraps around edges of the motor.

19. The system of Claim 10, further comprising:  
15 a cold plate configured to receive the pump, wherein when the pump is installed in the cold plate, the pump and cold plate are hydraulically connected.

20. The system of Claim 19, wherein the cold plate comprises:  
at least one pump inlet configured to align with a corresponding pump inlet of the  
20 pump, and  
at least one pump outlet configured to align with a corresponding pump outlet of the pump.

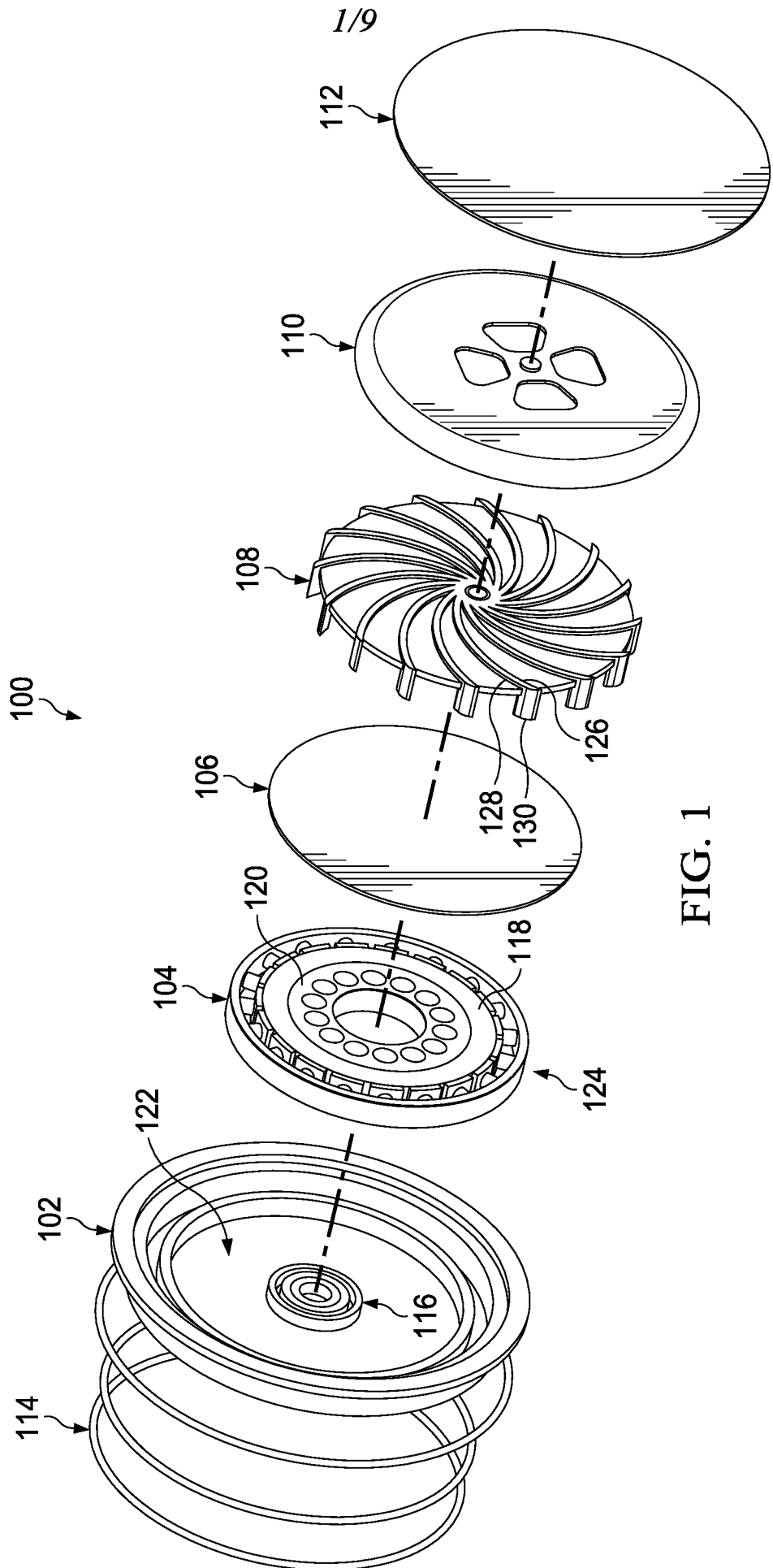


FIG. 1

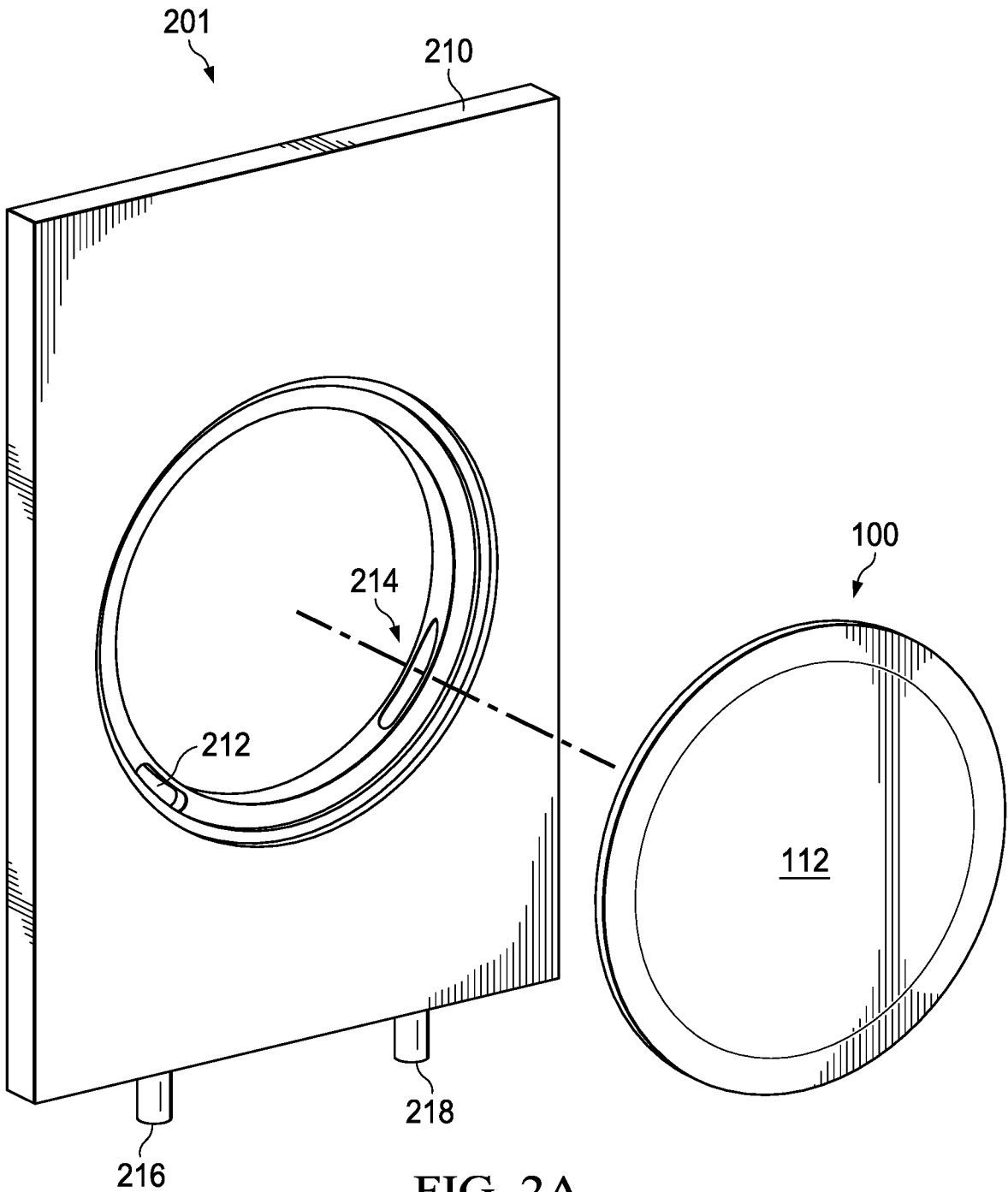


FIG. 2A

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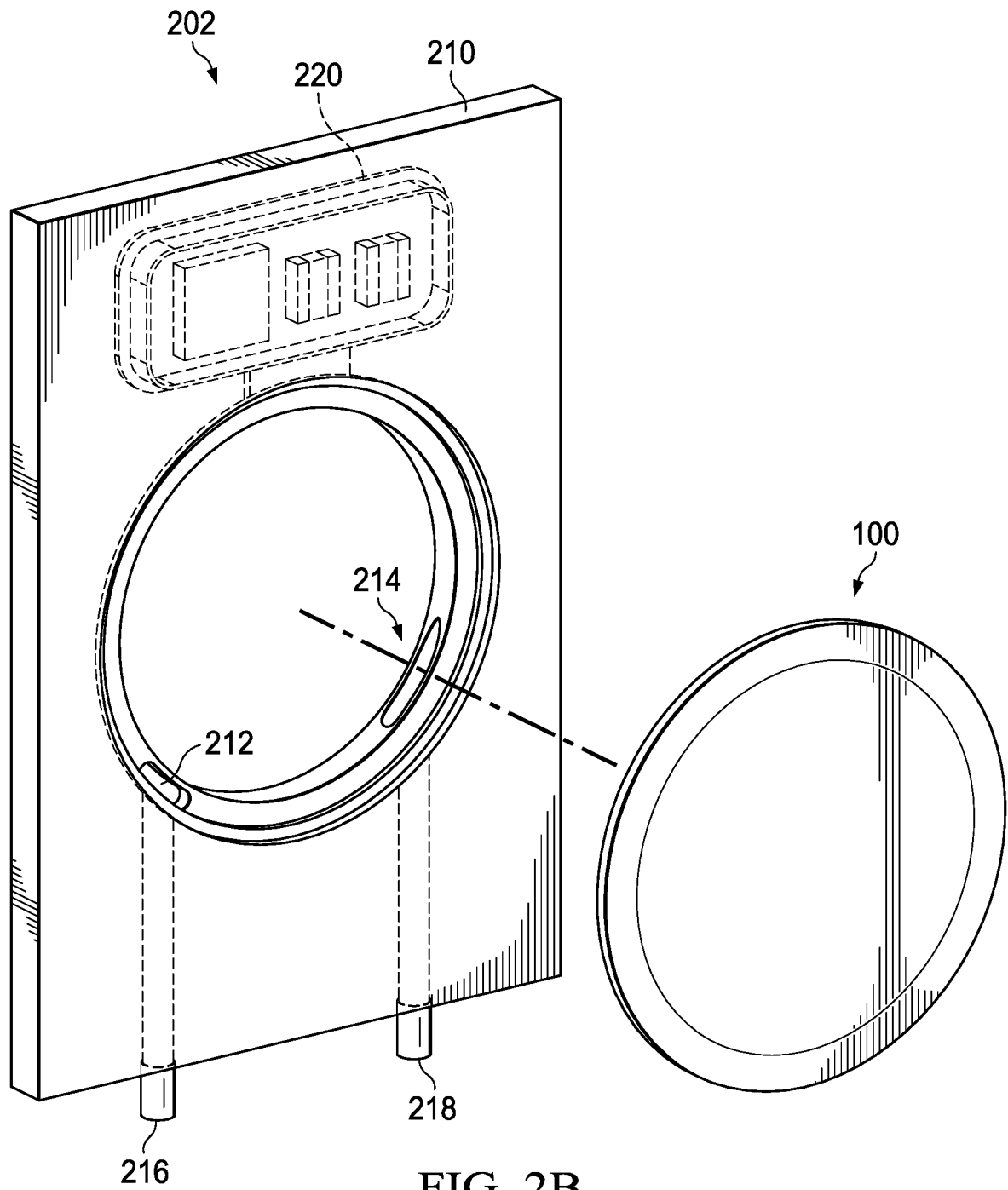


FIG. 2B

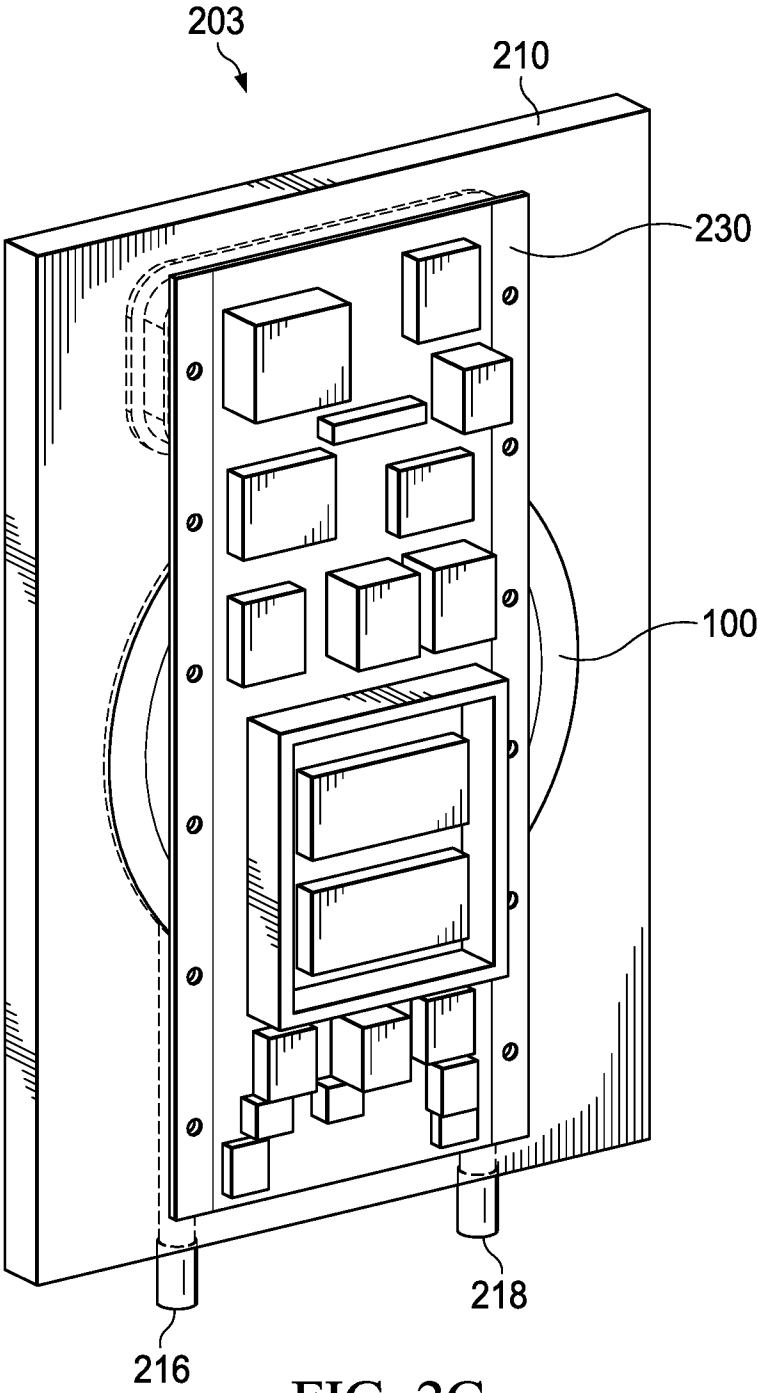


FIG. 2C

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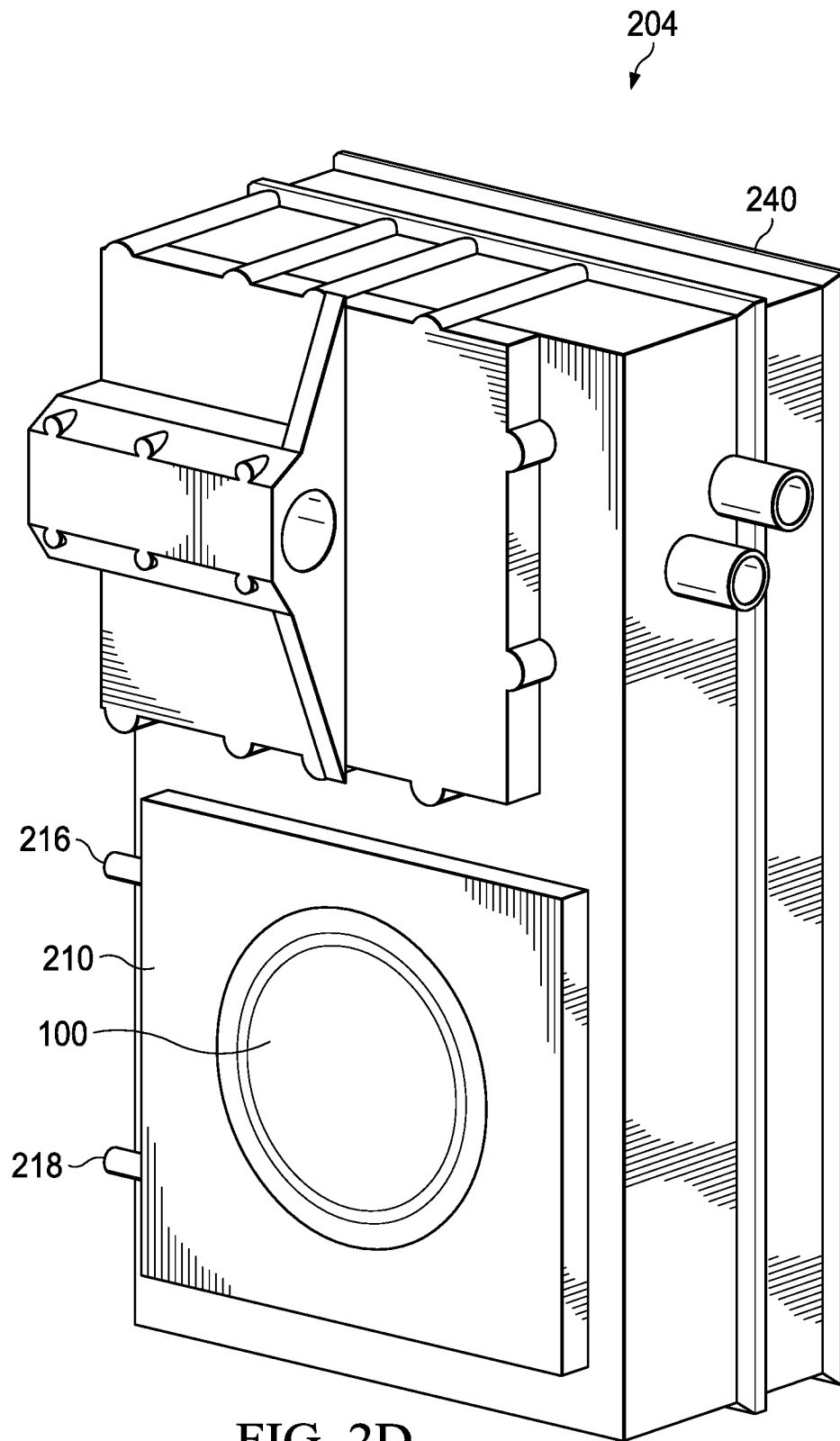
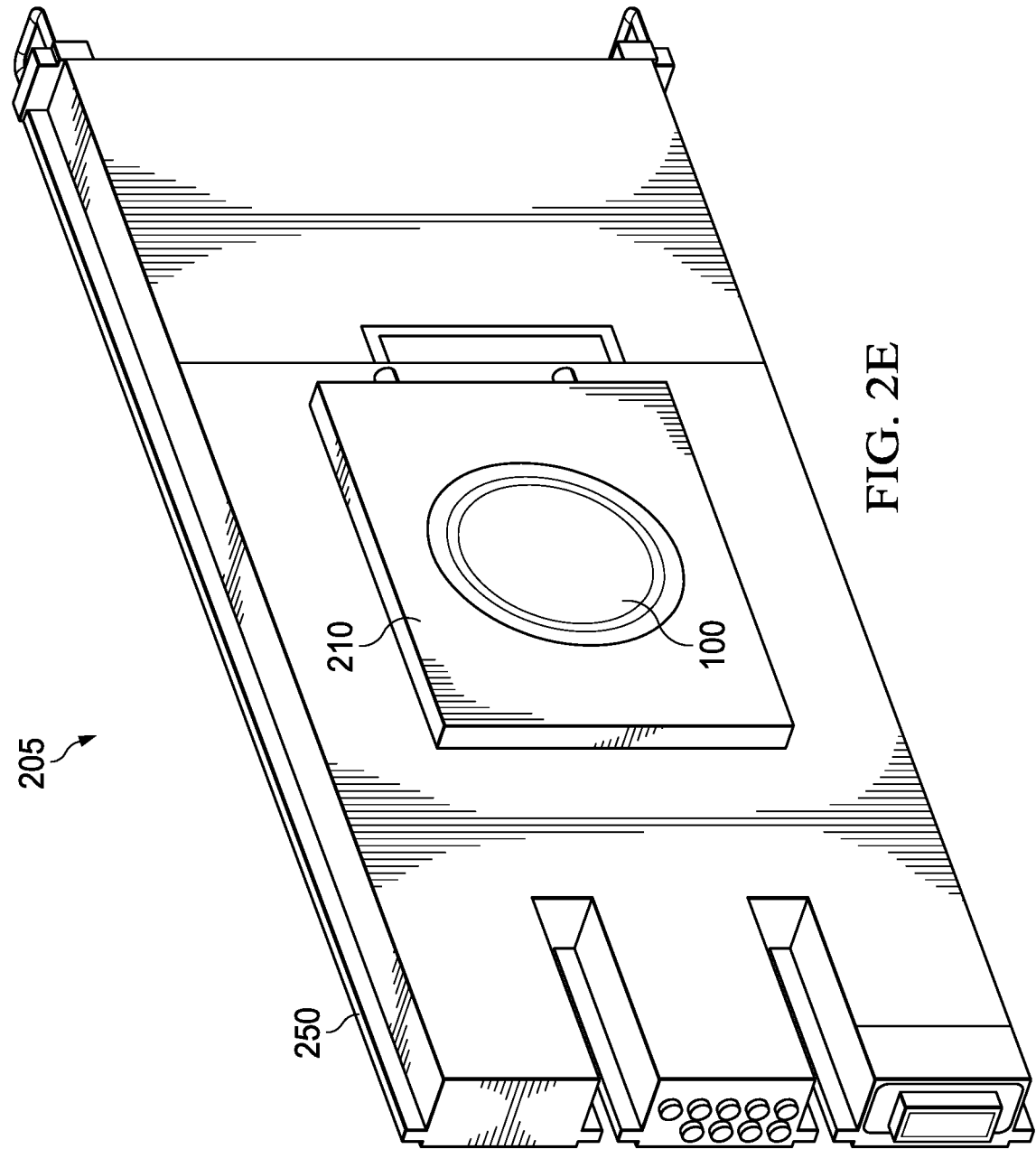
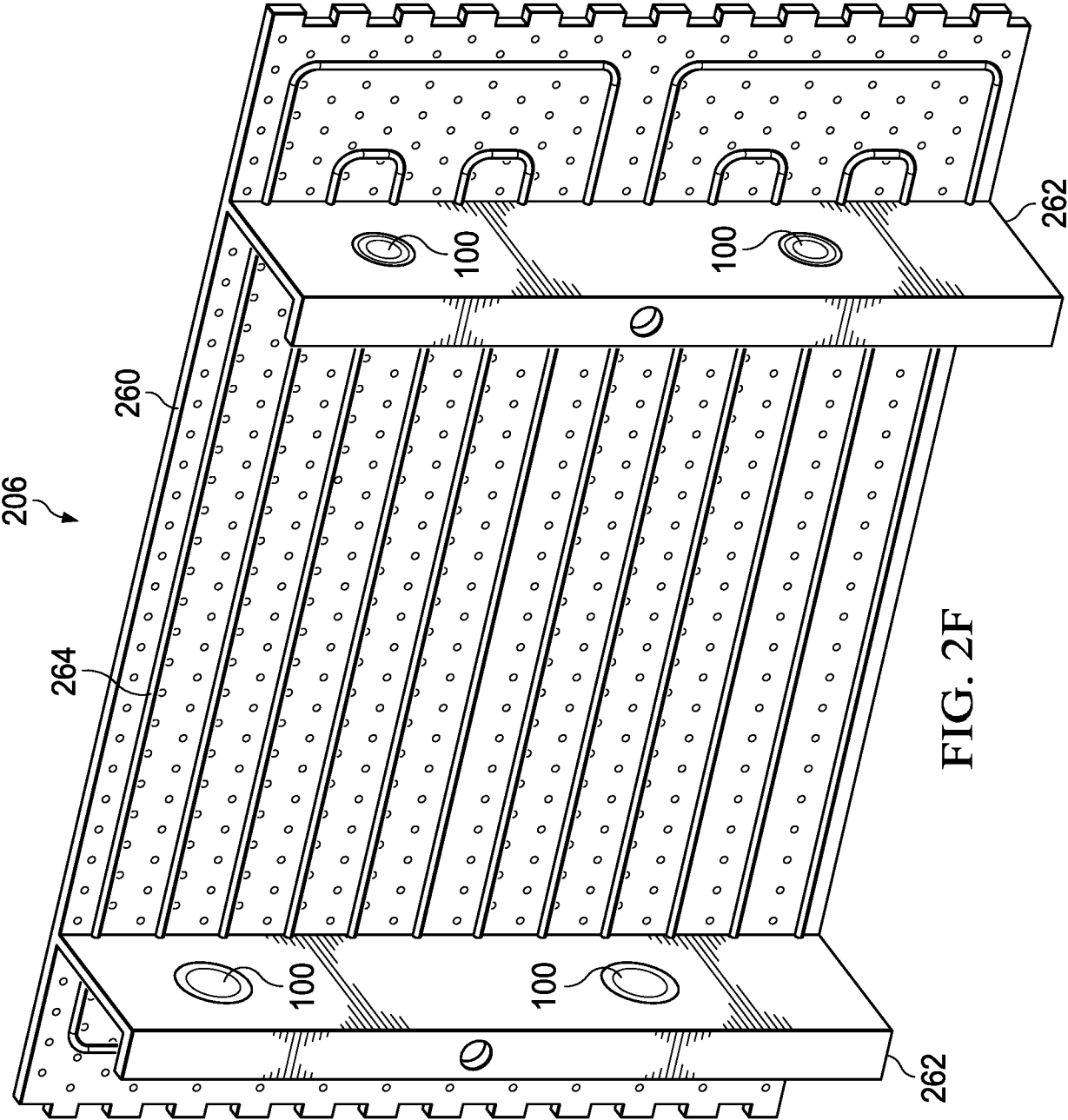
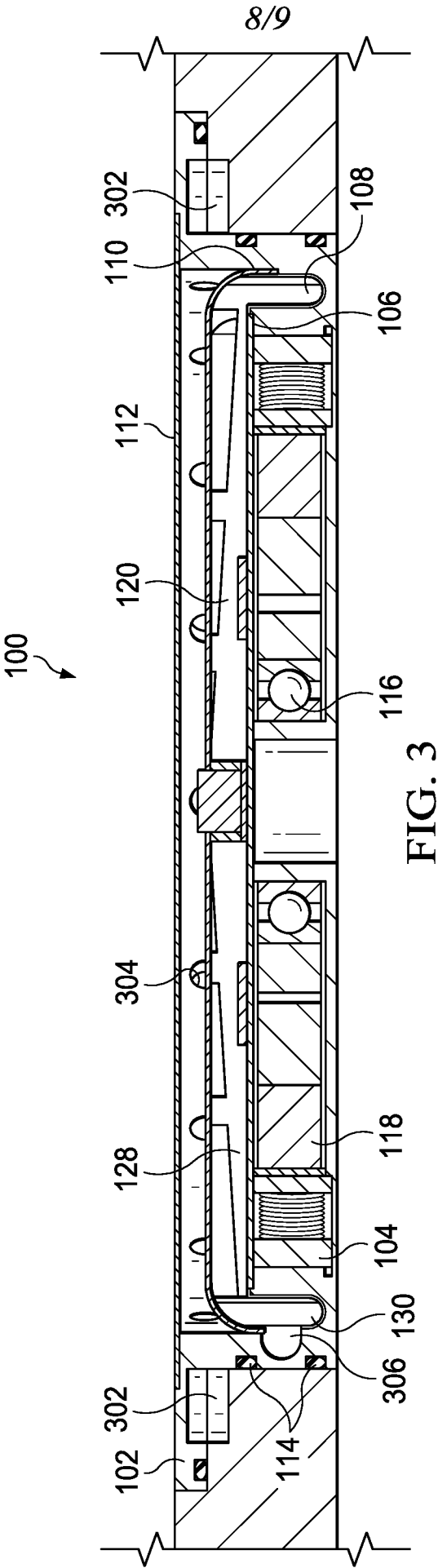


FIG. 2D







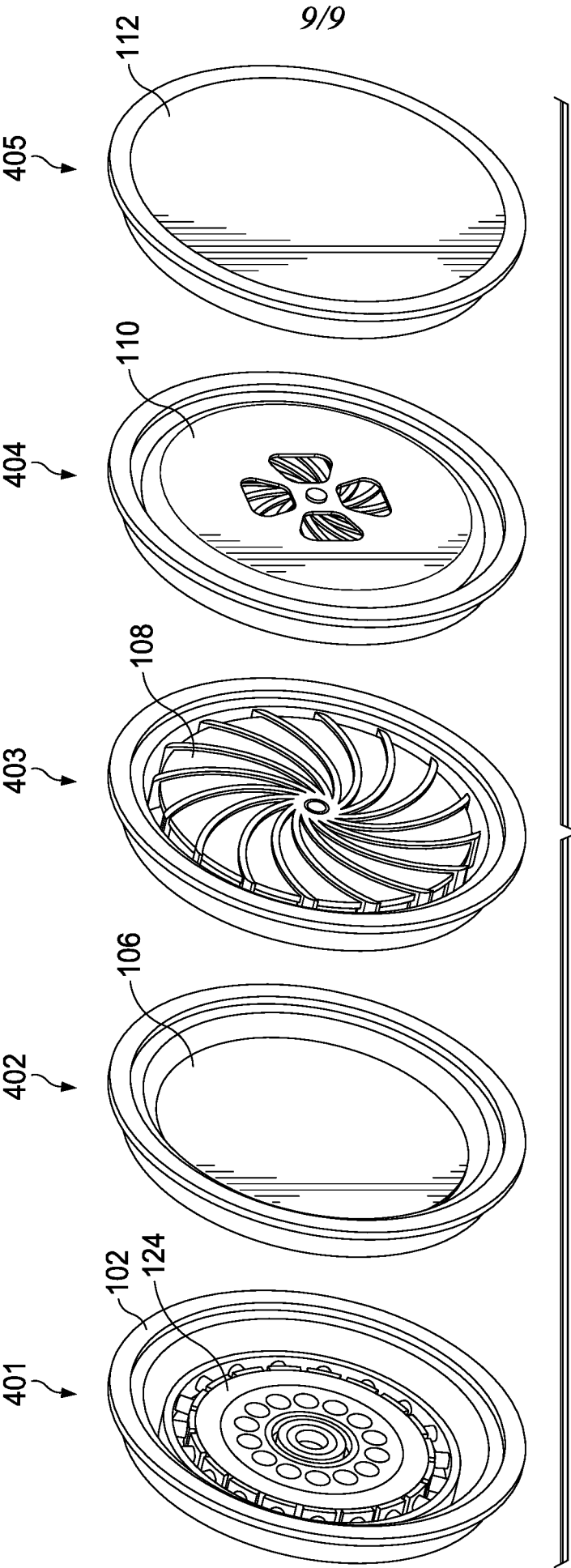


FIG. 4

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/012548

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br>INV. F04D13/06 F04D13/02 F04D29/60 F04D29/42<br>ADD.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                    |                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                    |                                                                      |
| <b>B. FIELDS SEARCHED</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                    |                                                                      |
| Minimum documentation searched (classification system followed by classification symbols)<br>F04D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                    |                                                                      |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                    |                                                                      |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>EPO-Internal, WPI Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                    |                                                                      |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                    |                                                                      |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No.                                                |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | US 2007/110592 A1 (LIU TAY-JIAN [TW] ET AL) 17 May 2007 (2007-05-17)               | 1-3,<br>6-12,<br>15-20                                               |
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| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                    |                                                                      |
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International application No

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