Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2753385 C 2015/10/06

(11)(21) **2 753 385**

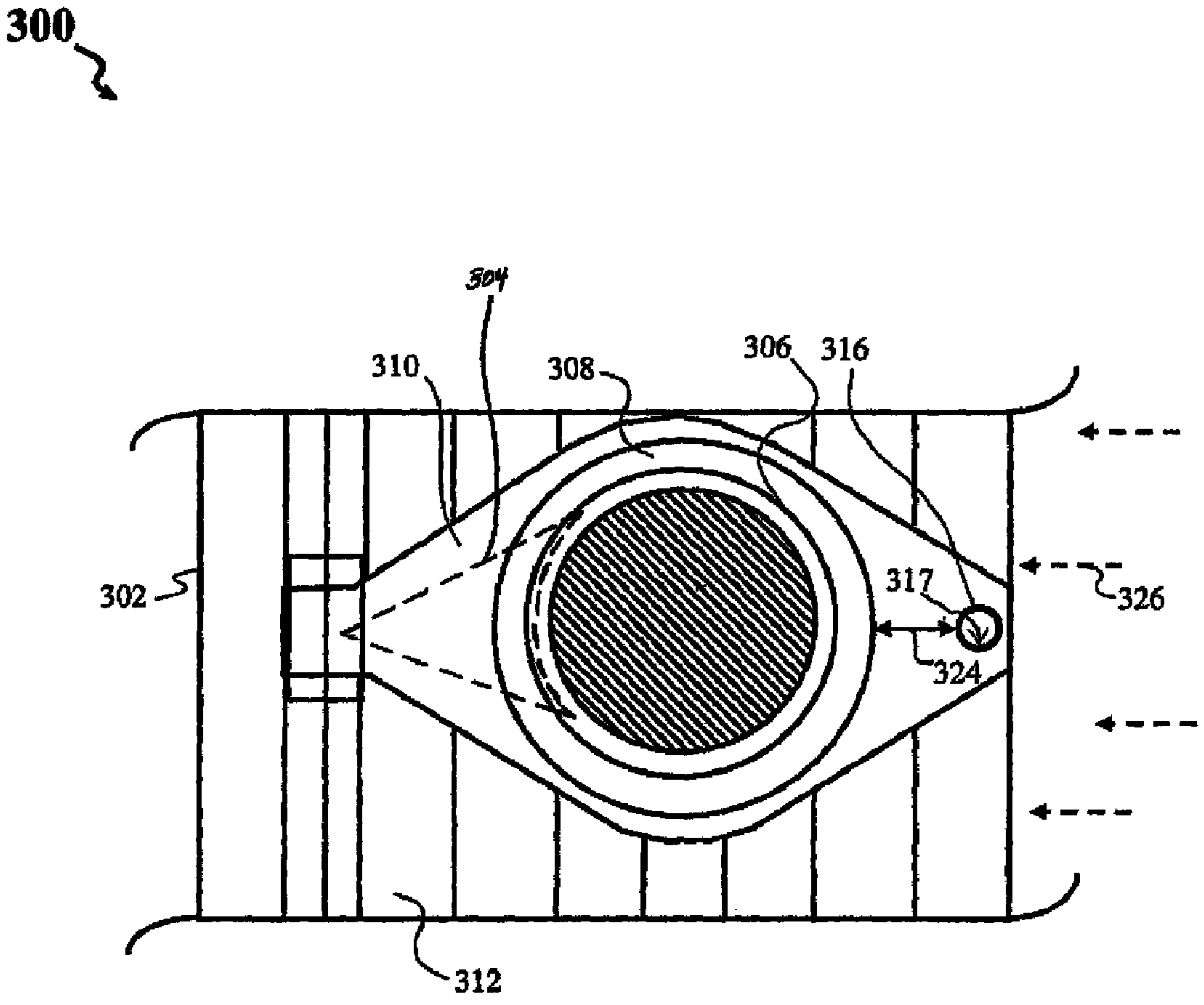
(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) **Date de dépôt PCT/PCT Filing Date:** 2010/02/23
(87) **Date publication PCT/PCT Publication Date:** 2010/08/26
(45) **Date de délivrance/Issue Date:** 2015/10/06
(85) **Entrée phase nationale/National Entry:** 2011/08/22
(86) **N° demande PCT/PCT Application No.:** US 2010/024995
(87) **N° publication PCT/PCT Publication No.:** 2010/096796
(30) **Priorité/Priority:** 2009/02/23 (US12/390,843)

(51) **Cl.Int./Int.Cl.** *F28F 1/10* (2006.01), *F28F 1/12* (2006.01), *F28F 1/32* (2006.01)
(72) **Inventeur/Inventor:**
HANCOCK, STEPHEN S., US
(73) **Propriétaire/Owner:**
TRANE INTERNATIONAL INC., US
(74) **Agent:** FETHERSTONHAUGH & CO.

(54) **Titre :** ECHANGEUR THERMIQUE
(54) **Title:** HEAT EXCHANGER



(57) **Abrégé/Abstract:**
A heat exchanger has a first fin having a hole, a collar attached to the first fin and associated with the hole, and a bluff body carried by the first fin. The bluff body is partially directly upstream of the collar. A heat exchanger has a fin having a hole, a collar attached to

(57) **Abrégé(suite)/Abstract(continued):**

the fin and associated with the hole, and a bluff body associated with the fin. A configuration of the bluff body is associated with a fin pitch separation distance of the heat exchanger. A method of increasing a heat exchange efficiency of a heat exchanger is provided that includes passing an air flow adjacent a surface of a fin, obstructing the air flow with a bluff body, reducing a thickness of a thermal boundary layer, and locating a reduced thickness portion of the thermal boundary layer adjacent to a collar associated with the fin.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
26 August 2010 (26.08.2010)

PCT

(10) **International Publication Number**
WO 2010/096796 A3

(51) **International Patent Classification**:
F28F 1/10 (2006.01) ***F28F 1/12*** (2006.01)
F28F 1/32 (2006.01)

(21) **International Application Number**:
PCT/US2010/024995

(22) **International Filing Date**:
23 February 2010 (23.02.2010)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
12/390,843 23 February 2009 (23.02.2009) US

(71) **Applicant** *(for all designated States except US)*: **TRANE INTERNATIONAL INC.** [US/US]; One Centennial Avenue, Piscataway, New Jersey 08855 (US).

(72) **Inventor; and**
(75) **Inventor/Applicant** *(for US only)*: **HANCOCK, Stephen S.** [US/US]; 17760 CR 134, Flint, Texas 75762 (US).

(74) **Agents**: **CONLEY ROSE, P.C.** et al.; 5601 Granite Parkway, Suite 750, Plano, Texas 75024 (US).

(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, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, 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, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (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, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

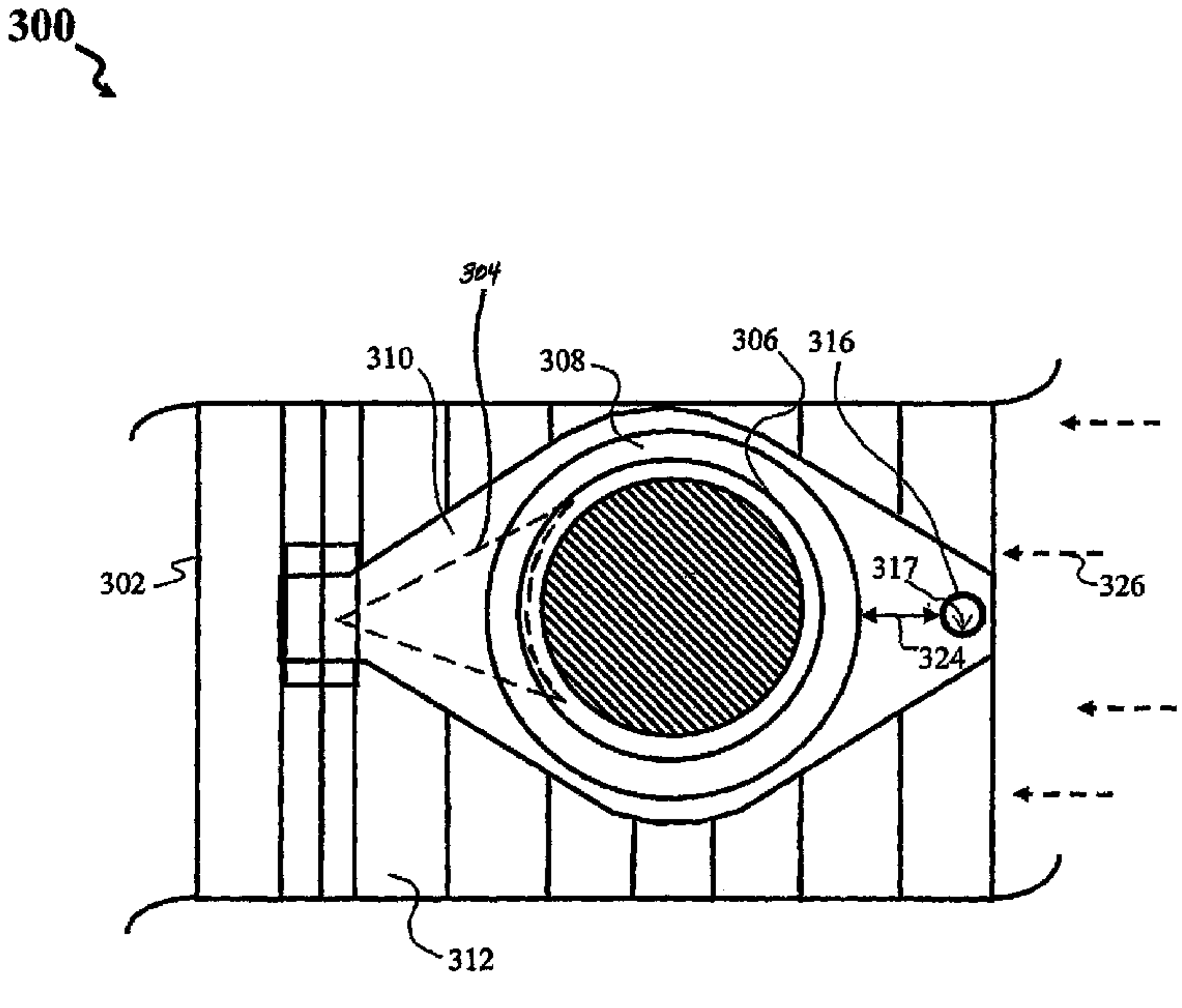
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

[Continued on next page]

(54) **Title**: HEAT EXCHANGER

Fig. 3



(57) **Abstract**: A heat exchanger has a first fin having a hole, a collar attached to the first fin and associated with the hole, and a bluff body carried by the first fin. The bluff body is partially directly upstream of the collar. A heat exchanger has a fin having a hole, a collar attached to the fin and associated with the hole, and a bluff body associated with the fin. A configuration of the bluff body is associated with a fin pitch separation distance of the heat exchanger. A method of increasing a heat exchange efficiency of a heat exchanger is provided that includes passing an air flow adjacent a surface of a fin, obstructing the air flow with a bluff body, reducing a thickness of a thermal boundary layer, and locating a reduced thickness portion of the thermal boundary layer adjacent to a collar associated with the fin.

WO 2010/096796 A3

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) Date of publication of the international search report:
4 November 2010

HEAT EXCHANGER

BACKGROUND

[0001] Heat exchangers are widely used in residential and commercial heating, ventilating, and air conditioning (HVAC) systems and applications. A plate fin heat exchanger or finned-tube heat exchanger generally comprises a plurality of thin metal plates or fins (hereinafter, referred to as “fins”). The fins have holes that accept tubes therethrough. In most plate fin heat exchangers, a large number of fins having multiple holes that are arranged to accept a generally serpentine arrangement of tubes that pass through the holes. The fins and tubes are connected so that heat conduction between the fins and tubes is possible. The fins typically have a large amount of surface area to interact with an incoming fluid flow. This fluid can be air, water, brine, refrigerant, or any other suitable heat transfer fluid hereafter referred to as “air”. The large amount of surface area promotes heat exchange between the fins and the incoming flow of air.

SUMMARY OF THE DISCLOSURE

[0002] In some embodiments, a heat exchanger is provided. The heat exchanger comprises a first fin having a hole, a collar attached to the first fin and associated with the hole, and a bluff body carried by the first fin wherein the bluff body is at least partially directly upstream of a portion of the collar.

[0003] In other embodiments, another heat exchanger is provided. The heat exchanger comprises a fin having a hole, a collar attached to the fin and associated with the hole, and a bluff body. The bluff body is associated with the fin and a configuration of the bluff body is associated with a fin pitch separation distance of the heat exchanger.

[0004] In still other embodiments, a method of increasing a heat exchange efficiency of a heat exchanger is provided. The method comprises passing an air flow adjacent a surface of a fin of the heat exchanger, at least partially obstructing the air flow with a bluff body associated with the fin, and reducing a thickness of a thermal boundary layer downstream of the bluff body.

[004a] In the above embodiments, the fin is a louvered fin and the bluff body is disposed (1) on a substantially flat non-louvered region of the fin that continuously surrounds the collar and is bordered by louvers of the fin on at least two opposing sides and a downstream side of the substantially flat non-louvered region and (2) between a louvered region of the fin located upstream relative to the bluff body and the collar, the space between the bluff body and the louvered region being free of collars; wherein the substantially flat non-louvered region is shaped differently from a shape of the hole; and wherein the louvers of the fin that border the substantially flat non-louvered region on the at least two opposing sides and the downstream side form a continuous louvered boundary around the substantially flat non-louvered region such that no substantially flat non-louvered portion of the fin other than the substantially flat non-louvered region is located between the louvers that border the substantially flat non-louvered region of the fin on the at least two opposing sides and the louvers that border the substantially flat non-louvered region of the fin on the downstream side.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] For a more complete understanding of this disclosure, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description, wherein like reference numerals represent like parts.

[0006] Figure 1 is an orthogonal top view of a portion of a plate fin heat exchanger;

[0007] Figure 2 is an oblique view of a portion of another plate fin heat exchanger;

[0008] Figure 3 is an orthogonal top view of a portion of still another plate fin heat exchanger;

[0009] Figure 4 is a an orthogonal side view of a thermal boundary layer caused by a bluff body of the plate fin heat exchanger of Figure 3;

[0010] Figure 5 is a flow chart illustrating a method for constructing a portion of a plate fin heat exchanger; and

[0011] Figure 6 is a flow chart illustrating a method of increasing a heat transfer efficiency of a heat exchanger.

DETAILED DESCRIPTION OF THE EMBODIMENT(S)

[0012] A heat exchange efficiency of a plate fin heat exchanger depends, among other things, on the structural features of the components of the plate fin heat exchanger and the orientation of those components with respect an incoming flow of air. Referring now to Figure 1, an orthogonal view of a section of a fin 102 of an existing plate fin heat exchanger 100 is shown. The fin 102 comprises a plurality of turbulence-inducing louvers 112 disposed on a surface of fin 102. An incoming flow of air 126 is indicated by dashed arrows. The dashed arrows point generally leftward in Figure 1, thereby indicating movement of the incoming flow of air 126 as being generally from right to left in Figure 1. The louvers 112 generally surround a non-louvered, generally flat, substantially oval-shaped base region 110. A substantially annular collar 108 is secured to the base region 110 and lies substantially coaxial with a hole formed in the fin 102. The collar 108 serves to increase the mechanical strength of the joinder between the fin and a tube 106 that passes through the hole and the collar 108. The collar 108 also serves to increase the heat conductivity between the tube 106 and the fin 102. The tube 106 is of the so-called “interactive” tube types and the tube 106 allows passage of fluids (i.e. refrigerants) through tube 106 and consequently generally perpendicularly through the thickness of the fin 102. The fin 102, tube 106, and collar 108 are each constructed of a suitable thermally-conductive material, such as, but not limited to, copper, aluminum, and the like.

[0013] When the plate fin heat exchanger 100 is used in a cooling mode of operation, the incoming flow of air 126 transfers heat to the fluid flowing through the tube 106. When the plate fin heat exchanger 100 is used in a heating mode of operation, heat is transferred from the fluid flowing through the tube 106 to the incoming flow of air 126. Of course, the above-described transferring of heat between the incoming flow of air 126 and the fluid flowing through the tube 106 is accomplished in part by transferring heat through the fin 102, collar 108, and/or tube 106 as intermediate heat conductors between the incoming flow of air 126 and the fluid flowing through the tube 106.

[0014] A thermal region 104 (experimentally identifiable by infrared imaging), the bounds of which are represented by a dashed line in Figure 1, delineates an area where a reduced amount of thermal mixing occurs due to the temperature difference between the incoming flow of air 126 and the components of the plate fin heat exchanger 100. The thermal region 104 is an area where little thermal mixing and heat exchange occurs between the incoming flow of air 126 and the components of the plate fin heat exchanger 100. Such thermal mixing and heat exchange is generally beneficial to the operation of the plate fin heat exchanger 100. However, the portion of the thermal mixing and heat exchange that occurs downstream of the tube 106 (to the left of the tube 106 in Figure 1) is not optimal since thermal mixing and heat exchange is preferred in areas having the highest flow agitation and temperature gradient, i.e. between the incoming flow of air 126 and the tube 106 (and generally near the upstream or right side portions of the tube 106 and the collar 108).

[0015] The present disclosure provides systems and methods for increasing the heat exchange efficiency of heat exchangers by causing thermal mixing and heat transfer near the interface between a fin, collar, and tube of the plate fin heat exchanger. The increase in heat exchange efficiency of heat exchangers is accomplished, at least in some embodiments, by providing bluff bodies on fins of heat exchangers. The bluff bodies, at least in some embodiments, are located substantially directly upstream of the tubes of heat exchangers.

[0016] Referring now to Figure 2, an oblique view of a portion of a plate fin heat exchanger 200 is shown. For clarity and ease of discussion, only two fins 202 of the plate fin heat exchanger 200 are shown and the fins 202 are arranged in a so-called “open stack” configuration. However, it should be understood that plate fin heat exchanger 200 comprises more than two fins 202. Further, it will be appreciated that the teachings disclosed herein are also applicable to any other type of heat exchanger that has a fin associated with a tube. Still further, alternative embodiments of plate fin heat exchangers and other types of heat exchangers may comprise any number of fins, even as few as one fin.

[0017] Referring now to Figure 2, plate fin heat exchanger 200 comprises fins 202. Each fin 202 comprises an annular collar 208 attached thereto in substantially the same manner collar 108 is attached to fin 102. Tubes 206, which are substantially similar to tube 106, are disposed through collars 208 and fins 202 in substantially the same manner tube 106 is disposed through collar 108 and fin 102. However, unlike plate fin heat exchanger 100, plate fin heat exchanger 200 comprises a plurality of bluff bodies 216.

[0018] The bluff bodies 216 are associated with the surfaces 204 of fins 202. A dominant aerodynamic drag characteristic of bluff bodies 216 is pressure drag (e.g., as opposed to frictional or viscous drag associated with a "streamlined" body). In this embodiment, bluff bodies 216 are located generally directly upstream of respective fin collars 208 so that associated bluff bodies 216 and collars 208 substantially lie along shared bisection lines 210. Bisection lines 210 (only two shown in Figure 2 for clarity) lie generally parallel with the direction of an incoming air flow 226. Of course, in other embodiments, bluff bodies may be generally upstream of the collars without lying on the bisection lines 210. For example, bluff bodies may alternatively be located upstream of the collars and/or tubes while still at least partially remaining within an upstream footprint of the associated collars and/or tubes generally defined by the width and/or diameter of the collars and/or tubes. When at least some of a bluff body is within an upstream footprint of the associated collars and/or tubes, the bluff body is referred to as being at least partially directly upstream of a portion of the collars and/or tubes.

[0019] In this embodiment, bluff bodies 216 are formed as indentations in fins 202 and protrude away from surfaces 204. The bluff bodies 216 are generally hemispherical in shape and may be referred to alternatively as "dimples" or "bumps". In alternative embodiments, a bluff body may comprise any other suitable shape and may be deposited onto surfaces such as surfaces 204 rather than being integral and formed from such surfaces. In either case, whether a bluff body is formed as a piece of a fin or whether a bluff body is attached to a fin, the bluff body is referred to as being carried by the fin. Bluff bodies 216 and other embodiments of bluff bodies may be formed by pressing, milling, machining, molding, or any other suitable manufacturing technique. As described in greater detail below, alternative embodiments of bluff bodies may be generally spherical, cylindrical, elliptical, rectangular, triangular, or any other suitable shape. It will be appreciated that in embodiments where the shape of the bluff body is not easily defined by a radius as is possible with hemispheres and cylinders, a substitute dimension may be selected for determining the size and location of the bluff body. For example, the substitute dimension may be selected as one-half the length of the bluff body, where the length is the maximum length of the bluff body as measured transverse to the incoming flow of air.

[0020] In this embodiment, a suitable radius 214 (only one shown in Figure 2 for clarity), for a hemispherical bluff body 216 is in a range of between about 0.5 to about 1.5 times a fin pitch 212 where the fin pitch 212 is defined as a distance between adjacent fins 202. For example, in an embodiment where a fin pitch has a value of about 1 inch, a radius may have a value of between about 1/2 inch to about 1 1/2 inches. In some embodiments, the radius of a bluff body may be about 1/20$^{\text{th}}$ to 3/20$^{\text{ths}}$ of an inch. Further, a suitable separation distance 224 between the bluff bodies 216 and the associated collars 208 is in a range of between about 1 to about 5 times the diameter of bluff body 216 (i.e. about 2 to about 10 times the radii 214 of bluff bodies 216). For example, in an embodiment where a fin pitch has a value of about 1 inch and a radius of the bluff body has a value of about 1 inch, the bluff body may be located between about 2 inches to about 10 inches upstream from the associated collar. In this embodiment, the separation distance is generally measured along bisection lines 210 between the collars 208 and the associated bluff bodies 216. In some embodiments, a bluff body may be located on a fin and separated from an associated collar and/or tube by a distance of about 0.1 to about 0.25 inches in an upstream direction. In some embodiments, the fin pitch may be a design parameter determined by the diameters of the tubes. In some embodiments, the diameter of tubes may be in a range of about 1/8 inch to about 1 inch. In an embodiment where the diameter of a tube is about 3/8 inch, the corresponding appropriate fin pitch may be in a range of about 0.05 inches to about 0.25 inches. It will be appreciated that the size and location of a bluff body 216 are parameters of the configuration of the bluff body 216. In some embodiments including the plate fin heat exchanger 200, the configuration of a bluff body (i.e. a dimension of the bluff body and the location of the bluff body relative to either the tube and/or the collar) is associated with and/or depends on the fin pitch of the heat exchanger.

[0021] Referring now to Figure 3, an orthogonal view of a section of a fin 302 of a plate fin heat exchanger 300 is shown. Plate fin heat exchanger 300 is substantially similar to plate fin heat exchanger 100, except that plate fin heat exchanger 300 comprises a bluff body 316 as described in more detail below. The fin 302 comprises a plurality of turbulence-inducing louvers 312 disposed on a surface of fin 302. However, it will be appreciated that alternative embodiments of heat exchangers may include no turbulence-inducing louvers. An incoming flow of air 326 is indicated by dashed arrows. The dashed arrows point generally leftward in Figure 3, thereby indicating movement of the incoming flow of air 326 as being generally from right to left in Figure 3. The louvers 312 generally surround a non-louvered, generally flat, substantially oval-shaped base region 310. A substantially annular collar 308 is secured to the base region 310 and lies substantially coaxial with a hole formed in the fin 302. The collar 308 serves to increase the mechanical strength of the joinder between the fin 302 and a tube 302 that passes through the hole and the collar 308. The collar 308 also serves to increase the heat conductivity between the tube 306 and the fin 308. The tube 306 is of the so-called "interactive" tube types and the tube 306 allows passage of fluids (i.e. refrigerants) through tube 306 and consequently generally perpendicularly through the thickness of the fin 306. The fin 306, tube 306, and collar 308 are each constructed of a suitable thermally-conductive material, such as, but not limited to, copper, aluminum, and the like.

[0022] When the plate fin heat exchanger 300 is used in a cooling mode of operation, the incoming flow of air 326 transfers heat to the fluid flowing through the tube 306. When the plate fin heat exchanger 300 is used in a heating mode of operation, heat is transferred from the fluid flowing through the tube 306 to the incoming flow of air 326. Of course, the above-described transferring of heat between the incoming flow of air 326 and the fluid flowing through the tube 306 is accomplished in part by transferring heat through the fin 302, collar 308, and/or tube 306 as intermediate heat conductors between the incoming flow of air 326 and the fluid flowing through the tube 306.

[0023] The plate fin heat exchanger 300 further comprises a bluff body 316 substantially similar to bluff body 216. The bluff body 316 lies generally directly upstream of collar 308 and protrudes up and away from surface 310. Bluff body 316 is a hemispherical bump with a radius 317. In some embodiments, the radius 317 may be in a range of about 1/20th to about 3/20ths of an inch. The bluff body 316 interferes with and agitates the flow of incoming air 326 diminishing a thermal region 304 that has been experimentally identified through the use of infrared imaging. The thermal region 304, the bounds of which are represented by a dashed line in Figure 3, delineates an area where a reduced amount of thermal mixing occurs due to the temperature difference between the incoming flow of air 326 and the components of the plate fin heat exchanger 300. The thermal region 304 is an area where little thermal mixing and heat exchange occurs between the incoming flow of air 326 and the components of the plate fin heat exchanger 300. Such thermal mixing and heat exchange is generally beneficial to the operation of the plate fin heat exchanger 300.

[0024] The incoming flow of air 326 flows over and around bluff body 316, improving thermal mixing primarily upstream of and around the outer surfaces of the tube 306 and the collar 308. By improving the thermal mixing in this manner and reducing the region of poor heat transfer represented by region 304 as opposed to the manner and location of region 104, a heat exchange efficiency of the plate fin heat exchanger 300 is improved.

[0025] In the embodiments comprising the bluff bodies 216 and 316, the bluff bodies 216 and 316 create a stream-wise vortex in the incoming flows of air 226 and 326 that facilitates the transfer of heat. In particular, for example, bluff body 316 generates two stream-wise vortices in the incoming flow of air 326. Alternatively, the two vortices may be considered two legs of a single vortex that wraps around the upstream-facing surface of bluff body 316. Due to the vortex shape, the vortex may be referred to as a "horseshoe vortex" or a "hairpin vortex". Figure 4 is an orthogonal side view of a thermal image of the effect the horseshoe vortex generated by bluff body 316 has on a thermal boundary layer, and the effect of this vortex on a thermal boundary layer 307 are depicted in Figure 4. Generally the thermal boundary layer 307 signifies an area over which a temperature gradient exists between the fin 302 and the incoming flow of air 326. Figure 4 shows that thermal boundary layer 307 is thickest upstream from the bluff body 316 at upstream portion 307a of the thermal boundary layer 307. Figure 4 further shows that the thermal boundary layer 307 is removed from the surface of fin 302 immediately downstream of bluff body 216 at offset portion 307b of the thermal boundary layer 307.

[0026] Still further, a thin reformation portion 307c forms adjacent the surface of fin 302 while some offset remnant portions 307d exist offset from fin 302 but disconnected from and downstream from offset portion 307b. Finally, it is shown that the thermal boundary layer 307 gradually increases in thickness between thin reformation portion 307c and the further downstream reduced thickness portion 307e. It will be appreciated that the bluff body 316 causes the thinning of the boundary layer 307 which indicates that heat transfer is accomplished more efficiently downstream of the bluff body 316 than upstream of the bluff body 316 at upstream portion 307a. By thinning the thermal boundary layer 307 in this manner and by causing the thinned thermal boundary layer 307 to exist substantially adjacent the collar 308 and the tube 306, the plate fin heat exchanger 300 exchanges heat more efficiently. Further, the vortex agitates the viscous boundary layer around the tube 306 thereby reducing a pressure drop that may occur near the tube 306. Empirical data indicates that, in some embodiments, the heat transfer efficiency of the fin 302 may be substantially higher by including the bluff body 316 as shown in Figures 3 and 4.

[0027] In some embodiments, a plate fin substantially similar to fin 302 may be used in heat exchangers for HVAC residential applications such as for example, heating and/or air conditioning systems in apartments, condominiums, dwellings, or houses. In other embodiments, a plate fin substantially similar to fin 302 may be used in heat exchangers for HVAC commercial applications such as, for example, HVAC systems in commercial, public or industrial buildings or facilities, or other types of buildings or facilities that distribute conditioned air. Also, in some embodiments, a plate fin substantially similar to fin 302 may be incorporated into various components and structures that might benefit from the use of a fin with a bluff body disposed thereon, such as for example, an evaporative coil of an outdoor air coil or a condenser coil in an air handling unit. In any event, it should be understood that the embodiments depicted in Figures 1-4 are described herein for illustrative purposes and are not intended to be limited to any particular heat exchanger, HVAC, or air handling application, type of dwelling, building or facility, or other structural or functional environment.

[0028] Figure 5 details the steps of a method 400 of constructing a HVAC heat exchanger in accordance with the principles disclosed herein. For example, method 400 may be used to construct one or more of the fins 202, 302.

[0029] At step 402, a plate fin is formed. For example, the plate fin may be structurally and functionally similar to that of the fins 202, 302. The fin may include a thin elongated plate constructed of a thermally conductive material such as copper or aluminum.

[0030] At step 404, a hole is formed through the fin. For example, the formed hole may be structurally and functionally similar to that of the opening provided by the holes associated with collars 108, 208, 308. The hole is sized to accommodate a tube such as 106, 206, 306 and might be formed by a mechanical punch or mill.

[0031] At step 406, a collar is assembled in association with the hole and the fin. For example, the collar may be structurally and functionally similar to the collar 108, 208, 308. In some embodiments, the collar may include a thermally conductive material and might be mounted over the associated hole, and fixed to the fin by welding or brazing. In other embodiments, the collar may be molded or pressed into the fin.

[0032] At step 408, a bluff body is formed adjacent to the collar on the fin. For example, the formed bluff body may be structurally and functionally similar to that of the bluff bodies 216, 316. The bluff body might be a hemi-spherical bump, or might include other shapes. In some embodiments, the bluff body may be formed by, for example pressing, stamping, milling, or molding the bluff body into the fin. In other embodiments, the bluff body might be disposed on the fin rather than formed from the fin. The size and location of the bluff body may be any of those locations and sized described above with respect to bluff bodies 216, 316. Note, it is to be understood that the steps 402, 404, 406, and 408 may be interchanged and may occur sequentially or in parallel. For example, the collar might be formed over the fin prior to forming the hole through at steps 406 and 404. Alternatively, the bluff body and the collar may be formed prior to forming the hole at steps 408, 406, and 404. This disposing the bluff body on radiative bodies, on a fin in this embodiment, at the above-described locations with above-described dimensions promotes enhanced heat transfer efficiency and greater thermal mixing.

[0033] Referring now to Figure 6, a method 500 of increasing a heat exchange efficiency of a heat exchanger is shown. The method 500 is accomplished, at block 502, by passing an incoming flow of air (such as incoming flow of air 126, 226, 326) over a surface of a fin such as fin 102, 202, 302. Next, at block 504, the incoming flow of air is at least partially obstructed by a bluff body (such as bluff body 216, 316) that is associated with the fin. Next at block 506, due to the obstruction caused by the bluff body, a thickness of a thermal boundary layer is reduced downstream of the bluff body. Finally at block 508, the thermal boundary layer is caused to be located adjacent a collar associated with the fin. It will be appreciated that the sizing and location of the bluff body on the fin contributes to the location of the reduced thickness boundary layer adjacent the collar. It will further be appreciated that in alternative embodiments where no collar is used, the reduced thickness boundary layer may be caused to be located adjacent a tube associated with the fin. In the manner described above, a heat exchange efficiency of a heat exchanger may be increased.

[0034] At least one embodiment is disclosed and variations, combinations, and/or modifications of the embodiment(s) and/or features of the embodiment(s) made by a person having ordinary skill in the art are within the scope of the disclosure. Alternative embodiments that result from combining, integrating, and/or omitting features of the embodiment(s) are also within the scope of the disclosure. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes, 2, 3, 4, etc.; greater than 0.10 includes 0.11, 0.12, 0.13, etc.). For example, whenever a numerical range with a lower limit, R_l, and an upper limit, R_u, is disclosed, any number falling within the range is specifically disclosed. In particular, the following numbers within the range are specifically disclosed: $R=R_l+k*(R_u-R_l)$, wherein k is a variable ranging from 1 percent to 100 percent with a 1 percent increment, i.e., k is 1 percent, 2 percent, 3 percent, 4 percent, 5 percent, ... 50 percent, 51 percent, 52 percent, ..., 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, or 100 percent. Moreover, any numerical range defined by two R numbers as defined in the above is also specifically disclosed. Use of the term "optionally" with respect to any element of a claim means that the element is required, or alternatively, the element is not required, both alternatives being within the scope of the claim. Use of broader terms such as comprises, includes, and having should be understood to provide support for narrower terms such as consisting of, consisting essentially of, and comprised substantially of. Accordingly, the scope of protection is not limited by the description set out above but is defined by the claims that follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated as further disclosure into the specification and the claims are embodiment(s) of the present invention. The discussion of a reference in the disclosure is not an admission that it is prior art, especially any reference that has a publication date after the priority date of this application.

CLAIMS

What is claimed is:

1. A heat exchanger, comprising:

a first fin having a hole;

a collar attached to the first fin and associated with the hole; and

a bluff body carried by the first fin wherein the bluff body is at least partially directly upstream of a portion of the collar;

wherein the first fin is a louvered fin and the bluff body is disposed (1) on a substantially flat non-louvered region of the first fin that continuously surrounds the collar and is bordered by louvers of the first fin on at least two opposing sides and a downstream side of the substantially flat non-louvered region and (2) between a louvered region of the first fin located upstream relative to the bluff body and the collar, the space between the bluff body and the louvered region being free of collars;

wherein the substantially flat non-louvered region is shaped differently from a shape of the hole; and

wherein the louvers of the first fin that border the substantially flat non-louvered region on the at least two opposing sides and the downstream side form a continuous louvered boundary around the substantially flat non-louvered region such that no substantially flat non-louvered portion of the first fin other than the substantially flat non-louvered region is located between the louvers that border the substantially flat non-louvered region of the first fin on the at least two opposing sides and the louvers that border the substantially flat non-louvered region of the first fin on the downstream side.

2. The heat exchanger according to claim 1, further comprising:

a second fin separated from the first fin by a fin pitch separation distance and wherein the bluff body comprises a radius having a value between about 0.5 to about 1.5 times the fin pitch separation distance.

3. The heat exchanger according to claim 1, further comprising:

a second fin separated from the first fin by a fin pitch separation distance wherein the bluff body has a maximum length measured substantially transverse to an incoming flow of air and wherein about one-half the maximum length is a value between about 0.5 to about 1.5 times the fin pitch separation distance.

4. The heat exchanger according to claim 1, wherein the bluff body is hemispherical in shape.

5. The heat exchanger according to claim 4, wherein the bluff body is formed as an indentation of the first fin.

6. The heat exchanger according to claim 4, wherein the bluff body is secured to the first fin.

7. The heat exchanger according to claim 1, further comprising:

a second fin separated from the first fin by a fin pitch separation distance wherein the bluff body is located on the first fin and offset from the collar in an upstream direction by a distance of about one to about five times a diameter of the bluff body.

8. The heat exchanger according to claim 1, further comprising:

a second fin separated from the first fin by a fin pitch separation distance wherein the bluff body is located on the first fin and offset from the collar in an upstream direction by a distance of about one to about five times a maximum length of the bluff body wherein the maximum length is measured substantially transverse to an incoming flow of air.

9. A heat exchanger, comprising:

a fin having a hole;

a collar attached to the fin and associated with the hole; and

a bluff body associated with the fin wherein a configuration of the bluff body is associated with a fin pitch separation distance of the heat exchanger;

wherein the fin is a louvered fin and the bluff body is disposed (1) on a substantially flat non-louvered region of the fin that continuously surrounds the collar and is surrounded by louvers of the fin on at least two opposing sides and a downstream side of the substantially flat non-louvered region and (2) between a louvered region of the fin located upstream relative to the bluff body and the collar, the space between the bluff body and the louvered region being free of collars;

wherein the substantially flat non-louvered region is shaped differently from a shape of the hole; and

wherein the louvers of the fin that border the substantially flat non-louvered region on the at least two opposing sides and the downstream side form a continuous louvered boundary around the substantially flat non-louvered region such that no substantially flat non-louvered portion of the fin other than the substantially flat non-louvered region is located between the louvers that border the substantially flat non-louvered region of the fin on the at least two opposing sides and the louvers that border the substantially flat non-louvered region of the fin on the downstream side.

10. The heat exchanger according to claim 9, wherein the bluff body comprises a radius having a value between about 0.5 to about 1.5 times the fin pitch separation distance.

11. The heat exchanger according to claim 9, wherein the bluff body has a maximum length measured substantially transverse to an incoming flow of air and wherein about one-half the maximum length is a value between about 0.5 to about 1.5 times the fin pitch separation distance.

12. The heat exchanger according to claim 9, wherein the bluff body is formed as an indentation of the fin.

13. The heat exchanger according to claim 9, wherein the bluff body is located on the fin and offset from the collar in an upstream direction by a distance of about one to about five times a diameter of the bluff body.

14. The heat exchanger according to claim 9, wherein the bluff body is located on the fin and offset from the collar in an upstream direction by a distance of about one to about five times a maximum length of the bluff body wherein the maximum length is measured substantially transverse to an incoming flow of air.

15. A method of increasing a heat exchange efficiency of a heat exchanger, comprising:

passing an air flow adjacent a surface of a fin of the heat exchanger;

at least partially obstructing the air flow with a bluff body associated with the fin; and

reducing a thickness of a thermal boundary layer downstream of the bluff body;

wherein the fin is a louvered fin and the bluff body is disposed (1) on a substantially flat non-louvered region of the fin that continuously surrounds the collar and is surrounded by louvers of the fin on at least two opposing sides and a downstream side of the substantially flat non-louvered region and (2) between a louvered region of the fin located upstream relative to the bluff body and the collar, the space between the bluff body and the louvered region being free of collars;

wherein the substantially flat non-louvered region is shaped differently from a shape of the hole; and

wherein the louvers of the first fin that border the substantially flat non-louvered region on the at least two opposing sides and the downstream side form a continuous louvered boundary around the substantially flat non-louvered region such that no substantially flat non-louvered portion of the fin other than the substantially flat non-louvered region is located between the louvers that border the substantially flat non-louvered region of the fin on the at least two opposing sides and the louvers that border the substantially flat non-louvered region of the fin on the downstream side.

16. The method of claim 15, wherein the reducing the thickness of the thermal boundary layer adjacent the collar comprises providing the bluff body with a dimension that is about 0.5 to about 1.5 times a fin pitch of the heat exchanger.

17. The method of claim 16, wherein the dimension is a radius of the bluff body.

18. The method of claim 15, wherein the reducing the thickness of the thermal boundary layer adjacent the collar comprises locating the bluff body upstream from the collar by about one to about five times a dimension of the bluff body.

19. The method of claim 18, wherein the dimension is a diameter of the bluff body.

20. The method of claim 17, wherein the bluff body is hemispherical in shape and has a radius of about 0.5 to about 1.5 times a fin pitch of the heat exchanger and wherein the bluff body is located about 1 to about 5 times a diameter of the bluff body upstream from the collar.

Fig. 1

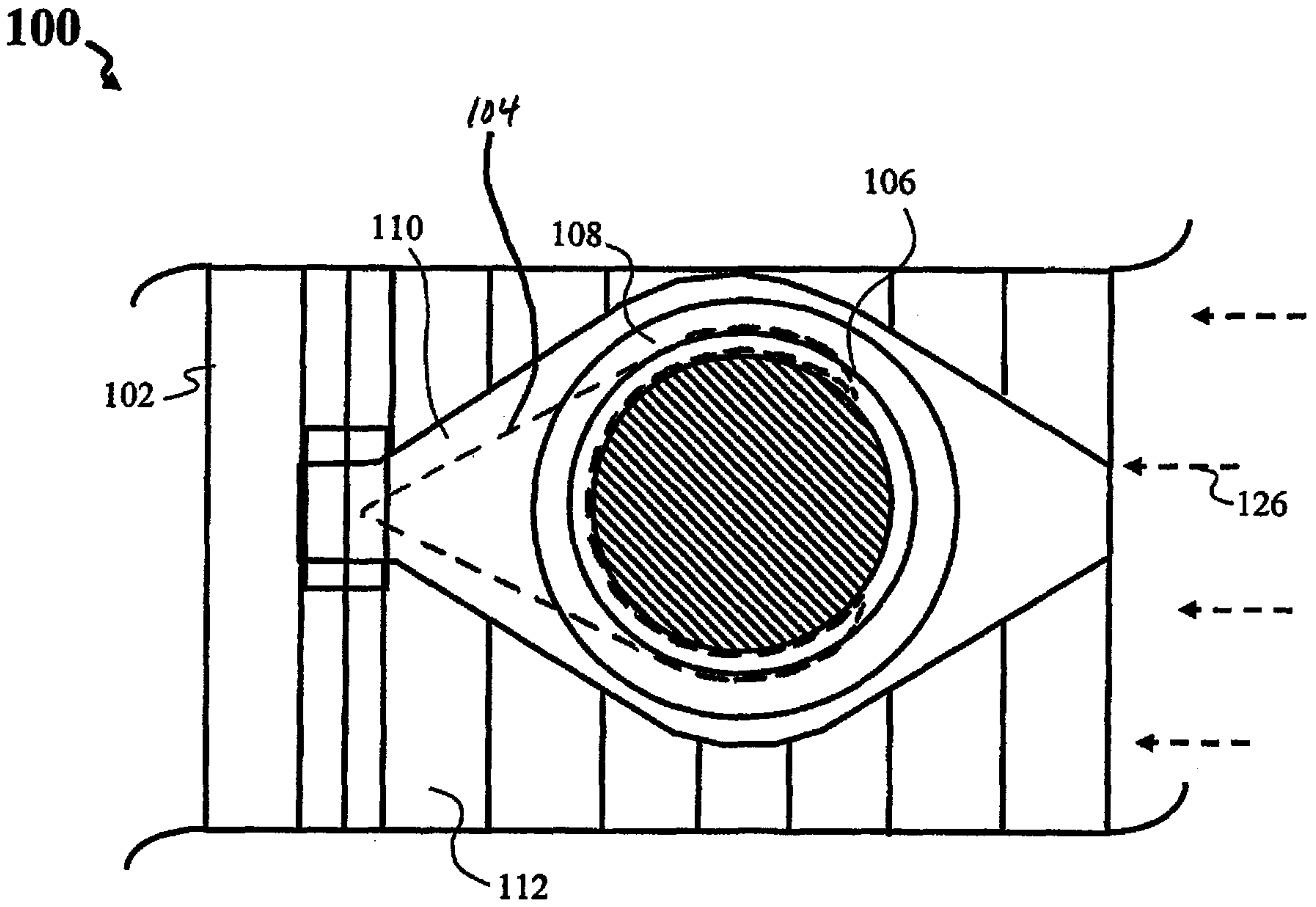


Fig. 2

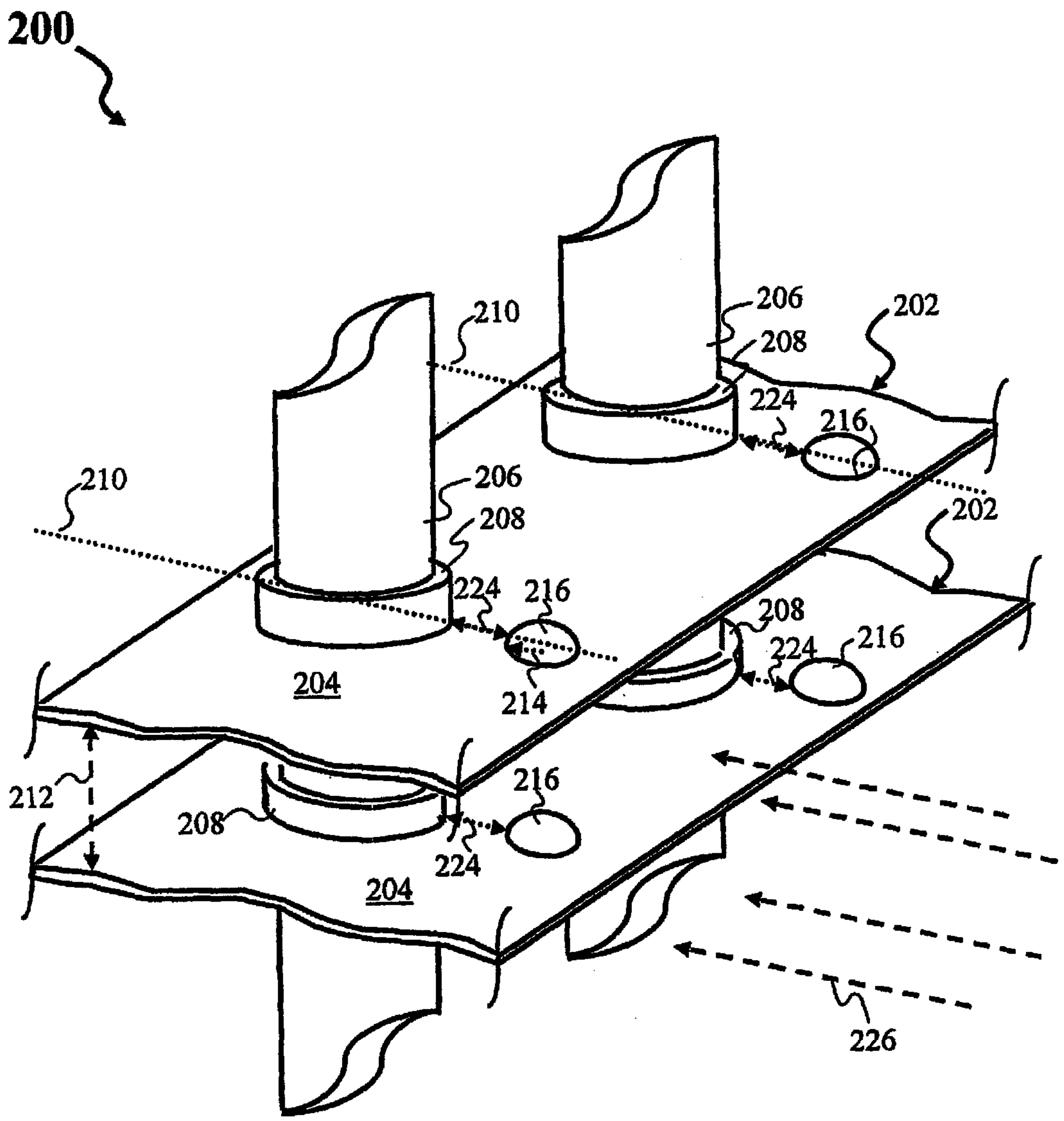

200
210
206
208
202
224
216
210
206
208
202
224
216
208
224
216
204
214
212
216
208
224
204
226

Fig. 3

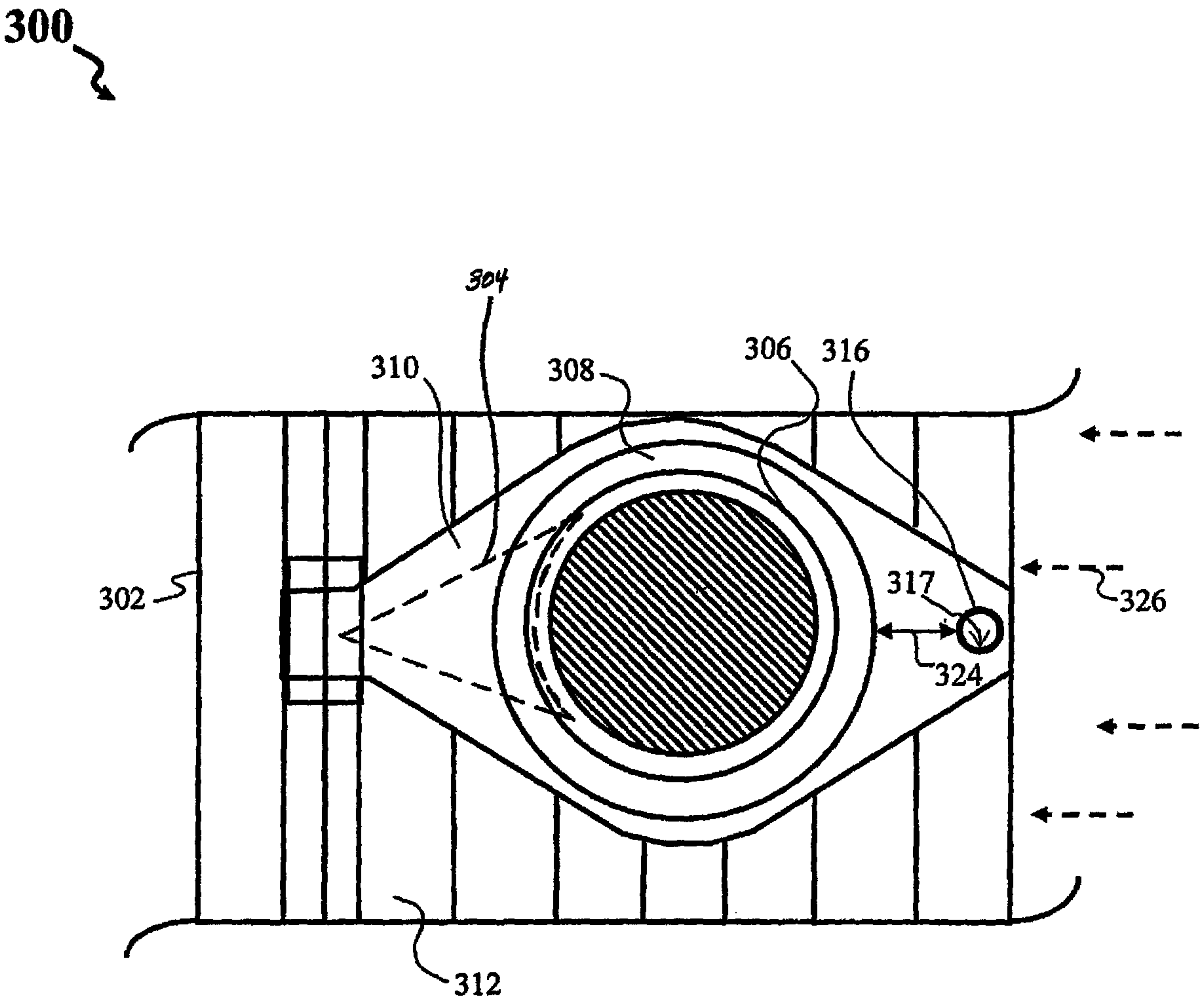


Fig. 4

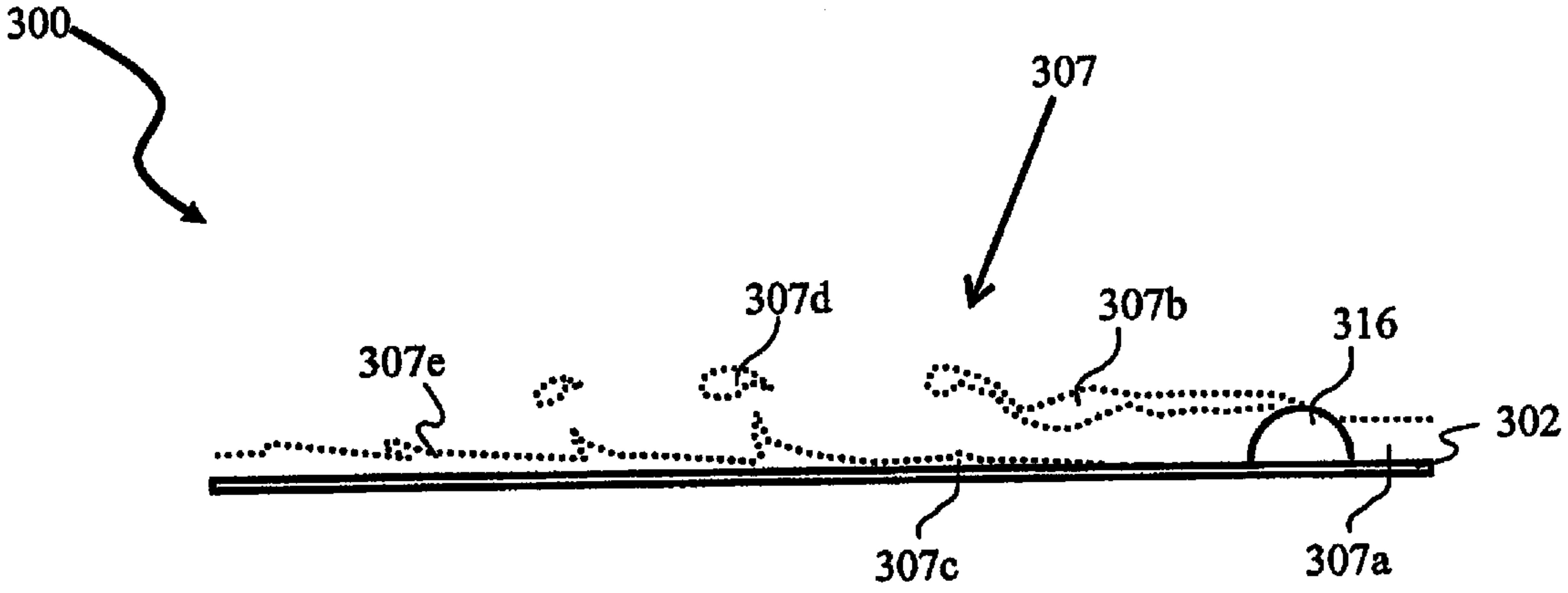


Fig. 5

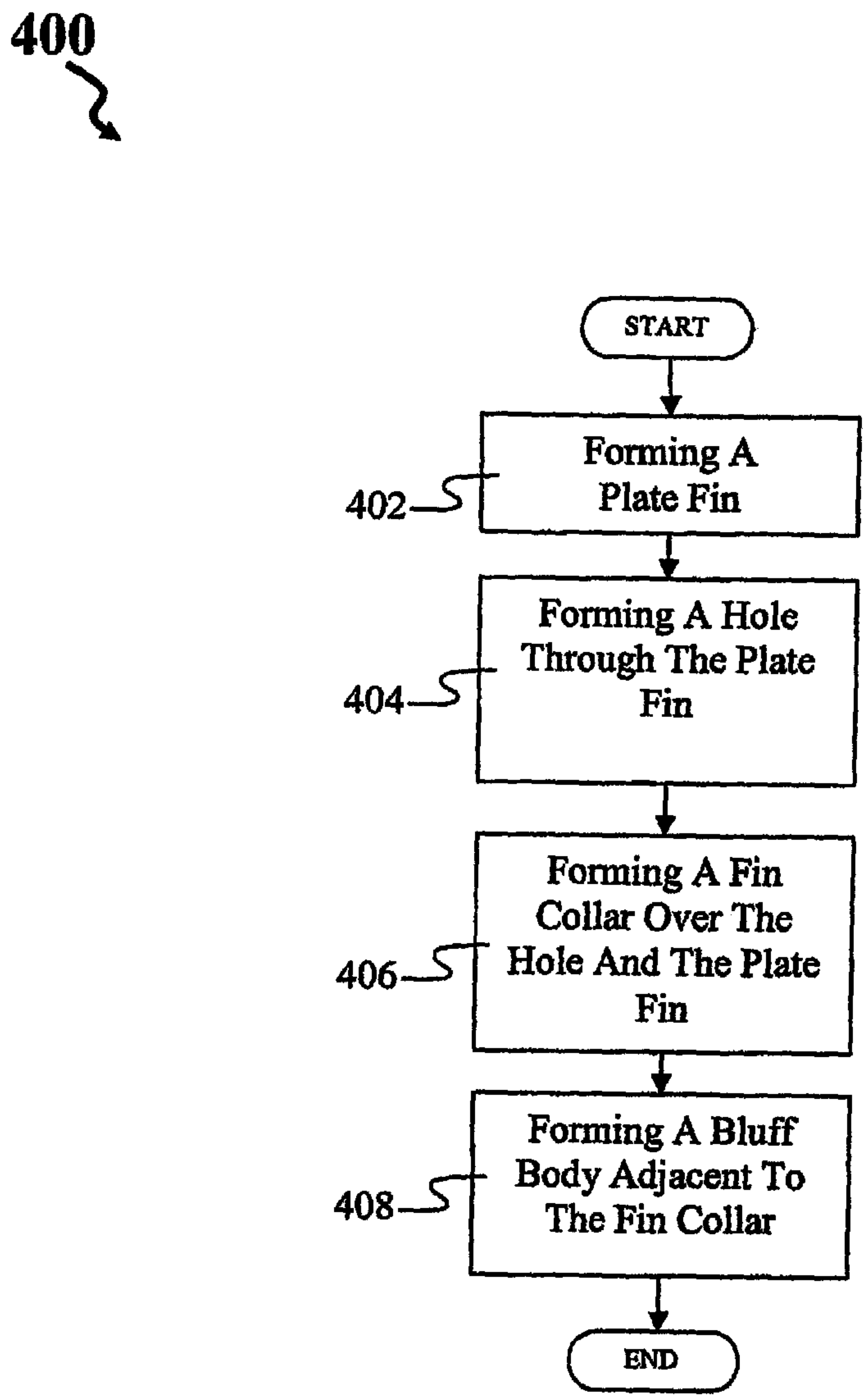
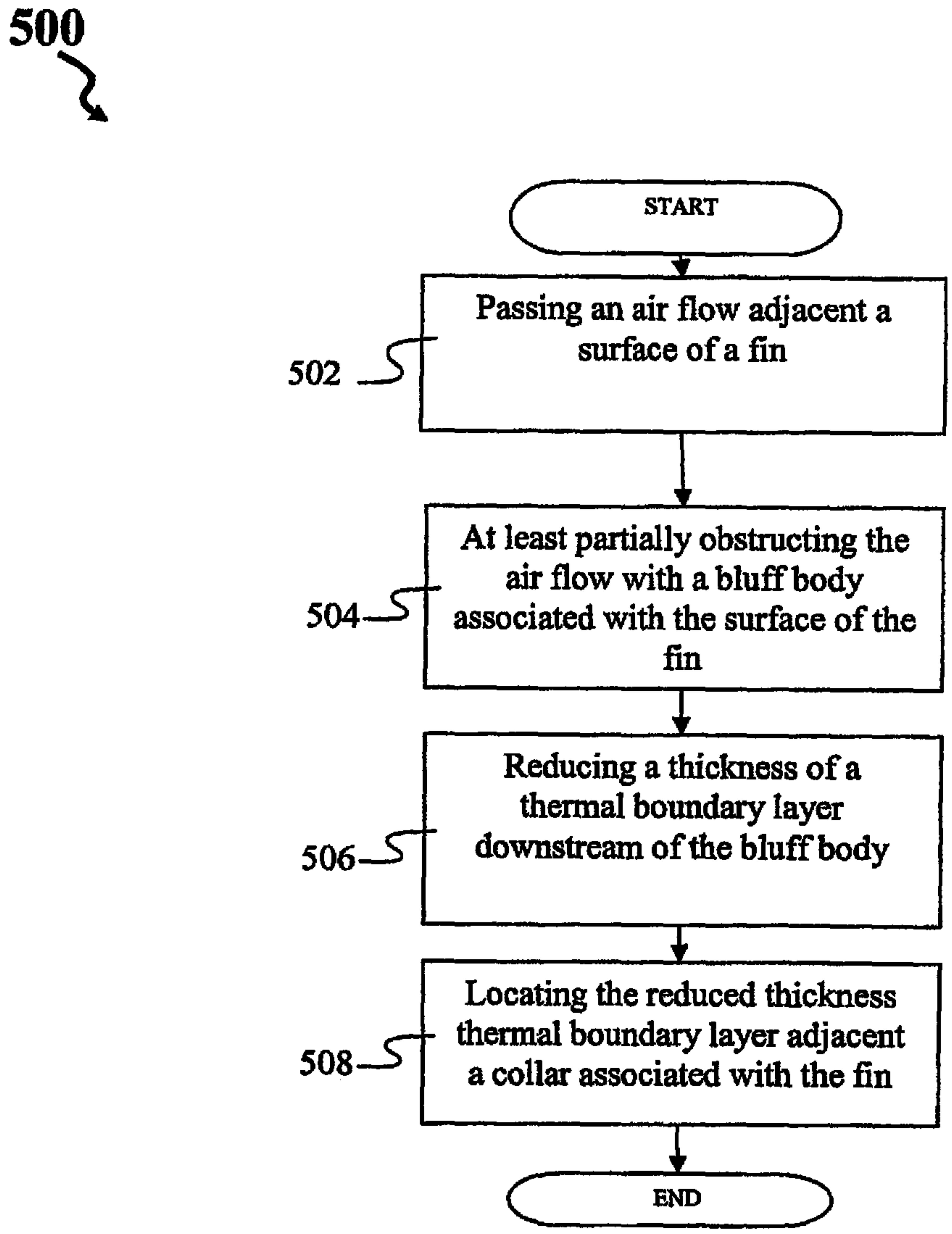
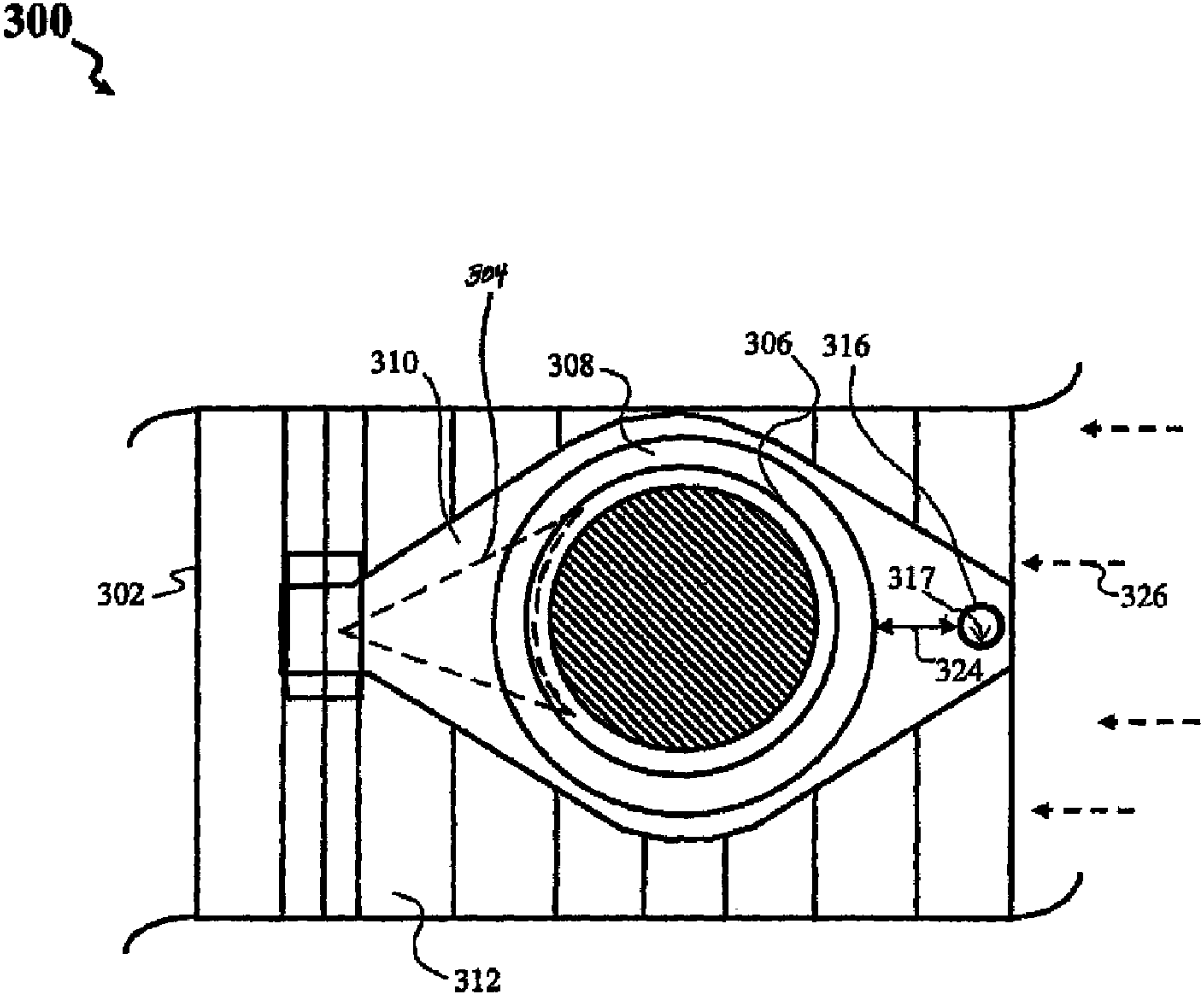

400
START
402
Forming A Plate Fin
404
Forming A Hole Through The Plate Fin
406
Forming A Fin Collar Over The Hole And The Plate Fin
408
Forming A Bluff Body Adjacent To The Fin Collar
END

Fig. 6


500
START
Passing an air flow adjacent a surface of a fin
502
At least partially obstructing the air flow with a bluff body associated with the surface of the fin
504
Reducing a thickness of a thermal boundary layer downstream of the bluff body
506
Locating the reduced thickness thermal boundary layer adjacent a collar associated with the fin
508
END


300
304
310
308
306
316
302
317
326
324
312