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(54) **THERMAL CONTROL FOR PROCESSOR-BASED DEVICES**

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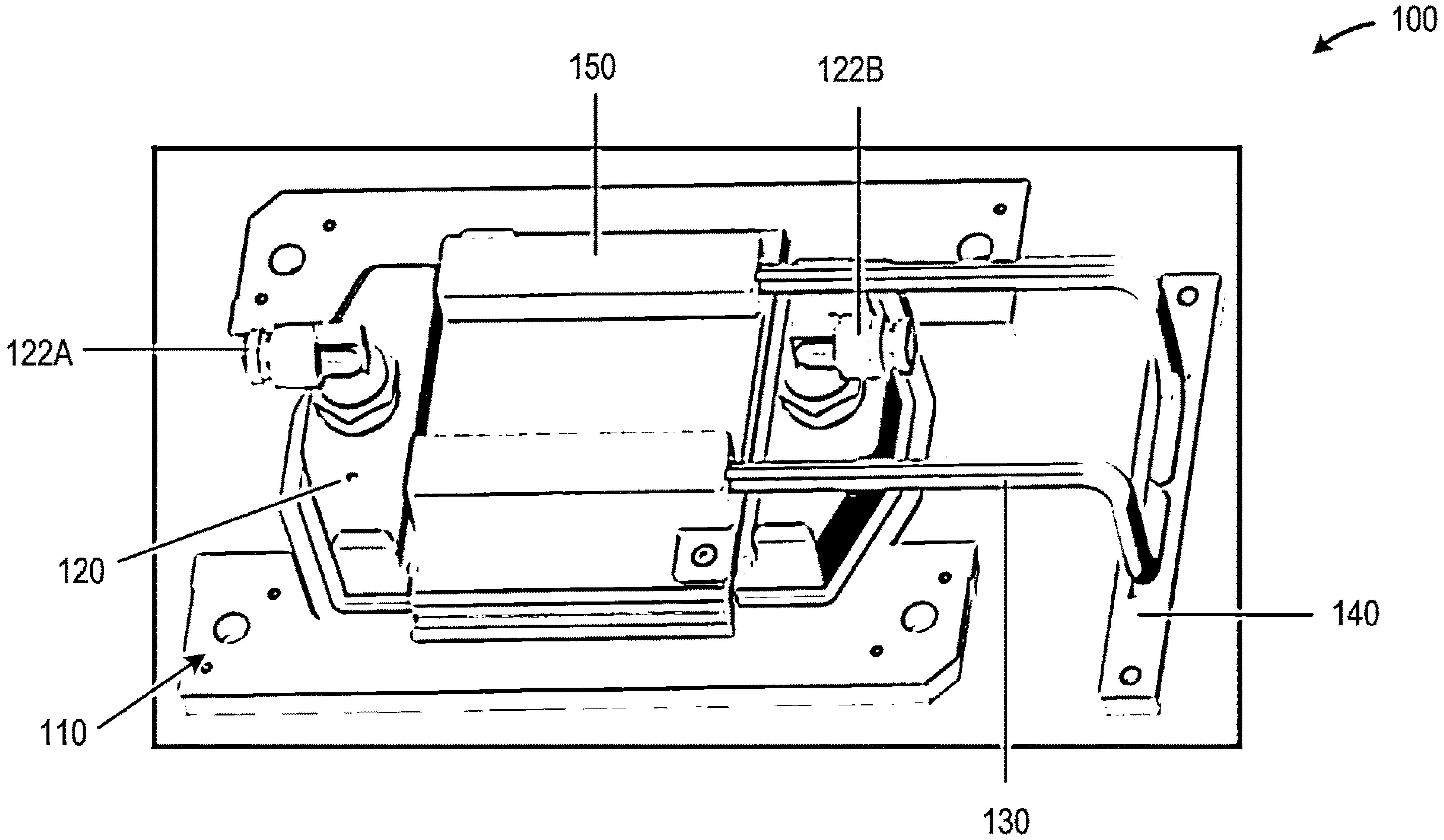
CPC ***H05K 7/20154*** (2013.01); ***H05K 7/209*** (2013.01); ***H05K 7/20927*** (2013.01); ***H05K 7/20209*** (2013.01)

(57) **ABSTRACT**

The present disclosure is directed to systems and methods of improving the thermal performance of processor-based devices. Such thermal performance improvement may include limiting the degree of tilt experienced by a semiconductor device as a thermal solution coupled to the semiconductor device is tightened to the substrate. Such thermal performance improvements may include increasing the available heat transfer area associated with a particular heat producing semiconductor device. Such thermal performance improvements may include thermally coupling one or more cool blocks thermally coupled to one or more remote heat-producing devices to a central cool block that may be cooled using a cooling medium or coupled to a central heat-producing semiconductor device.



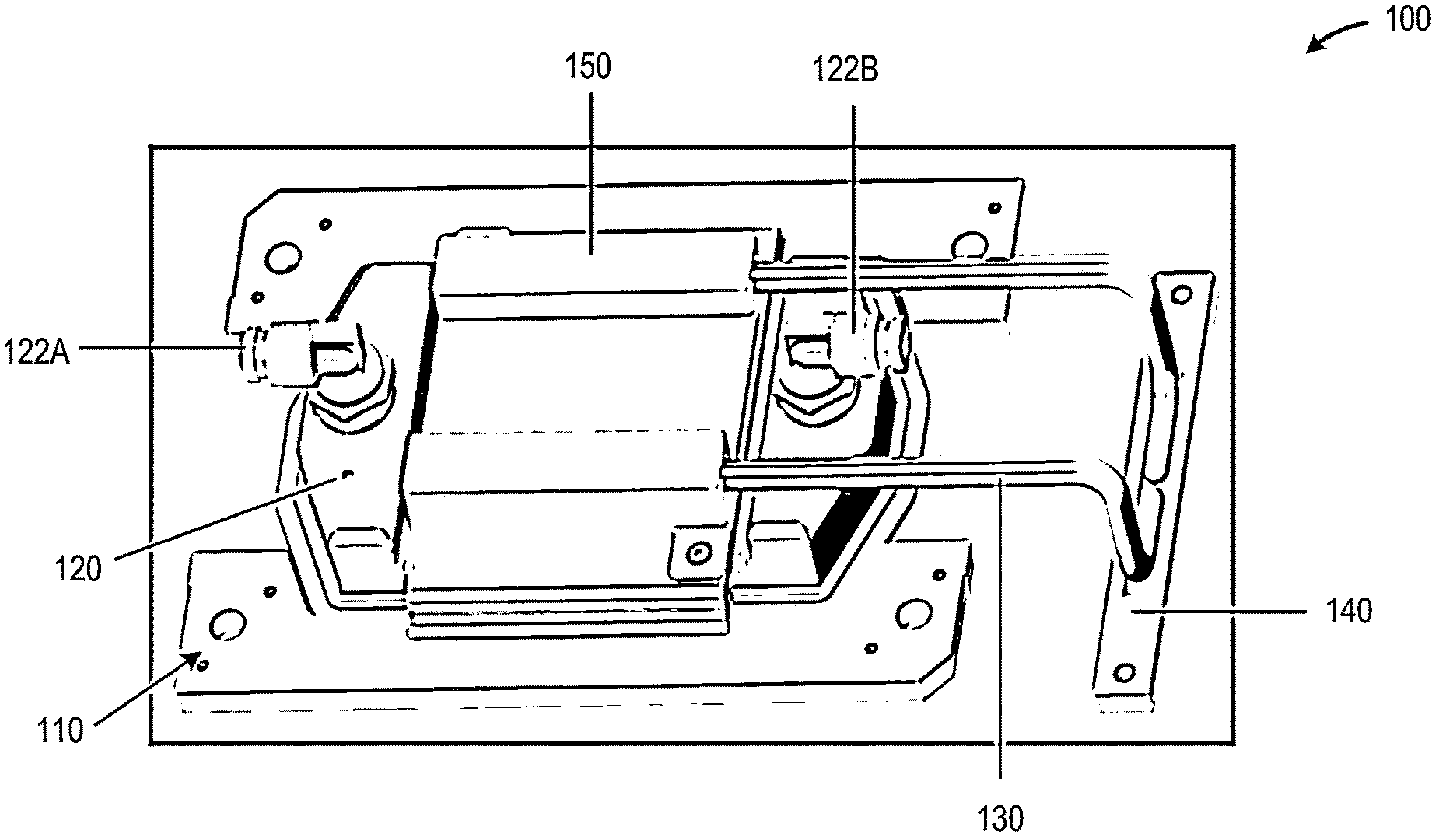

100
150
122B
122A
120
110
140
130

FIG. 1A

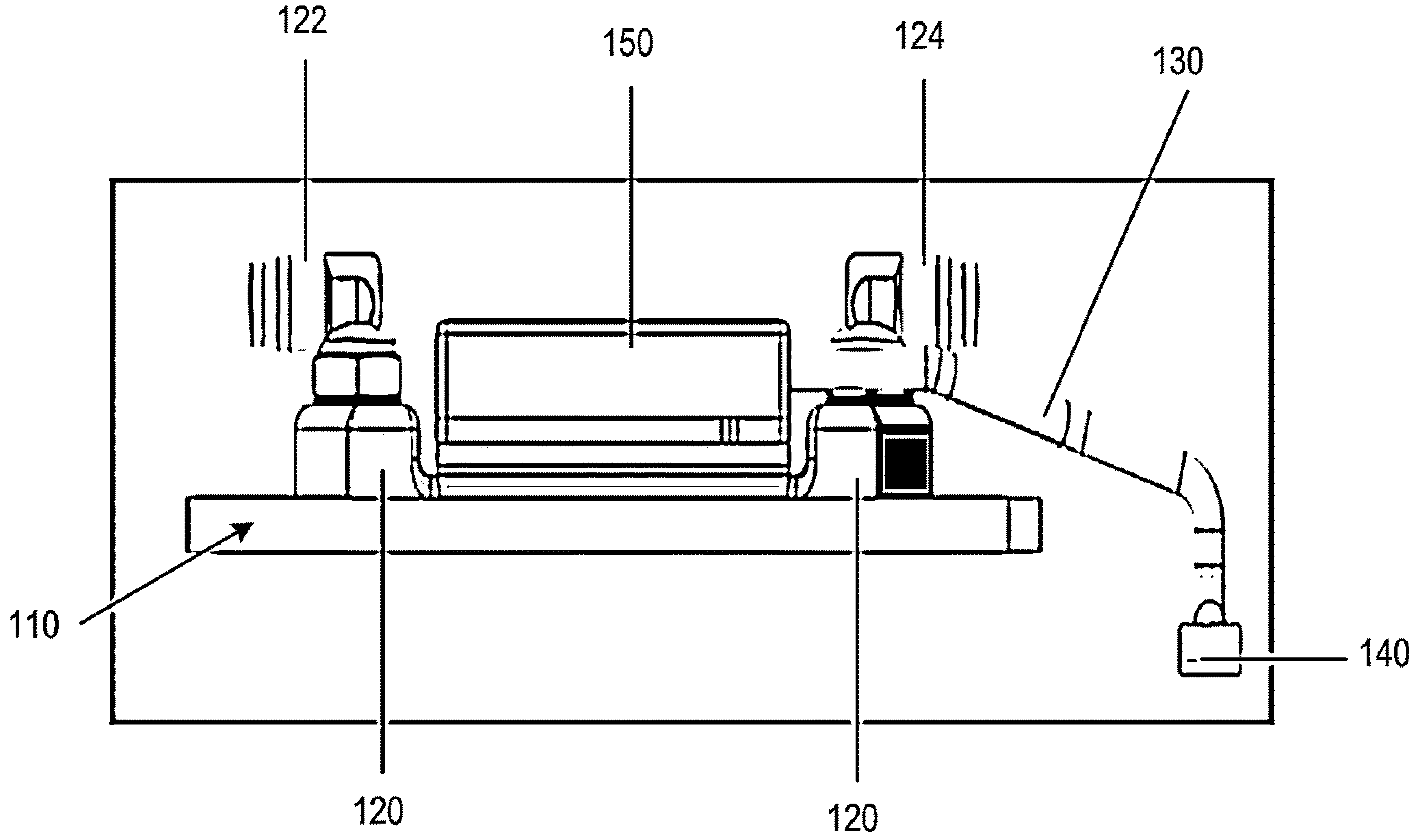

122
150
124
130
110
140
120
120

FIG. 1B

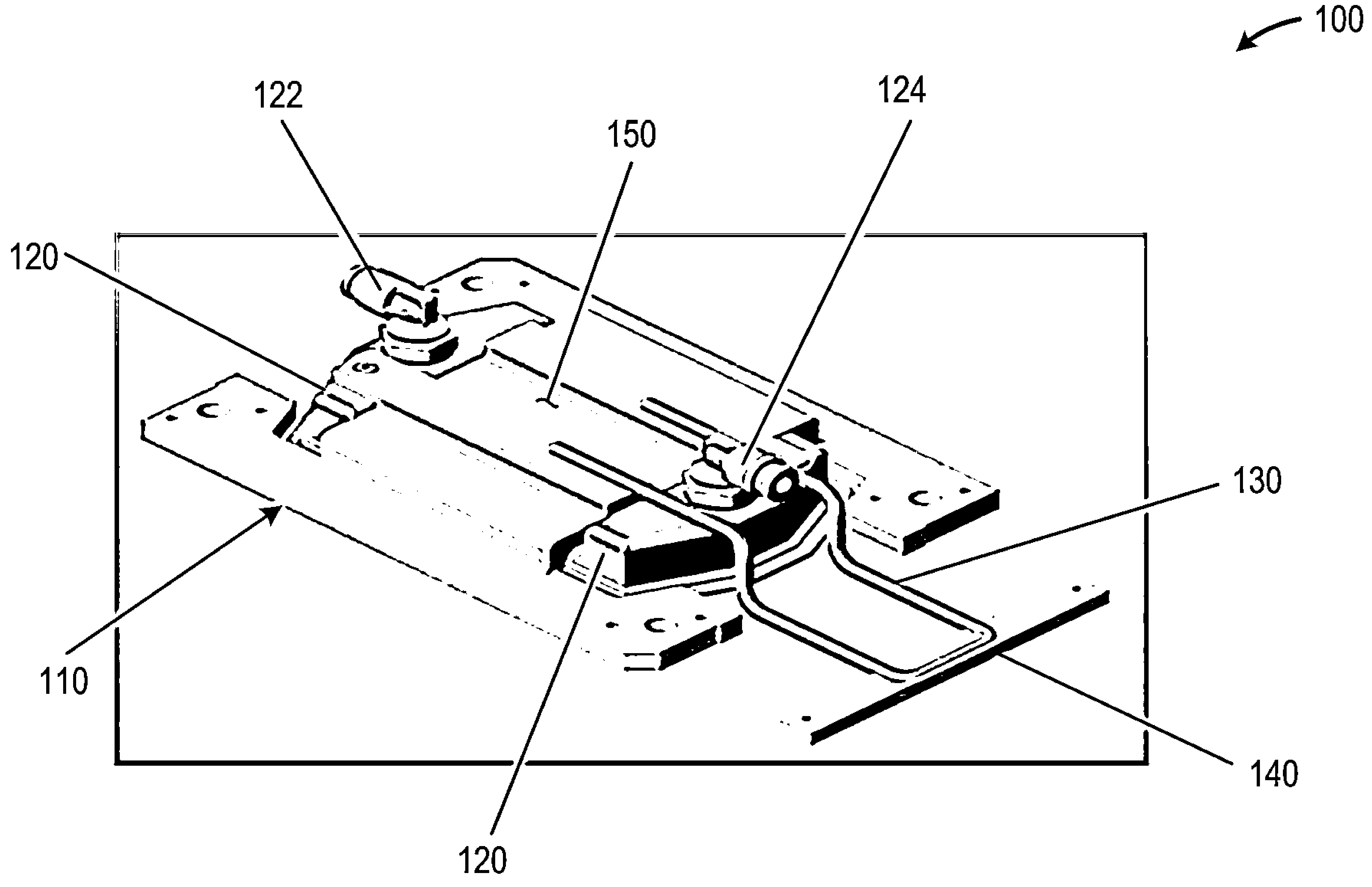


FIG. 1C

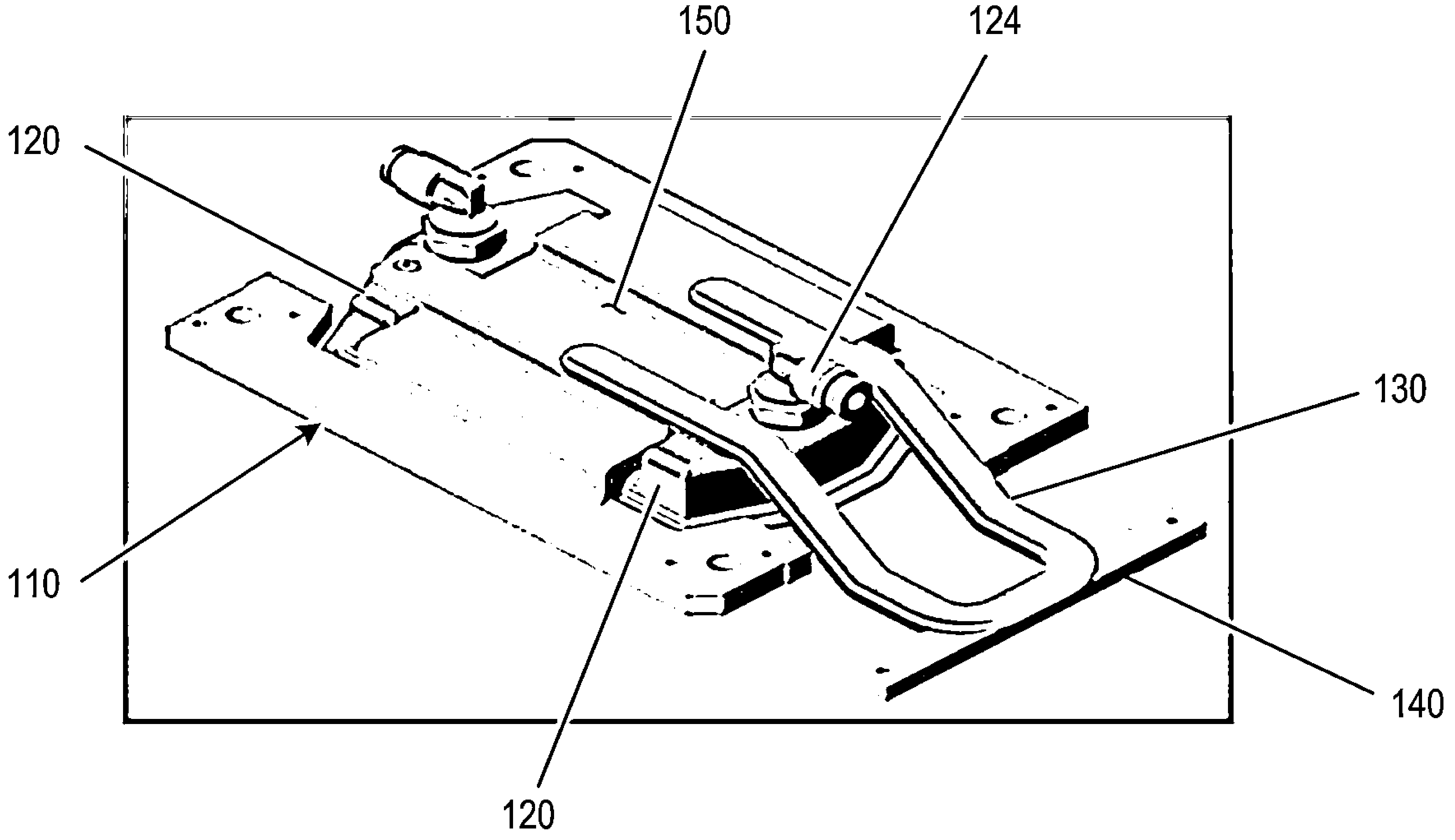


FIG. 1D

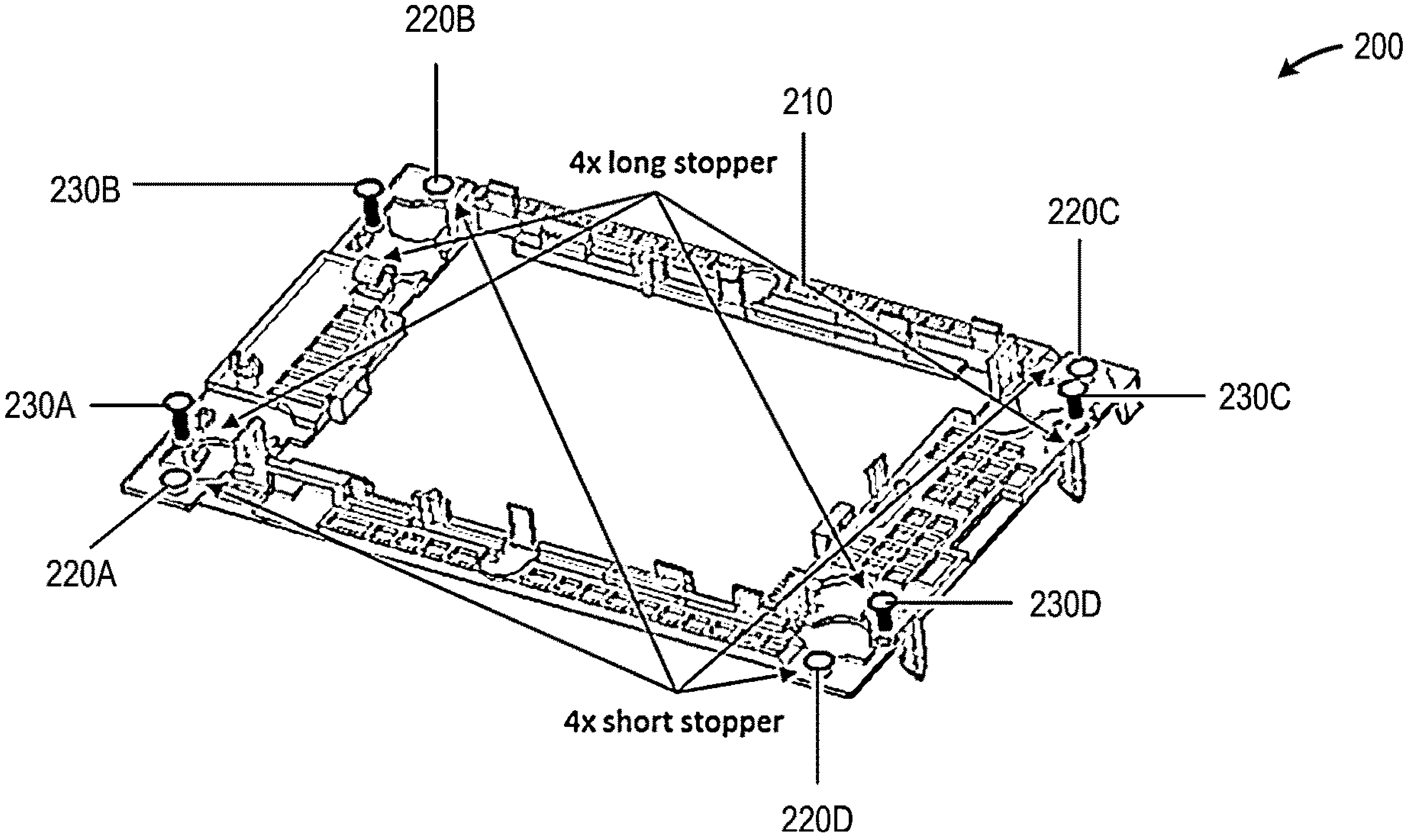

220B
200
210
4x long stopper
230B
220C
230A
230C
220A
230D
4x short stopper
220D

FIG. 2A

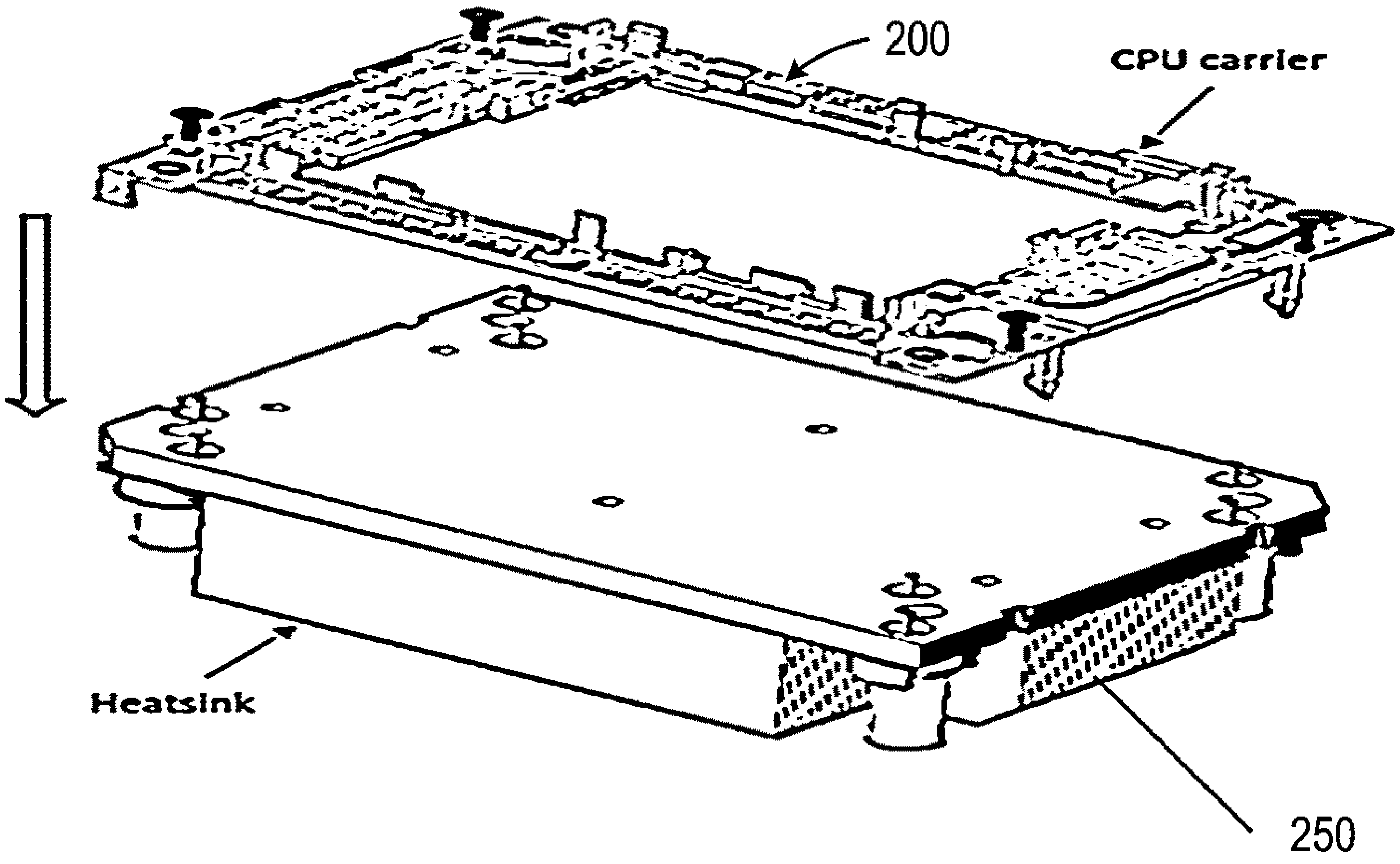

200
CPU carrier
Heatsink
250

FIG. 2B

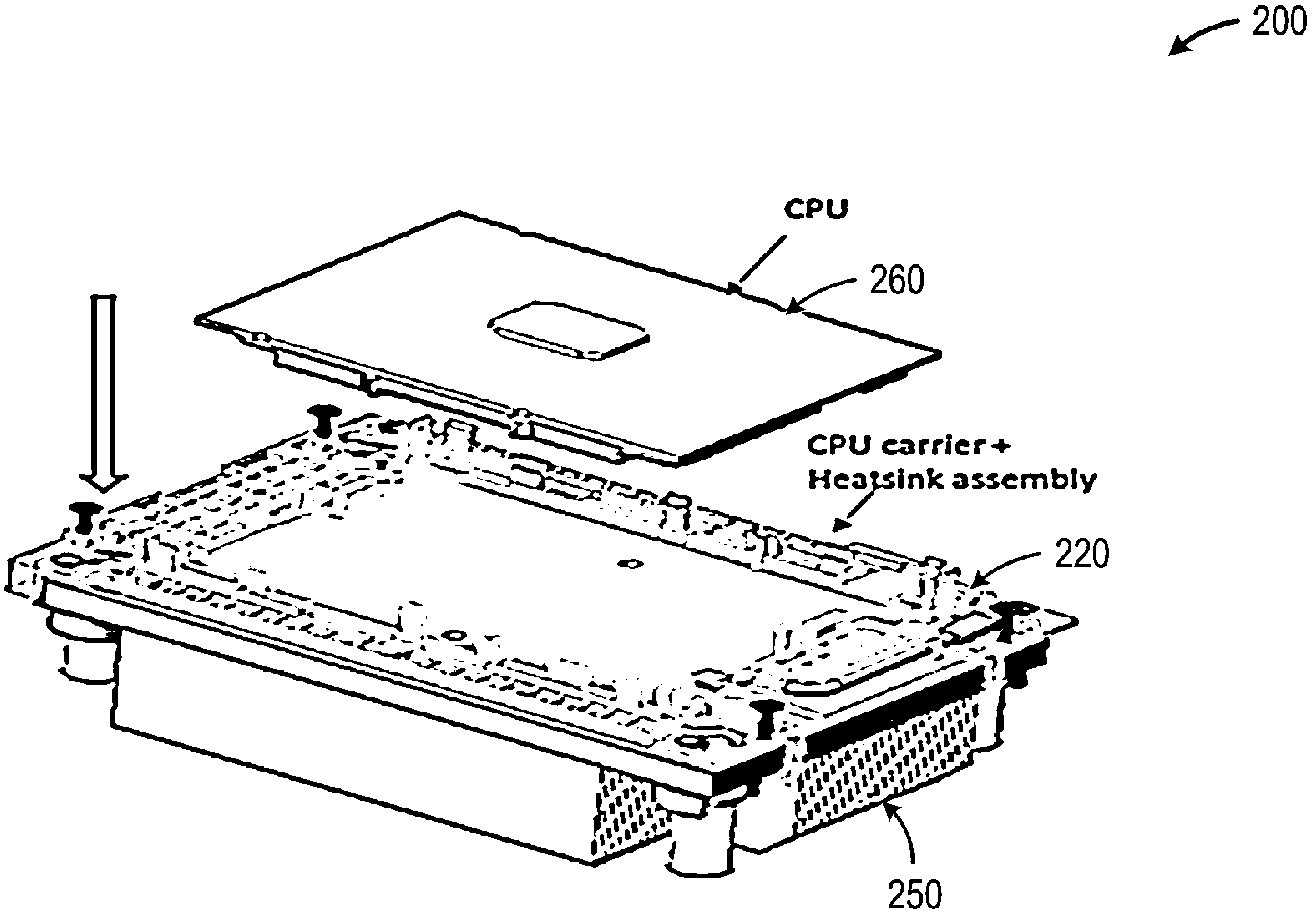

200
CPU
260
CPU carrier + Heatsink assembly
220
250

FIG. 2C

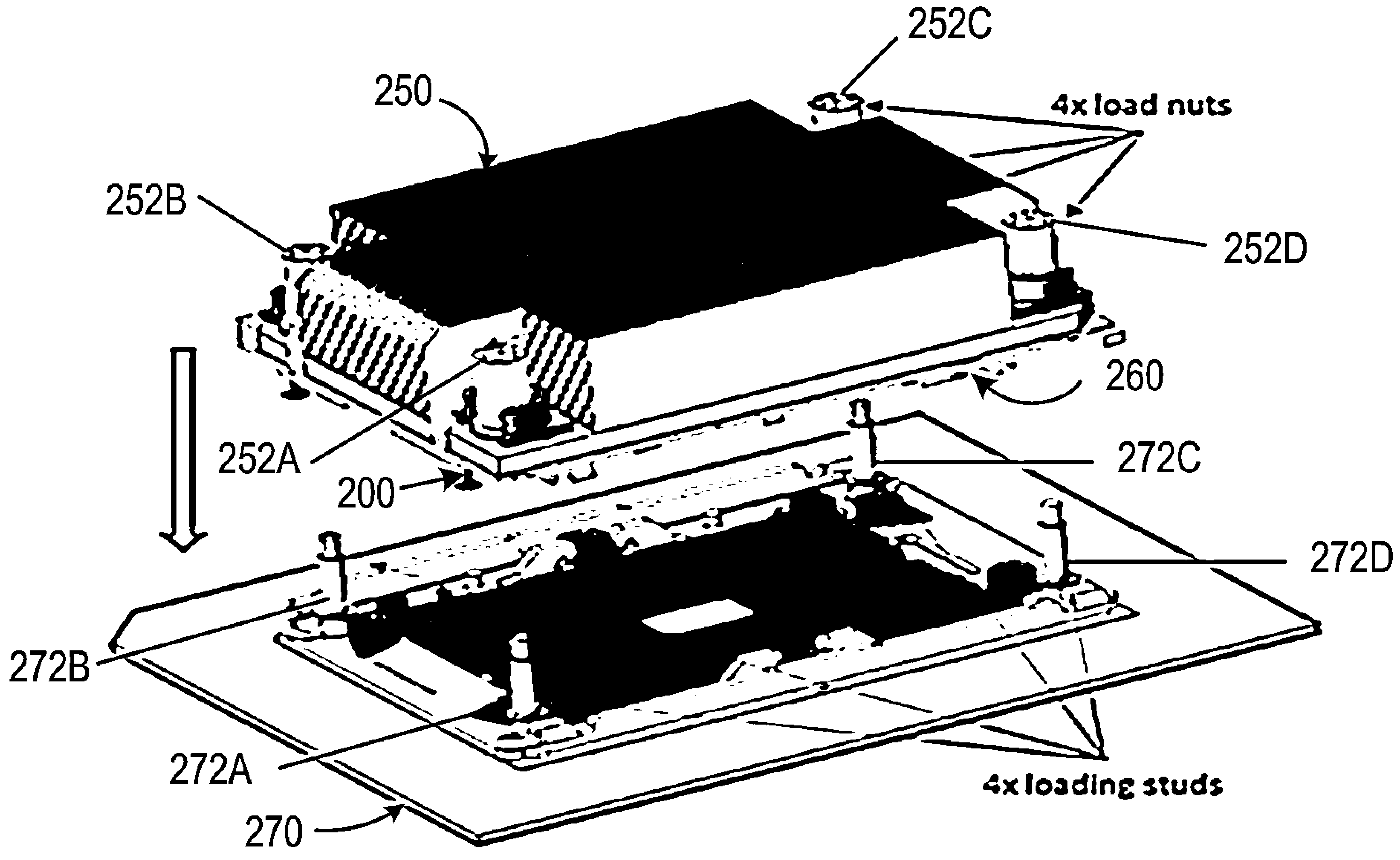

252C
250
4x load nuts
252B
252D
260
252A
200
272C
272D
272B
272A
4x loading studs
270

FIG. 2D

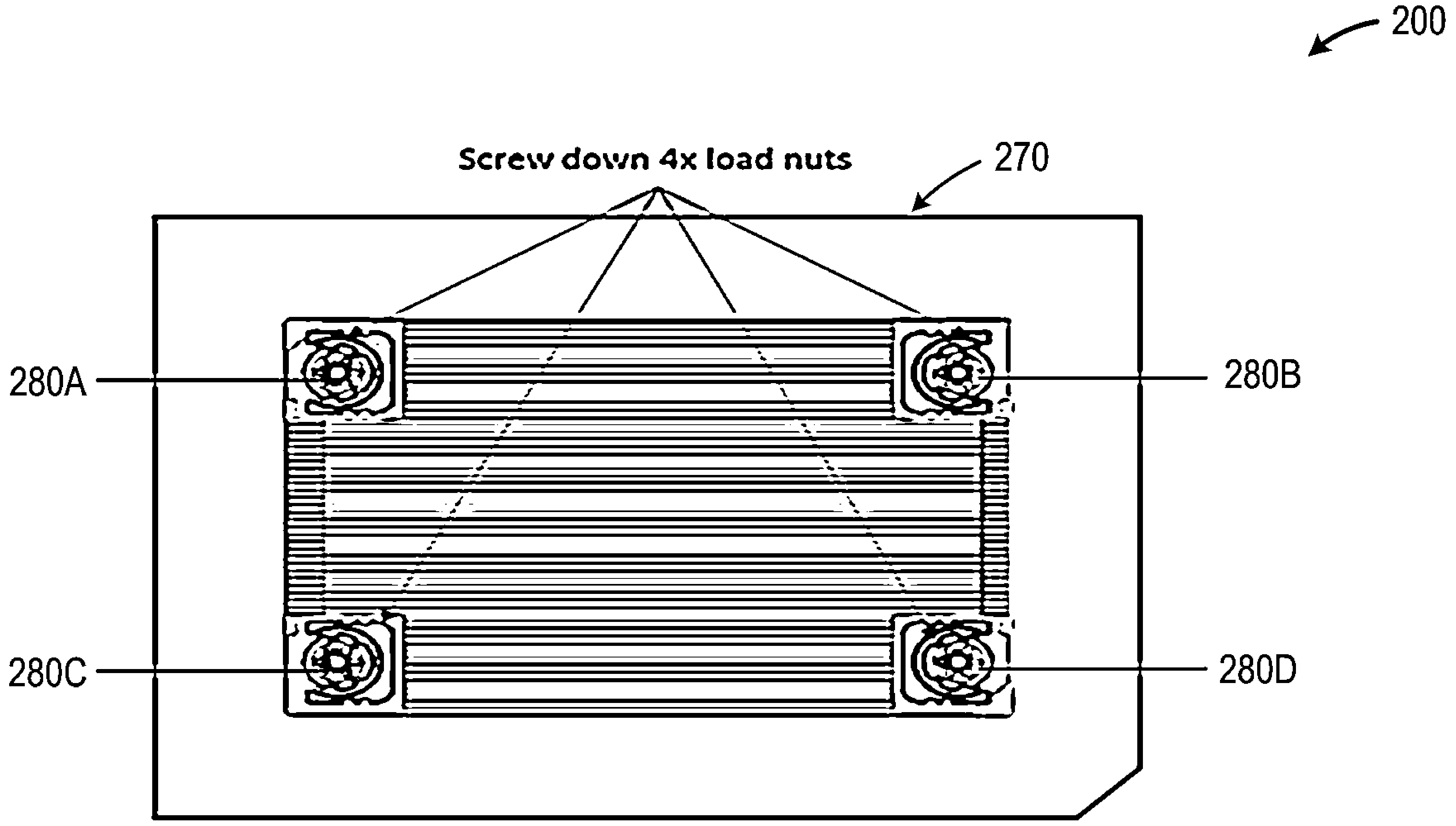


FIG. 2E

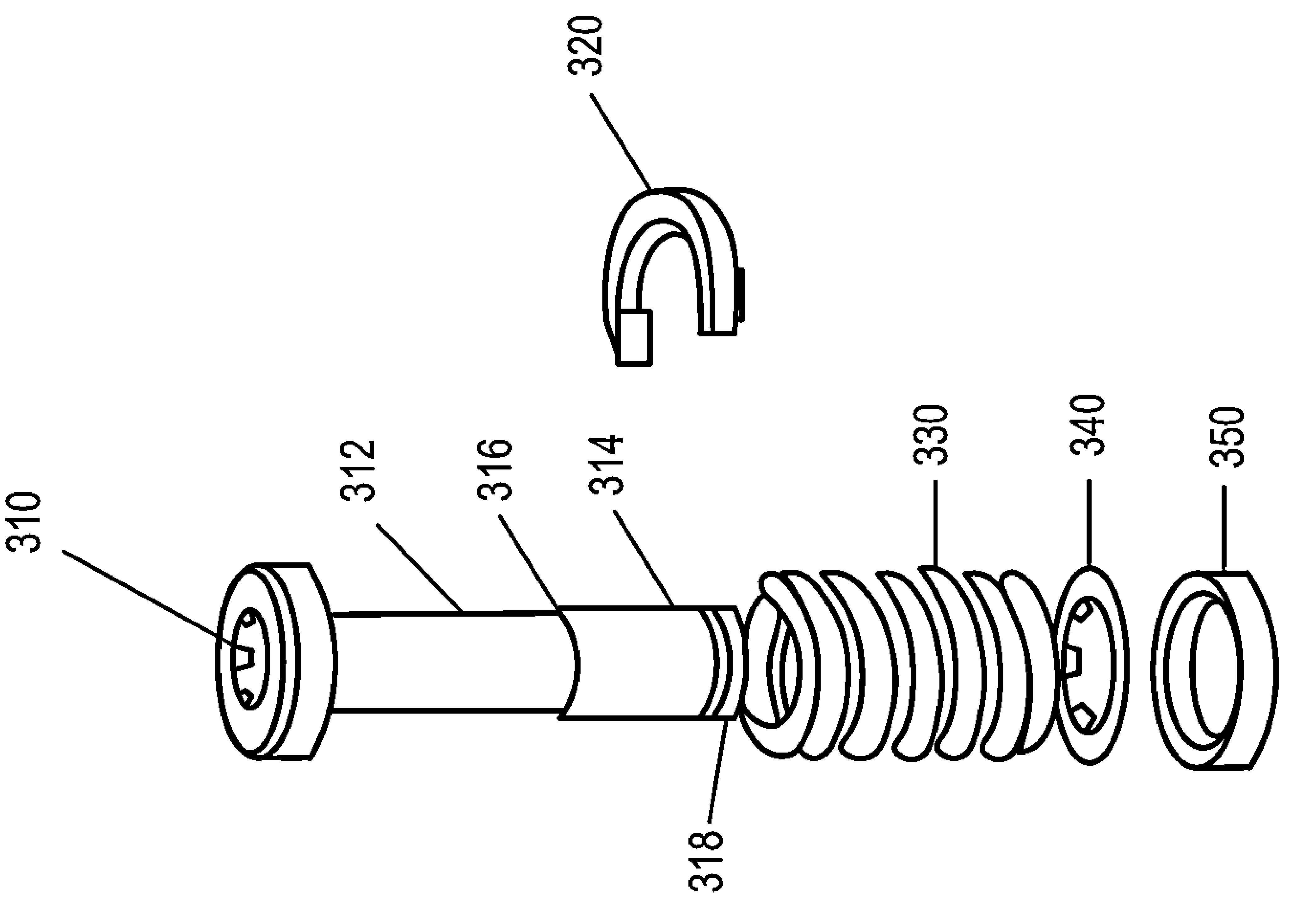


FIG. 3A

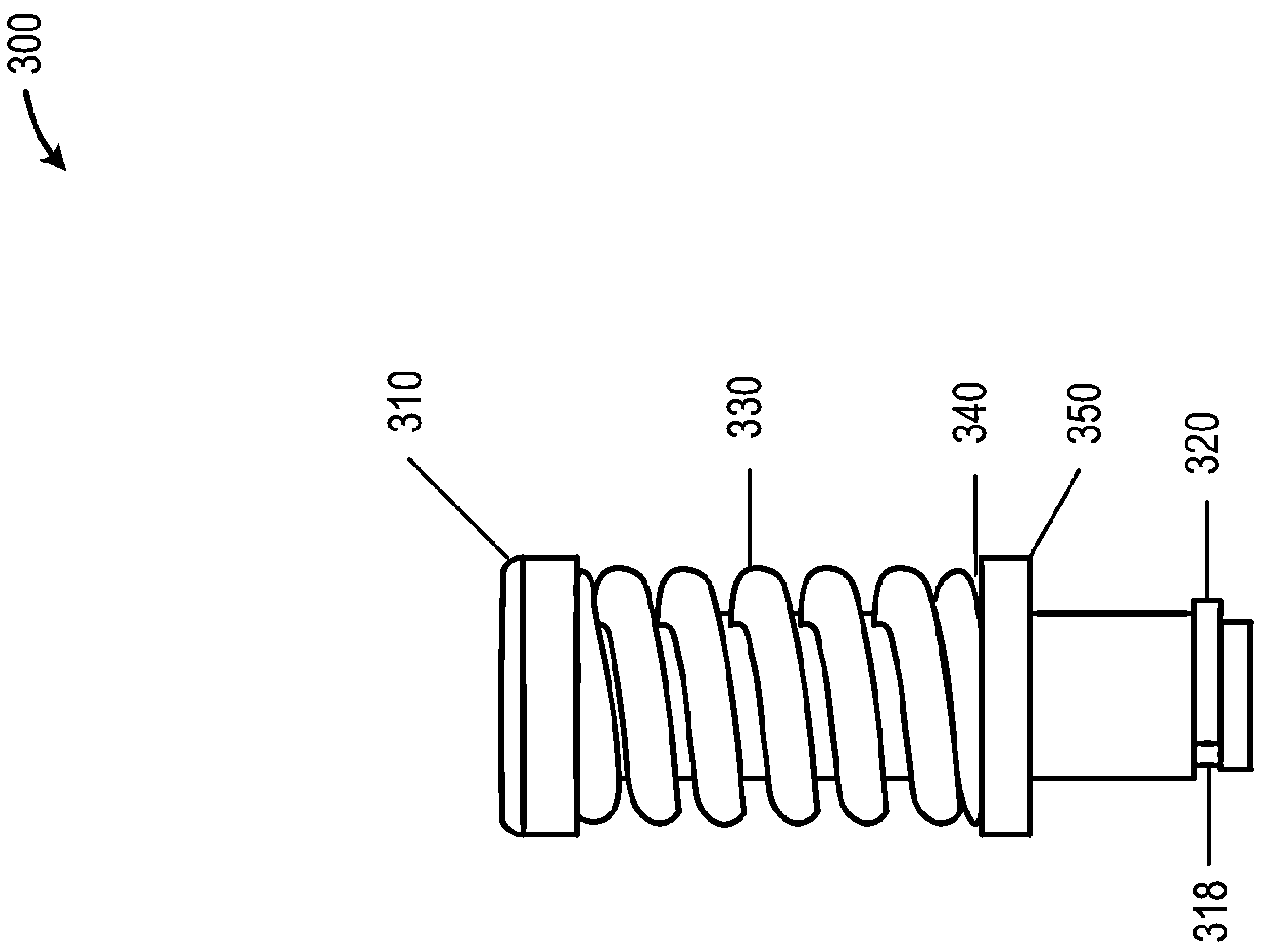


FIG. 3B

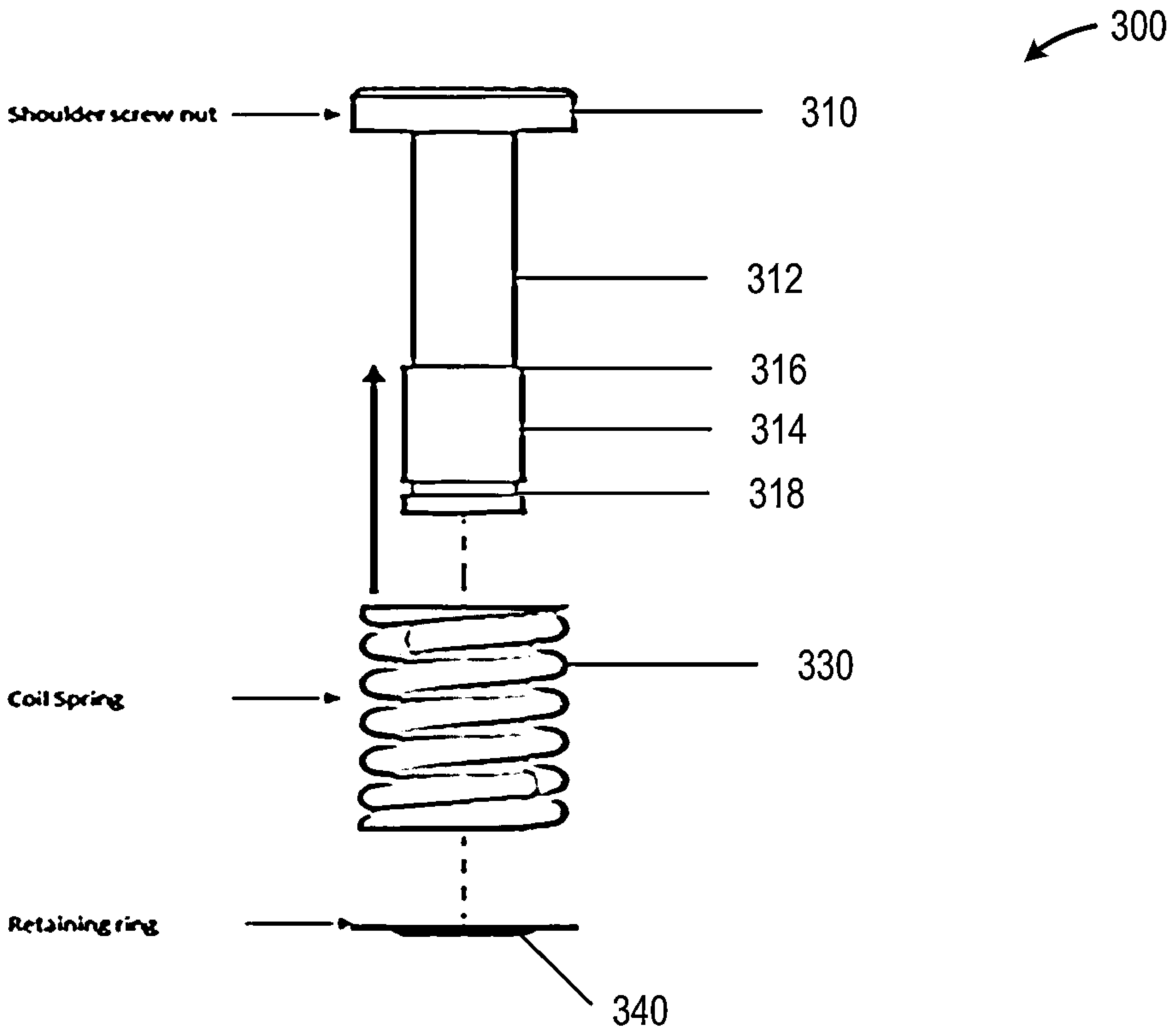

300
Shoulder screw nut
310
312
316
314
318
Coil Spring
330
Retaining ring
340

FIG. 3C

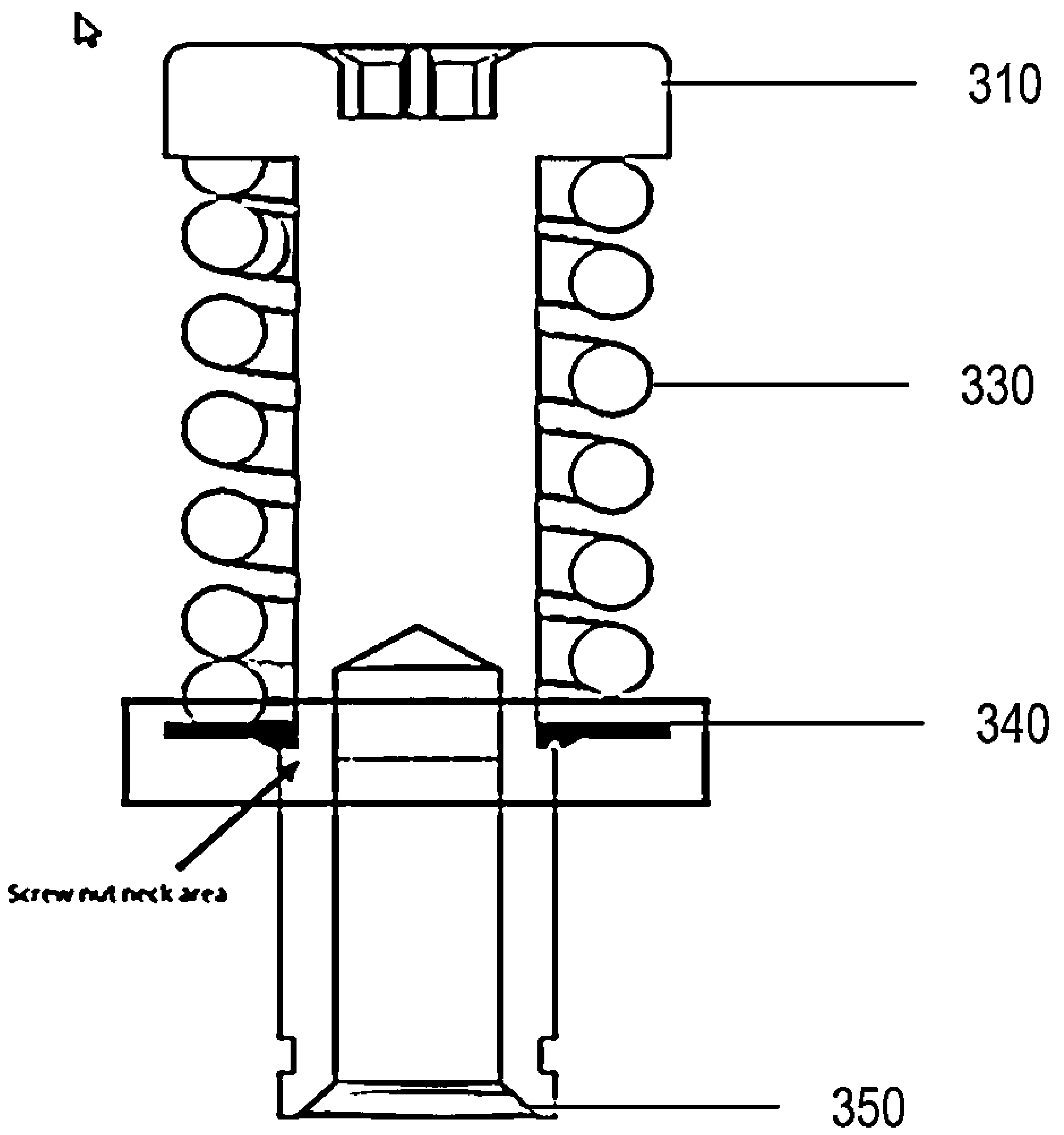

310
330
340
Screw nut neck area
350

FIG. 3D

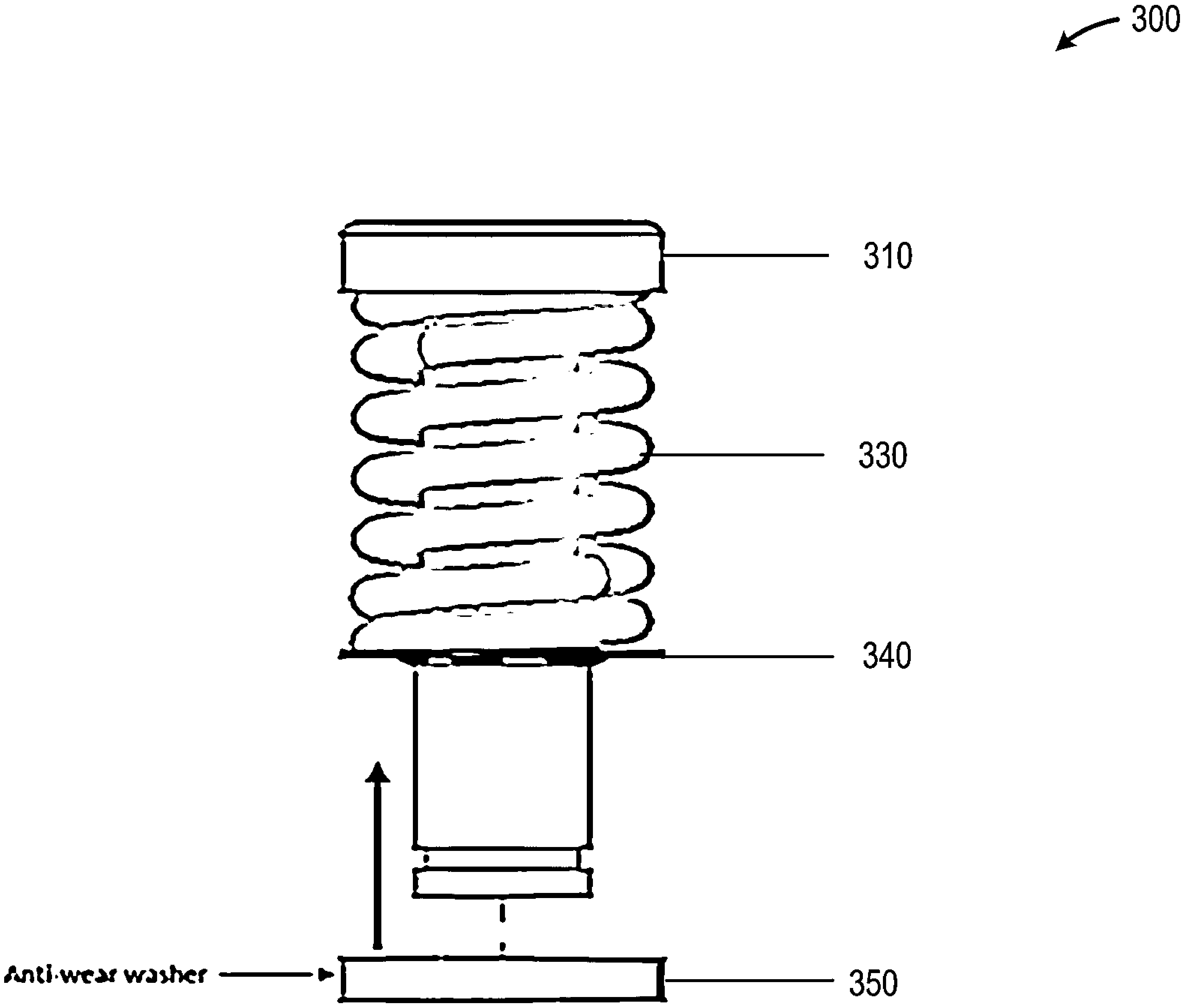


FIG. 3E

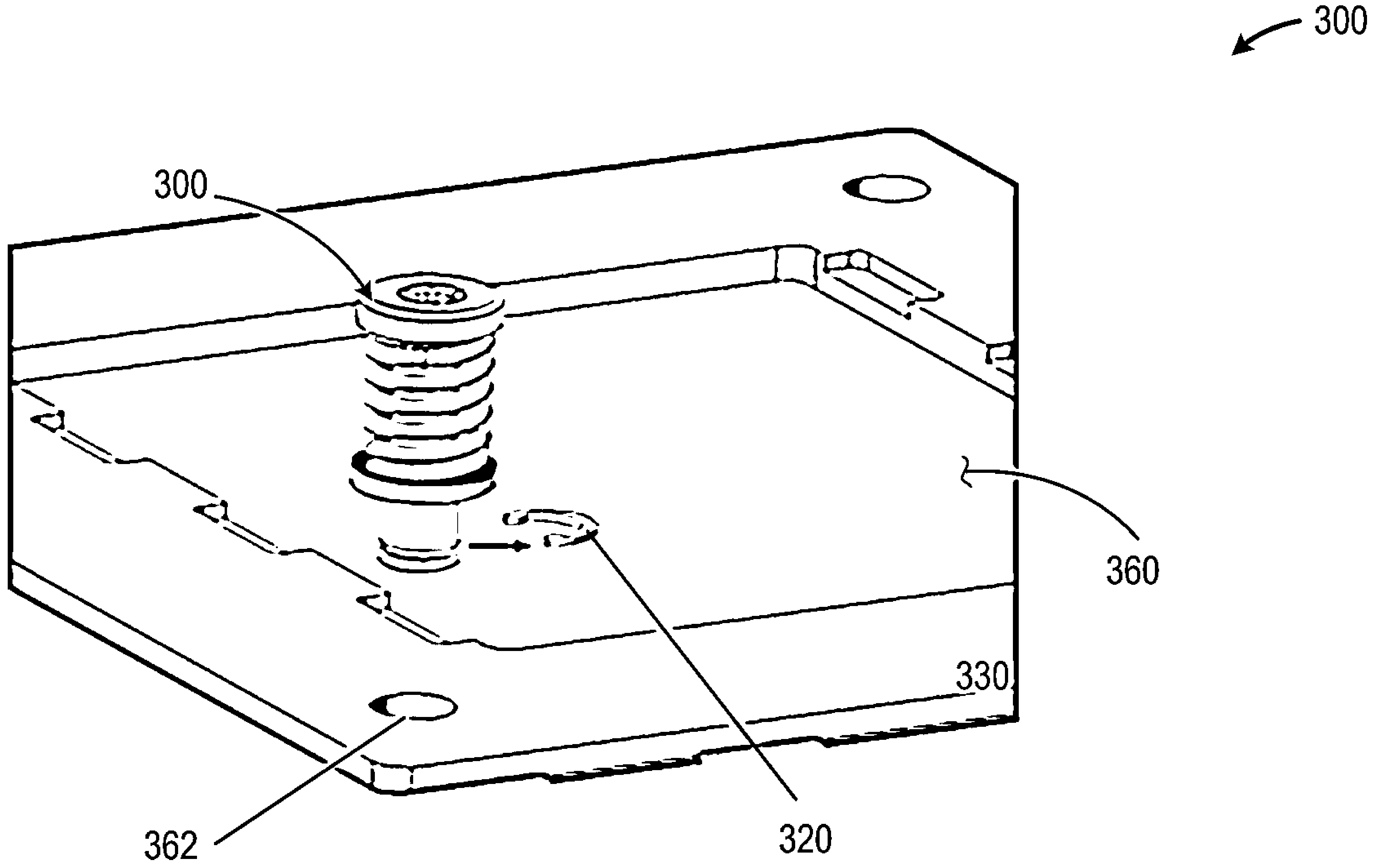


FIG. 3F

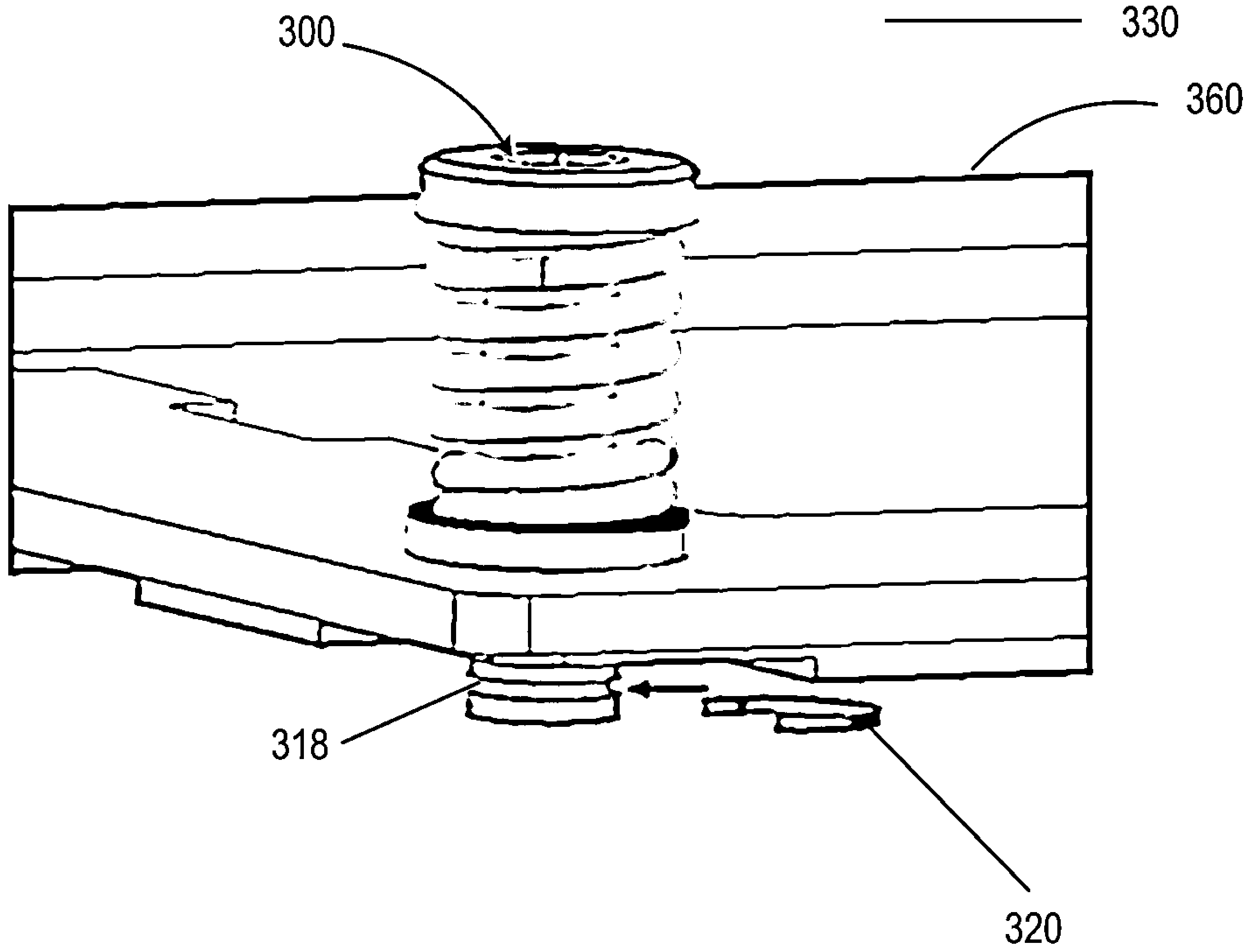


FIG. 3G

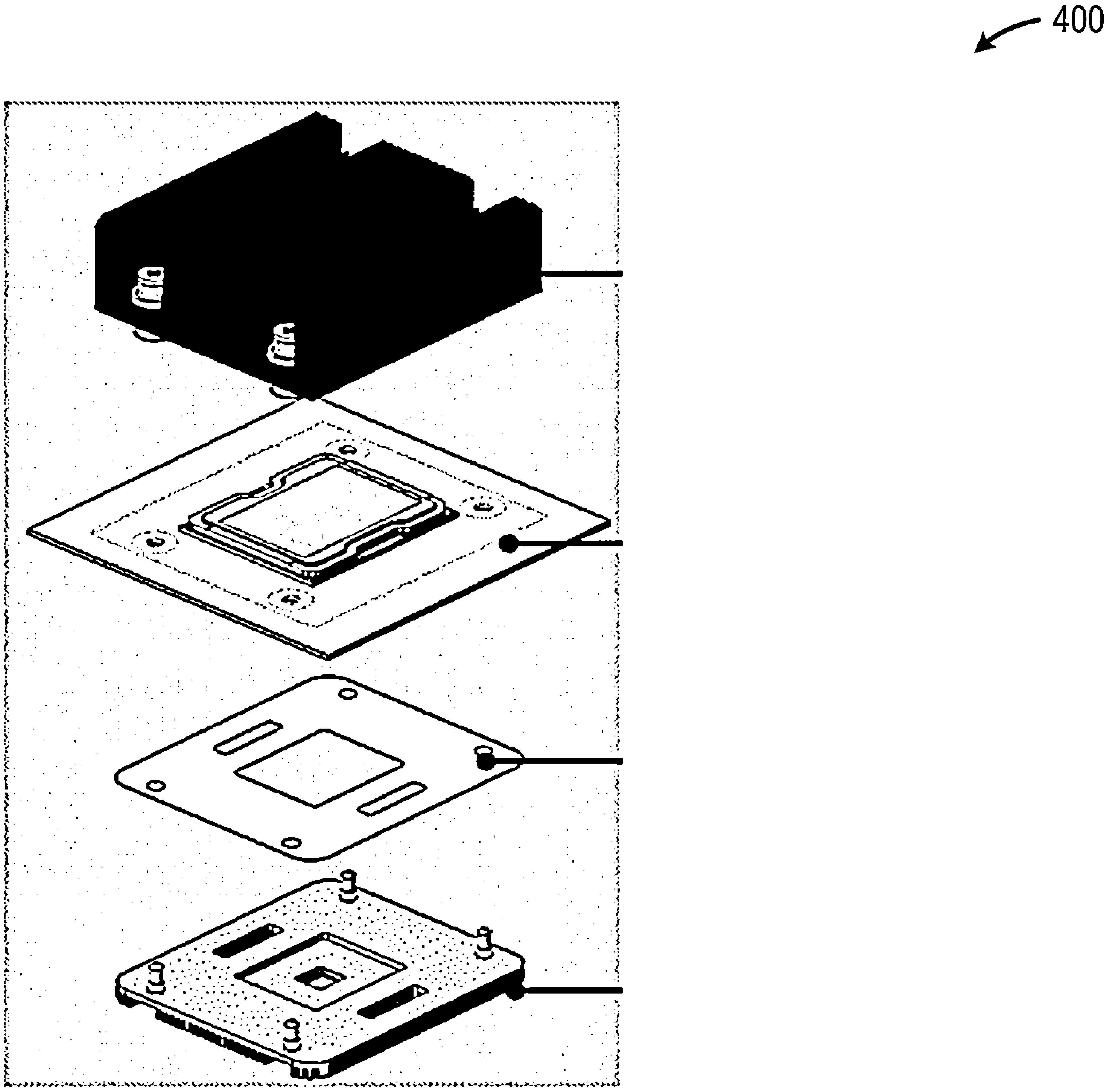


FIG. 4A

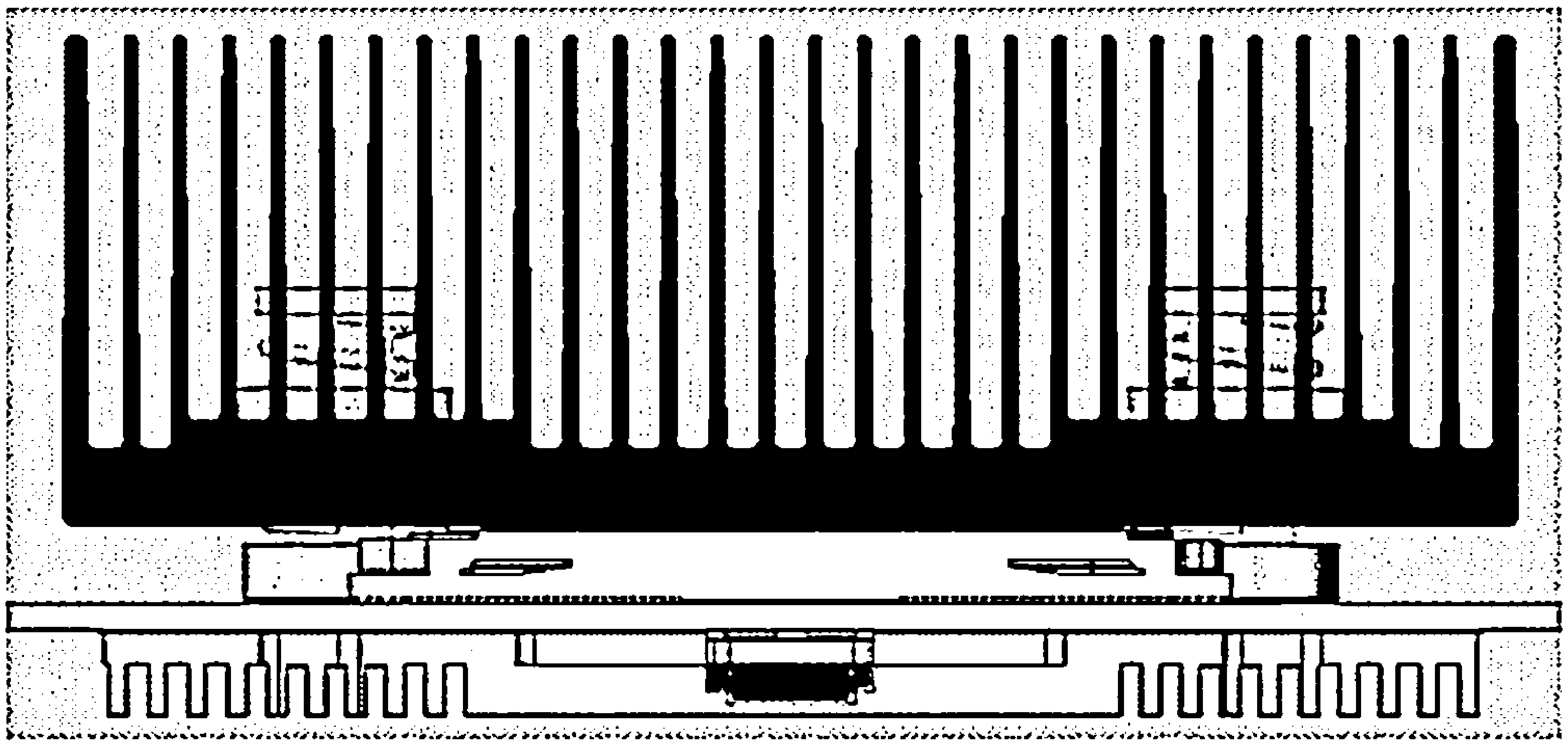


FIG. 4B

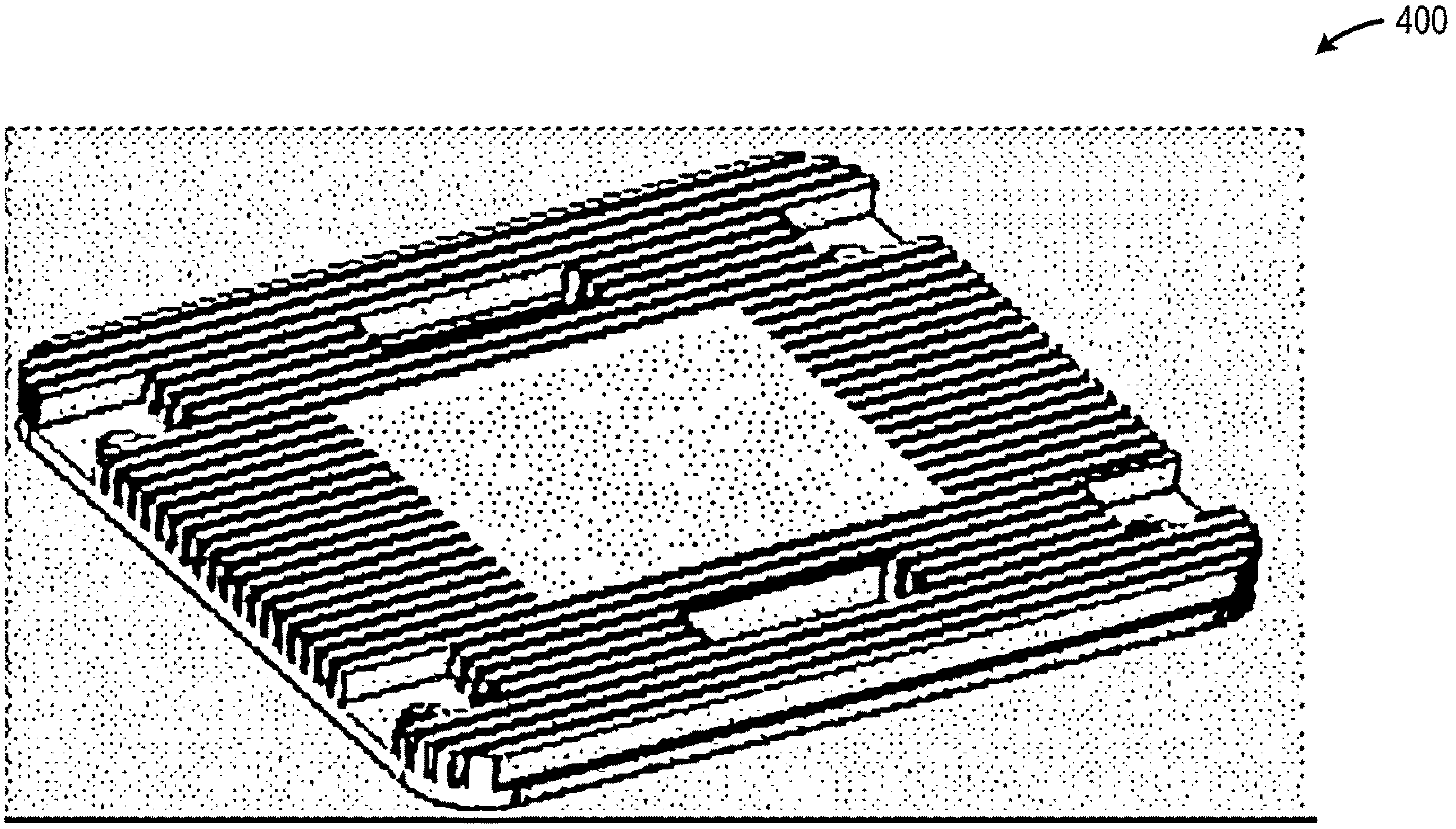


FIG. 4C

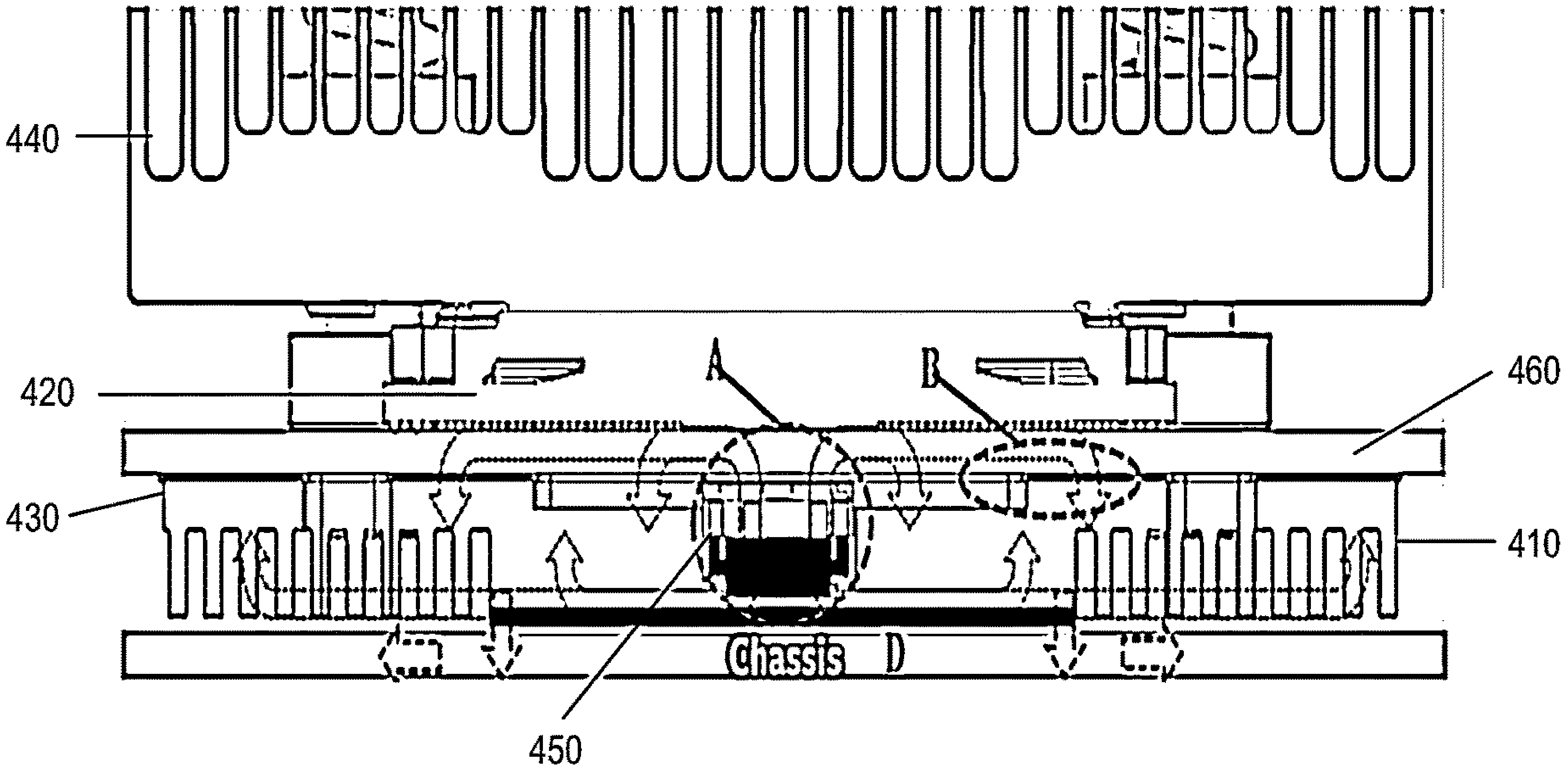


FIG. 4D

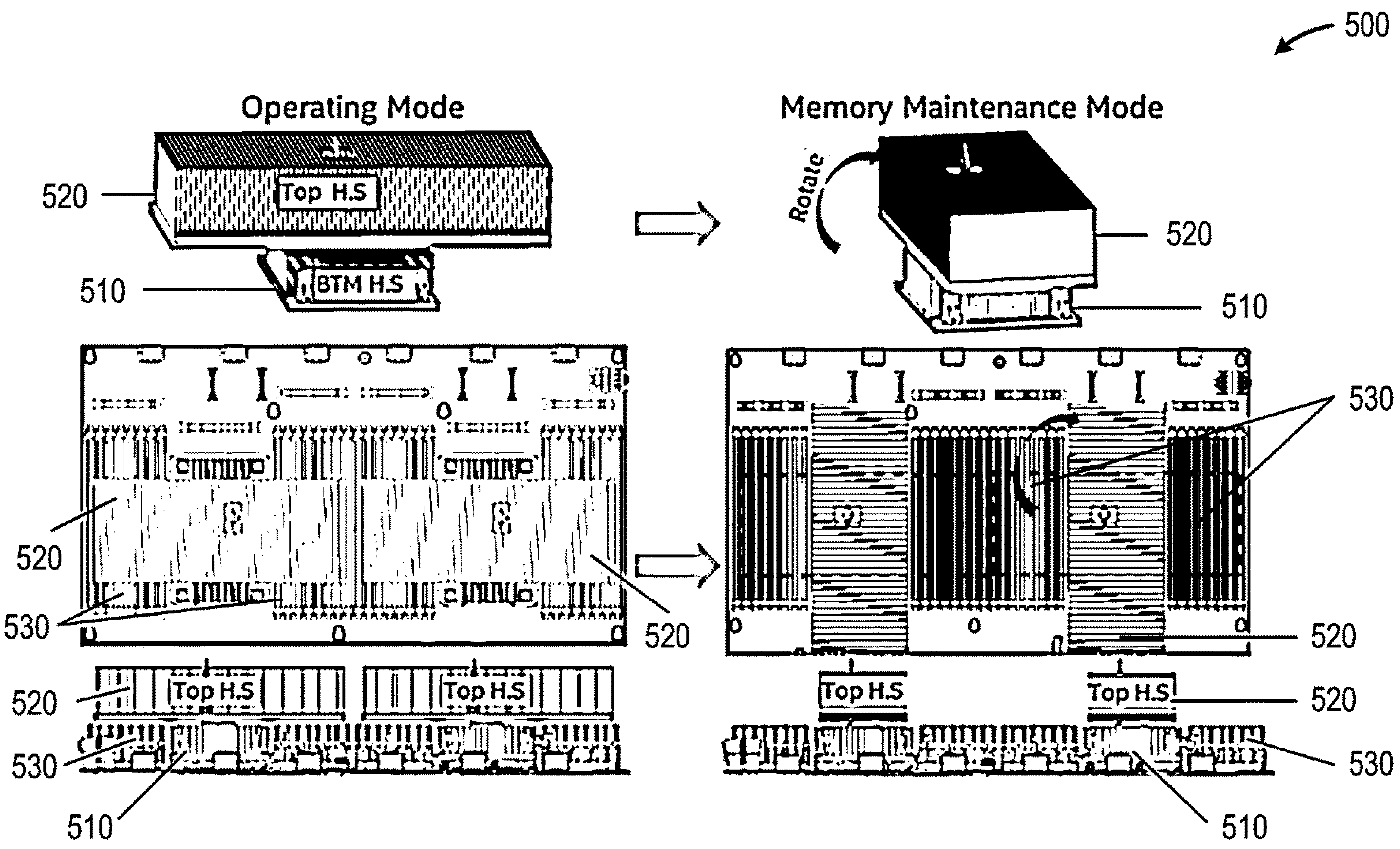

500
Operating Mode
Memory Maintenance Mode
520
Top H.S
510
BTM H.S
Rotate
520
510
530
520
530
520
520
Top H.S
Top H.S
520
530
510
Top H.S
Top H.S
520
530
510

FIG. 5A

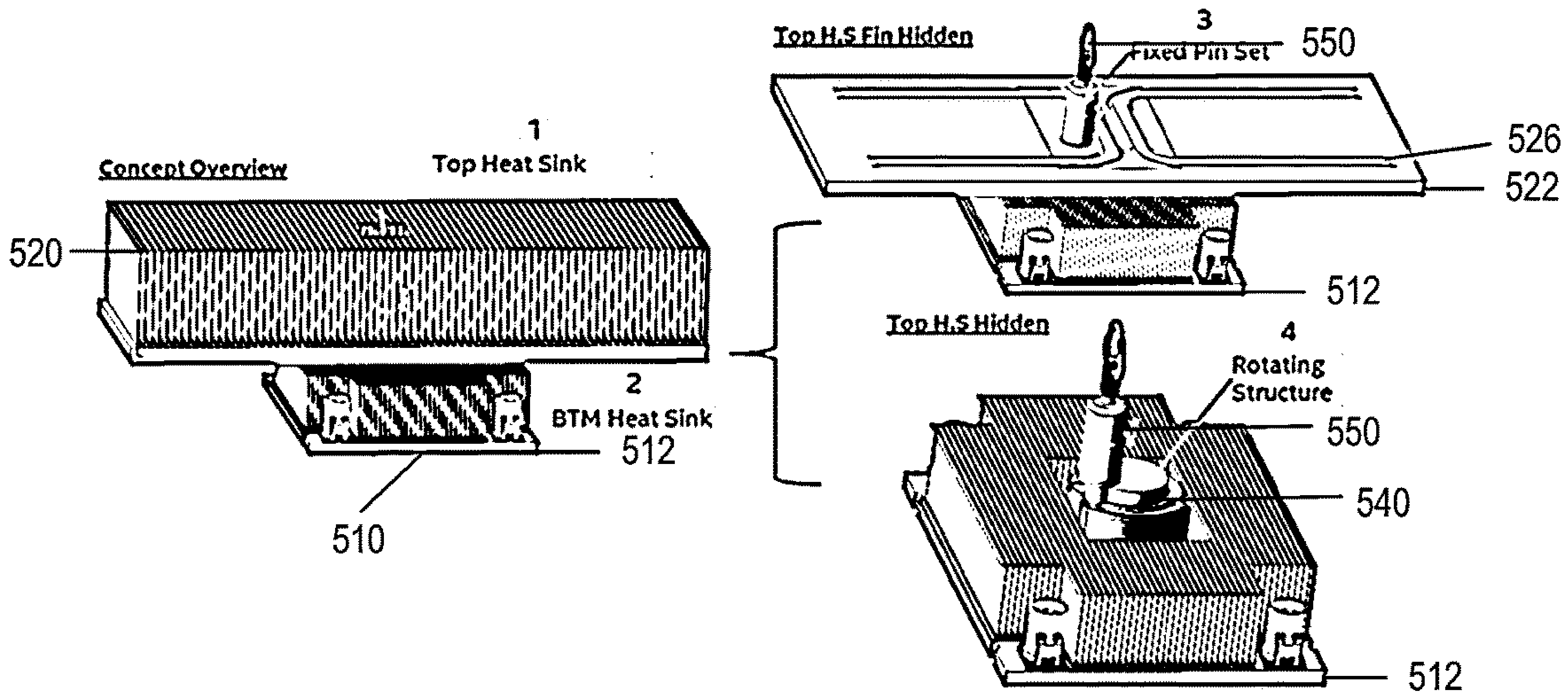

Concept Overview
1
Top Heat Sink
520
2
BTM Heat Sink
512
510
Top H.S Fin Hidden
3
Fixed Pin Set
550
526
522
512
Top H.S Hidden
4
Rotating Structure
550
540
512

FIG. 5B

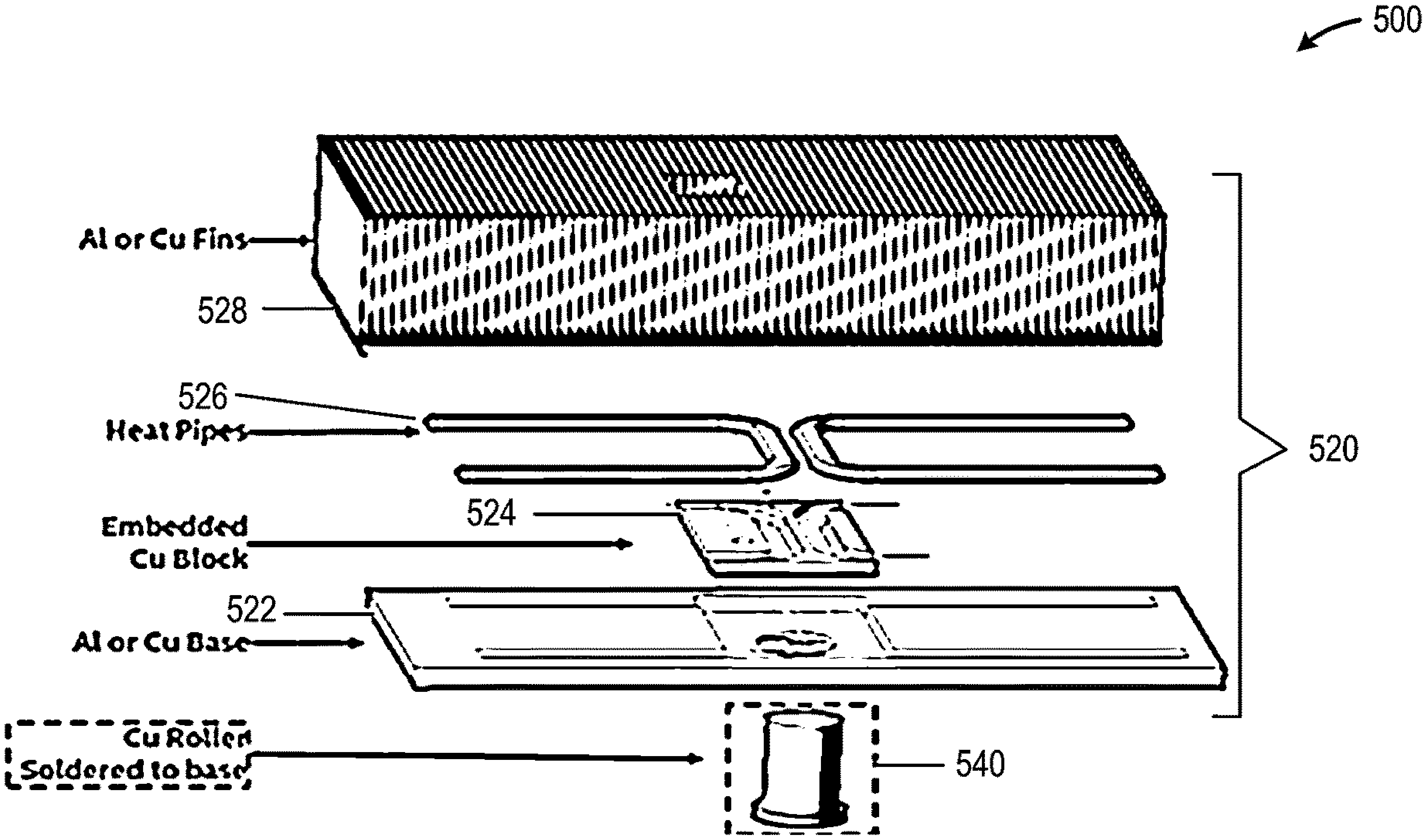

500
Al or Cu Fins
528
526
Heat Pipes
520
524
Embedded Cu Block
522
Al or Cu Base
Cu Roller Soldered to base
540

FIG. 5C

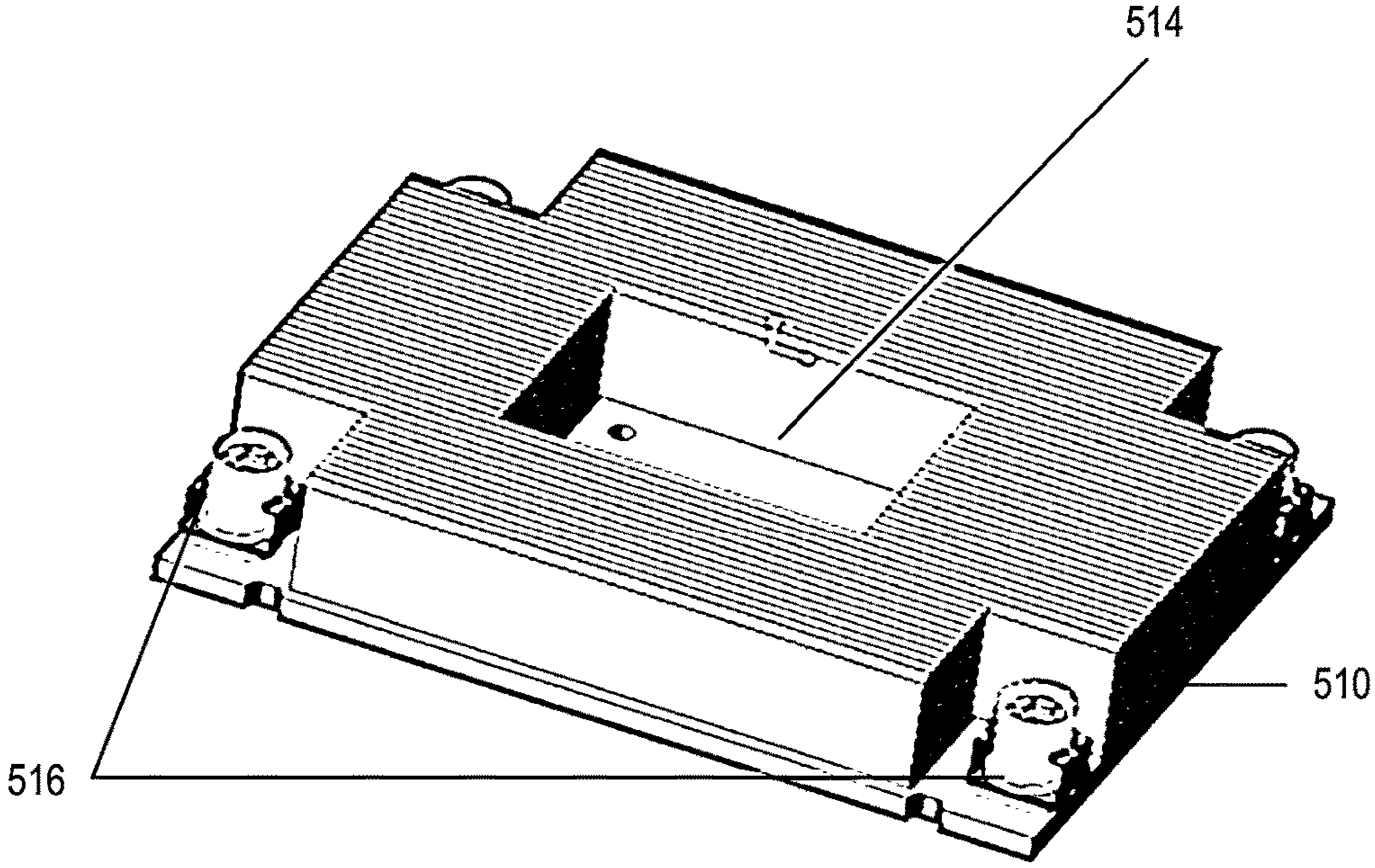

514
510
516

FIG. 5D

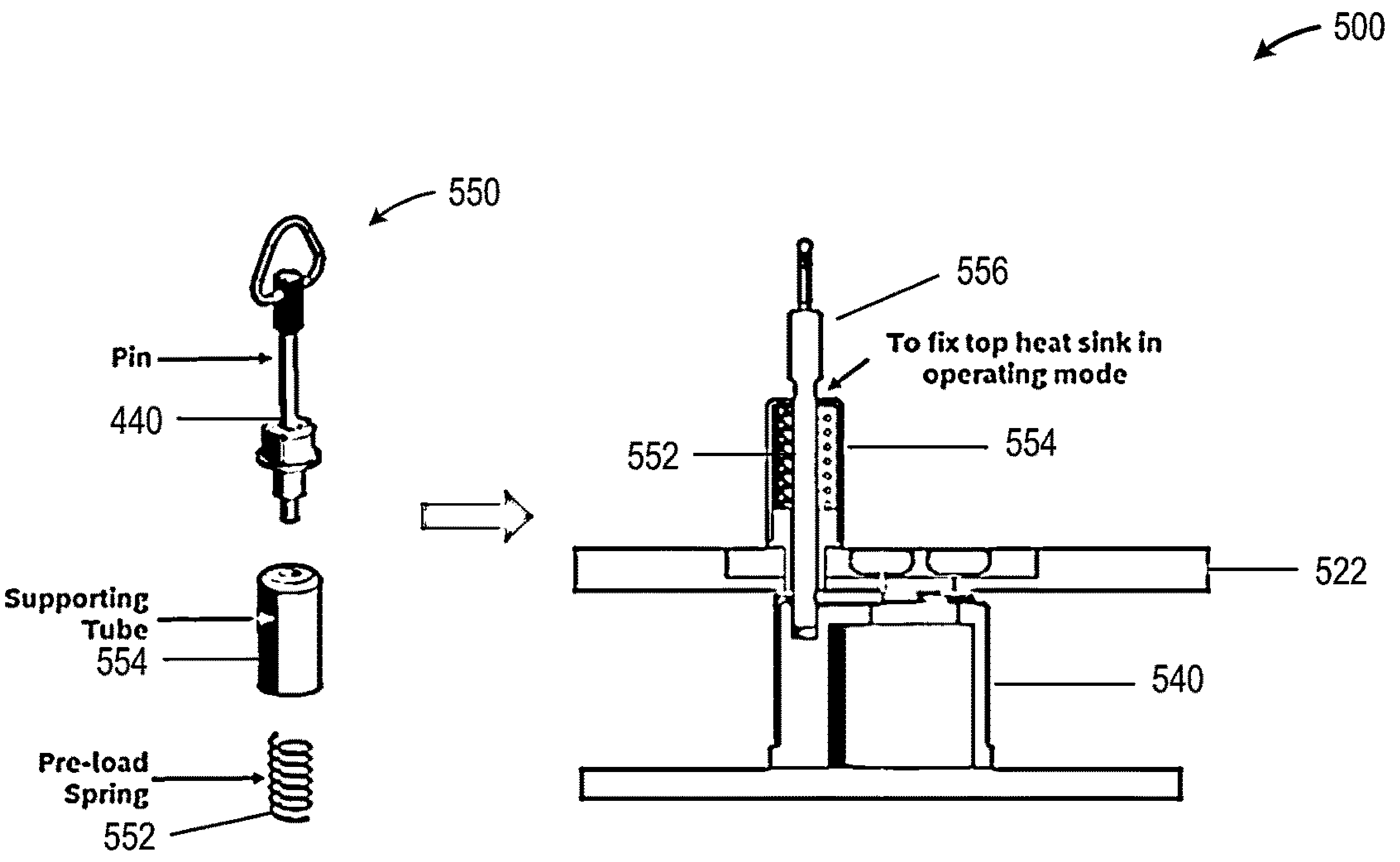

500
550
Pin
440
Supporting Tube
554
Pre-load Spring
552
556
To fix top heat sink in operating mode
552
554
522
540

FIG. 5E

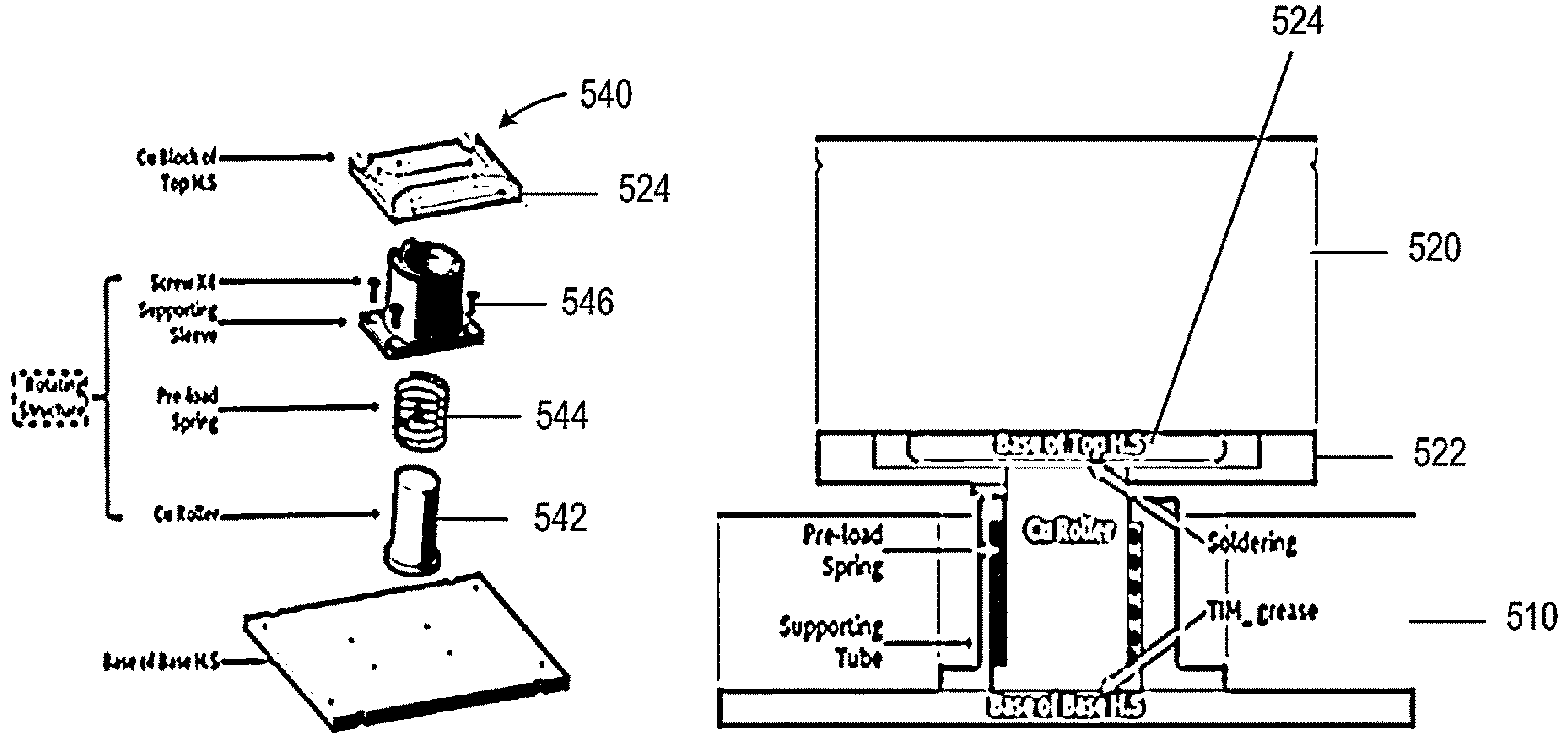

540
Cu Block of Top HS
524
Screw X4
Supporting Sleeve
546
Rolling Structure
Pre-load Spring
544
Cu Roller
542
Base of Base HS
524
520
Base of Top HS
522
Cu Roller
Pre-load Spring
Soldering
Supporting Tube
TIM_grease
510
Base of Base HS

FIG. 5F

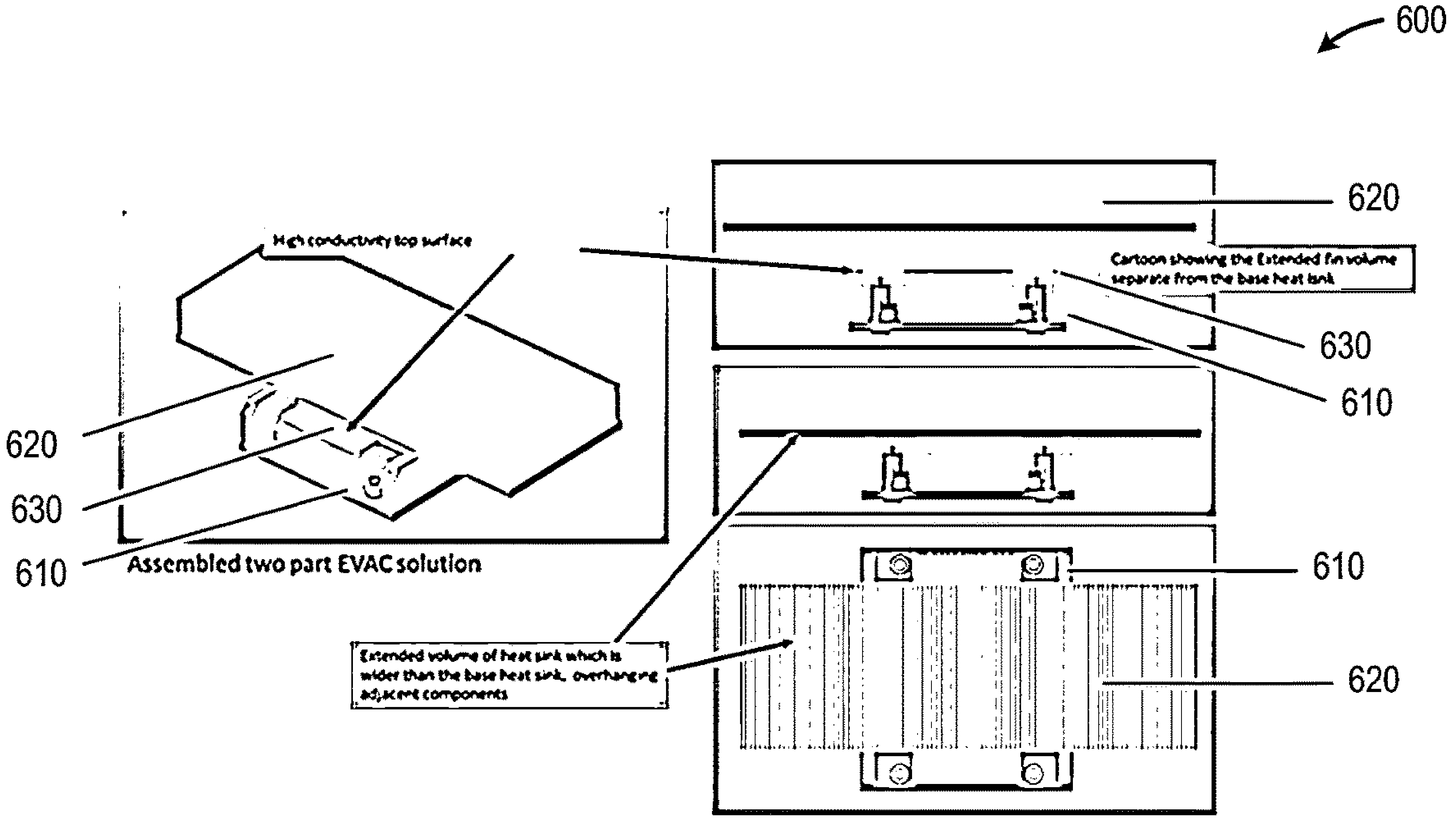

600
High conductivity top surface
620
630
610
Assembled two part EVAC solution
620
Cartoon showing the Extended fin volume separate from the base heat sink
630
610
610
Extended volume of heat sink which is wider than the base heat sink, overhanging adjacent components
620

FIG. 6A

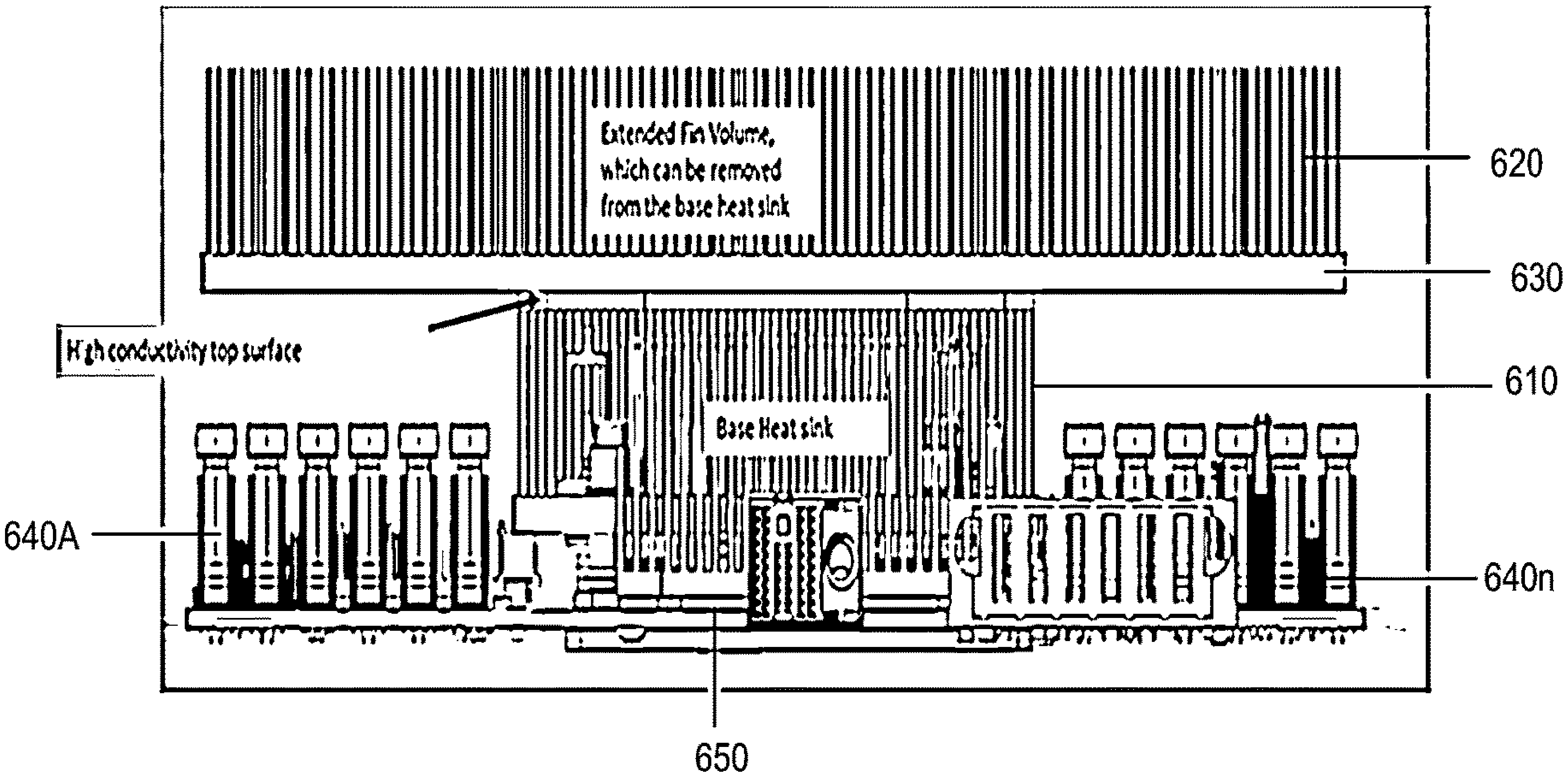
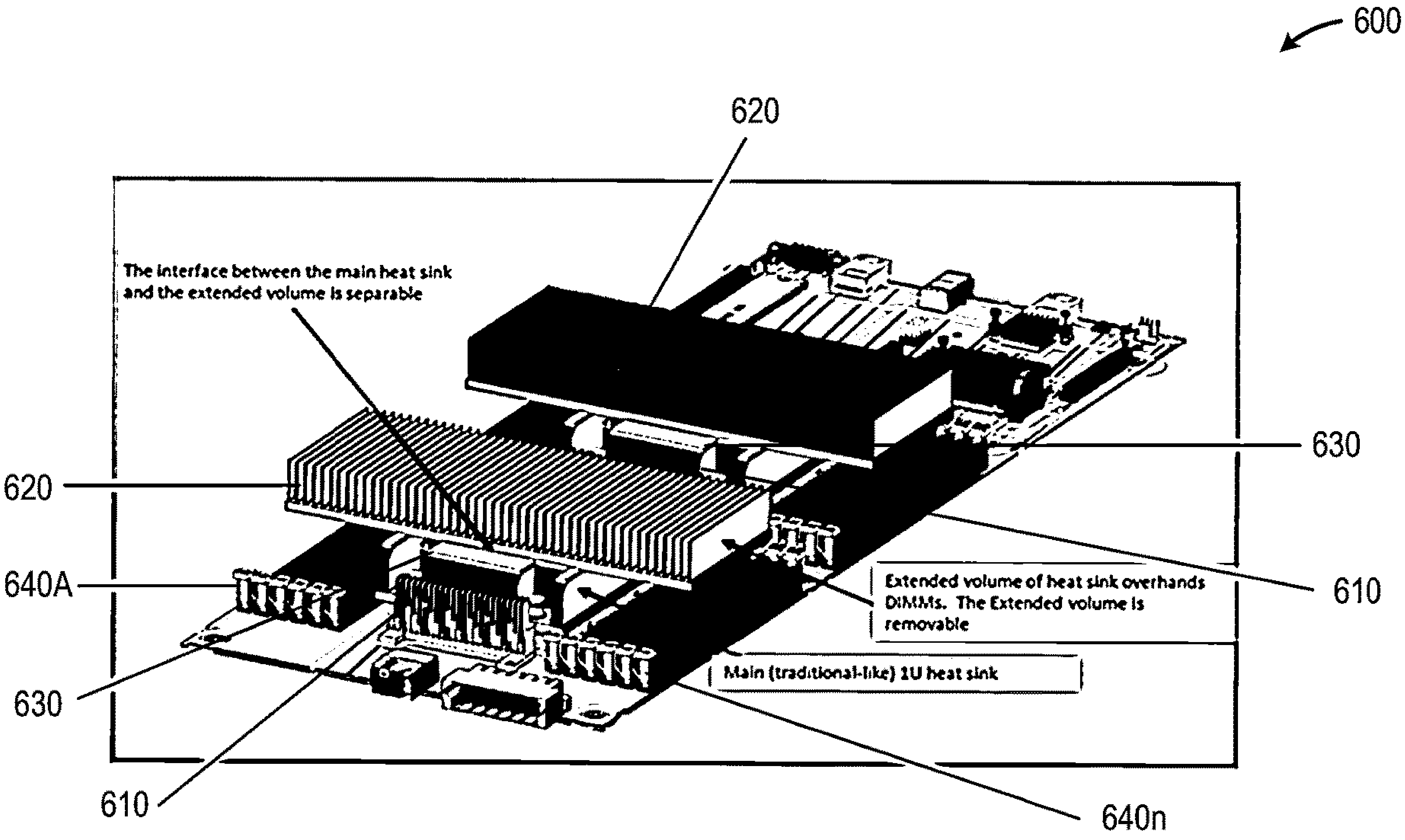

Extended Fin Volume, which can be removed from the base heat sink
620
630
High conductivity top surface
610
Base Heat sink
640A
640n
650

FIG. 6B

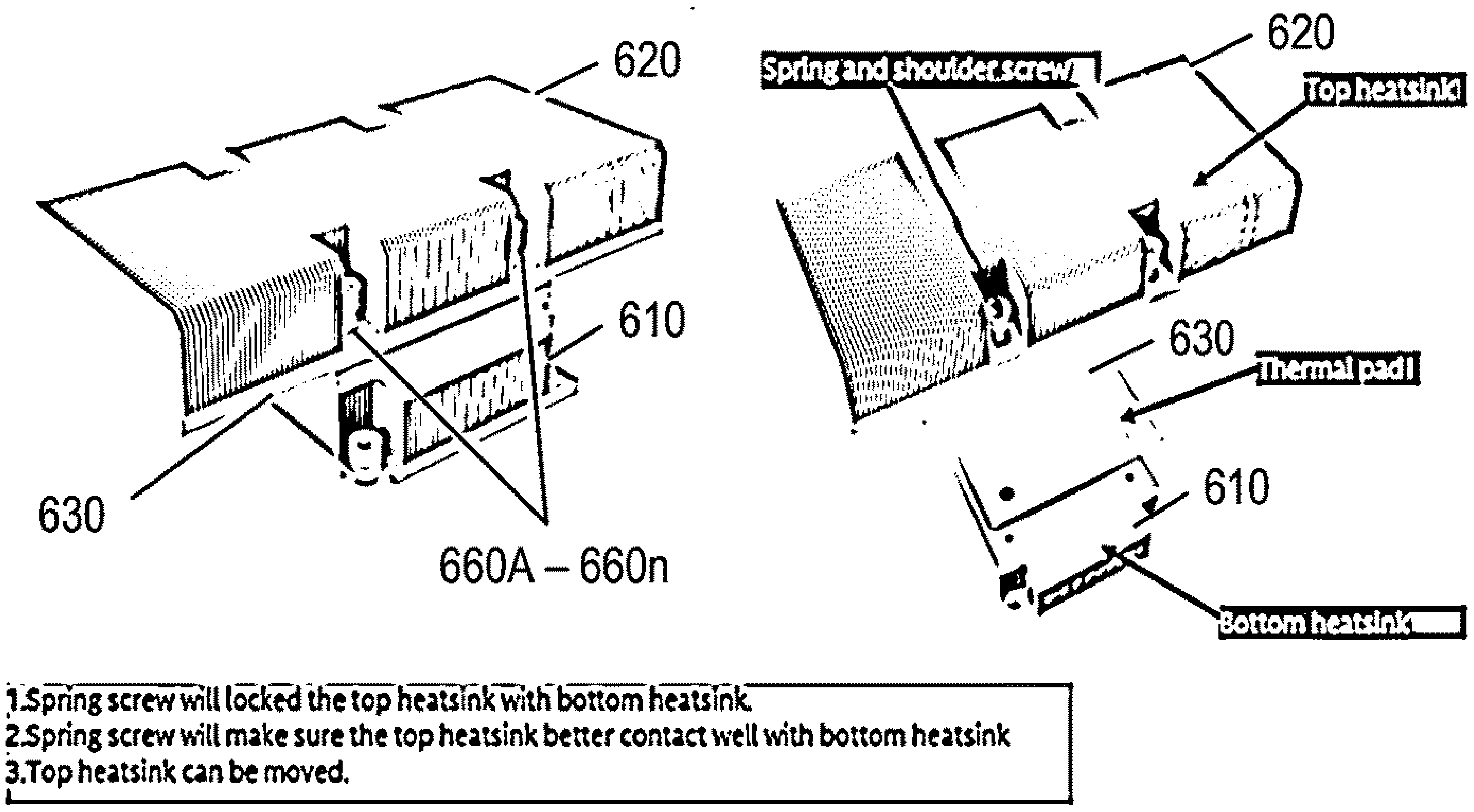


The interface between the main heat sink and the extended volume is separable

Extended volume of heat sink overhands DIMMs. The Extended volume is removable

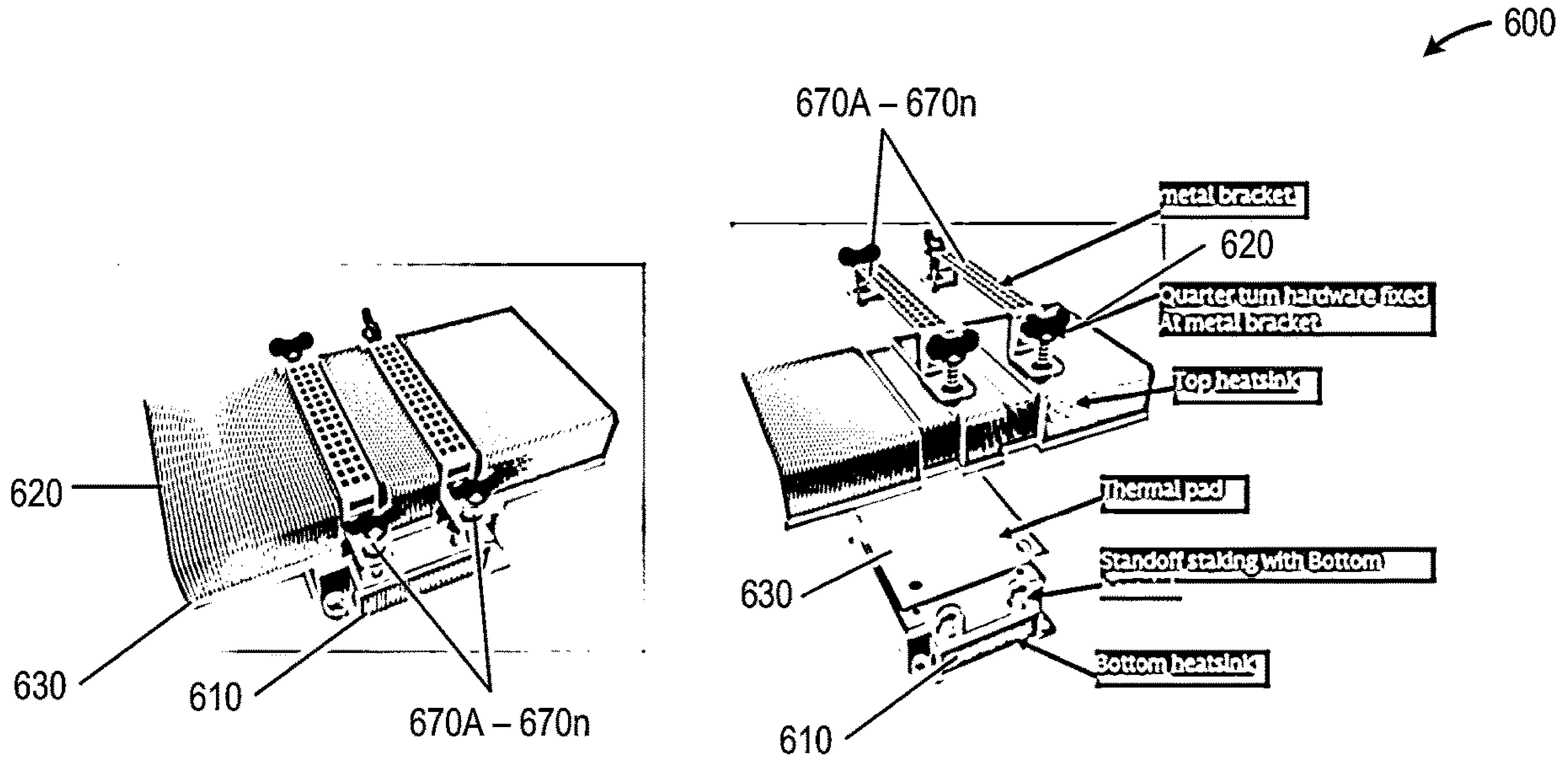
Main (traditional-like) 1U heat sink

FIG. 6C



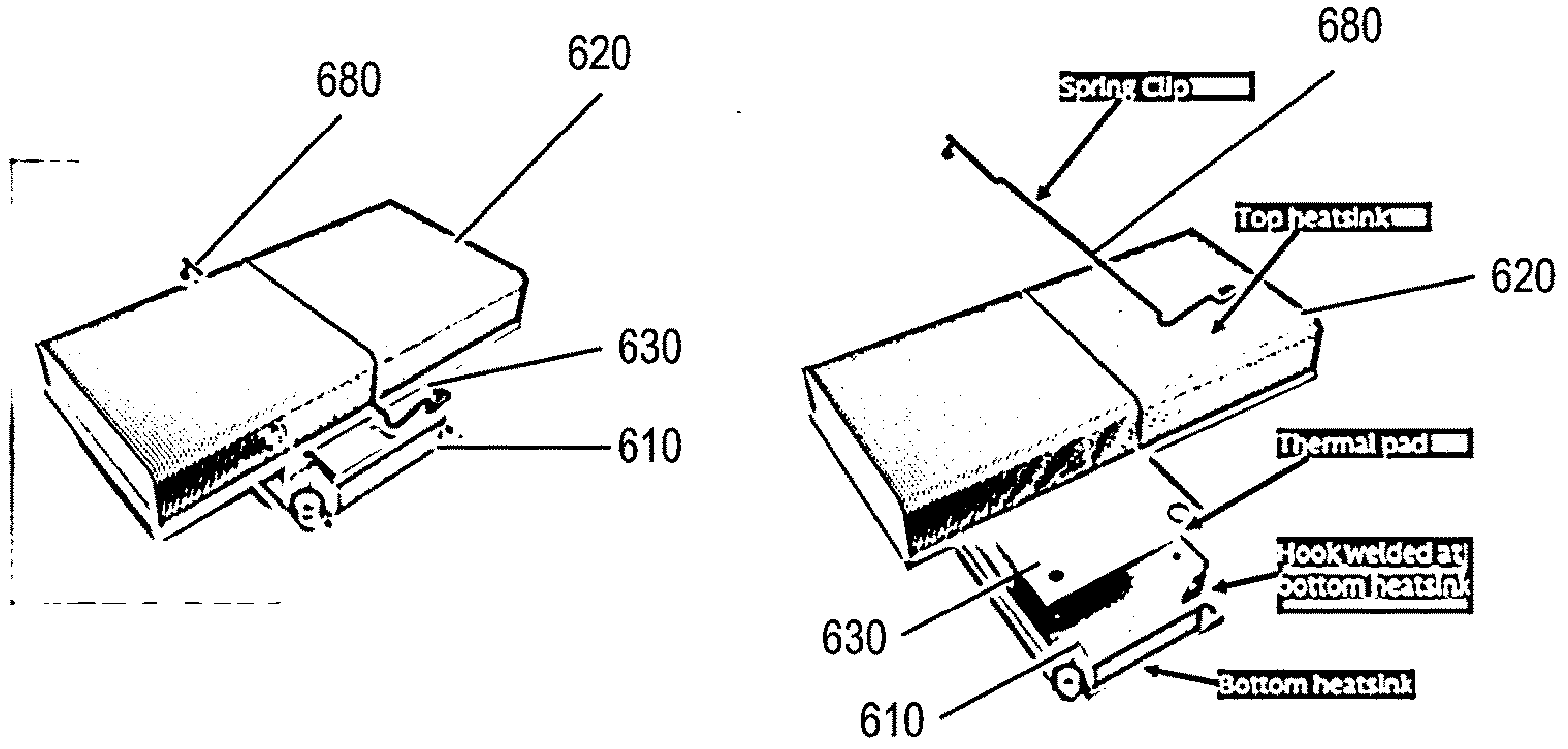
1.Spring screw will locked the top heatsink with bottom heatsink.
2.Spring screw will make sure the top heatsink better contact well with bottom heatsink
3.Top heatsink can be moved.

FIG. 6D



1.Southco quarter turn hardware will fixed with 2 metal bracket.
2.Southco quarter turn with spring can provide the preload to heatsink make sure top heatsink and bottom heatsink contact well.
3. It is tool-less, the top heatsink can be easily removed when just turn the butterfly quarter turn.

FIG. 6E



1.Spring clip will locked the top heatsink with bottom heatsink.
2. Spring clip will make sure the top heatsink better contact well with bottom heatsink.
3. It is tool-less.

FIG. 6F

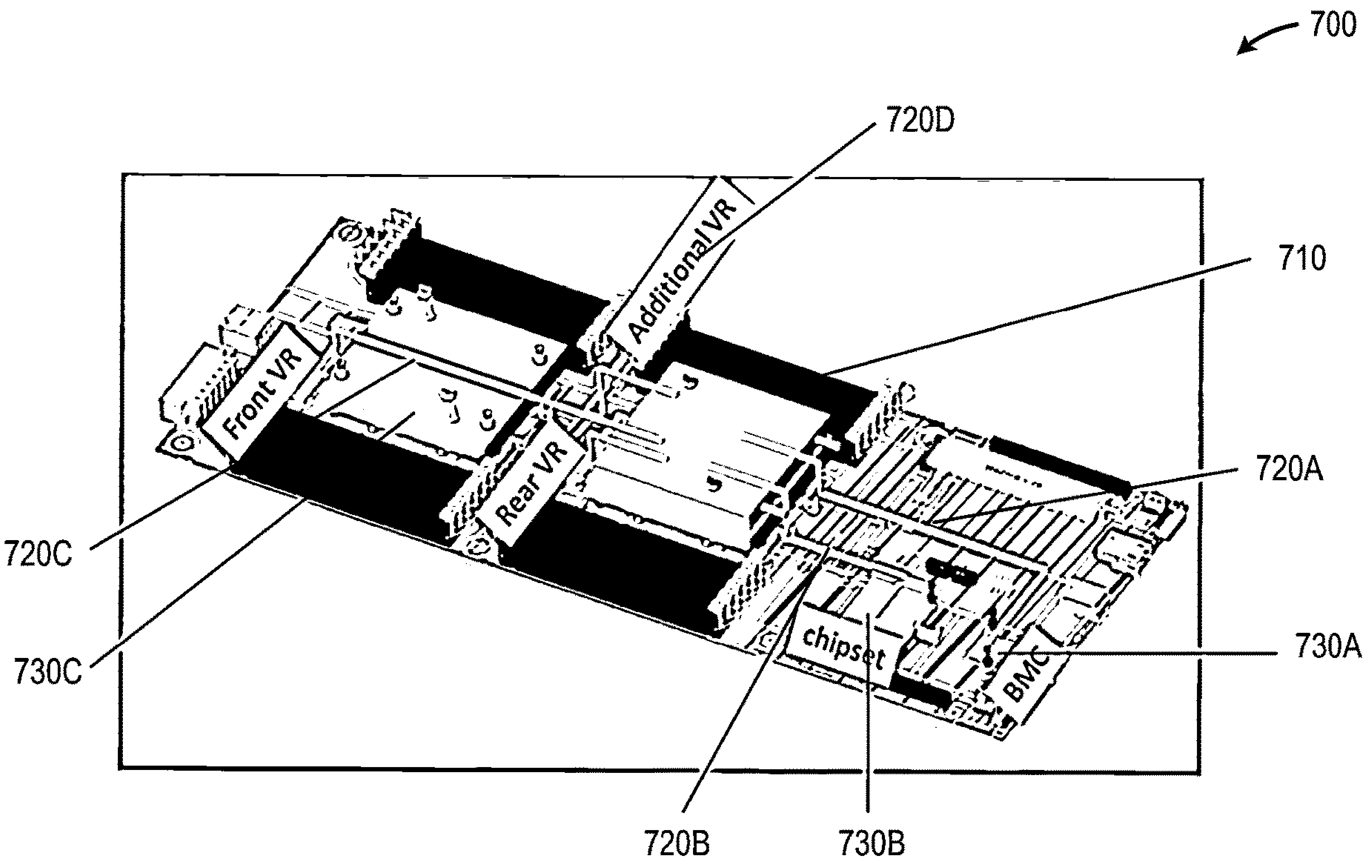

700
720D
Additional VR
710
Front VR
Rear VR
720A
720C
730C
chipset
BMC
730A
720B
730B

FIG. 7A

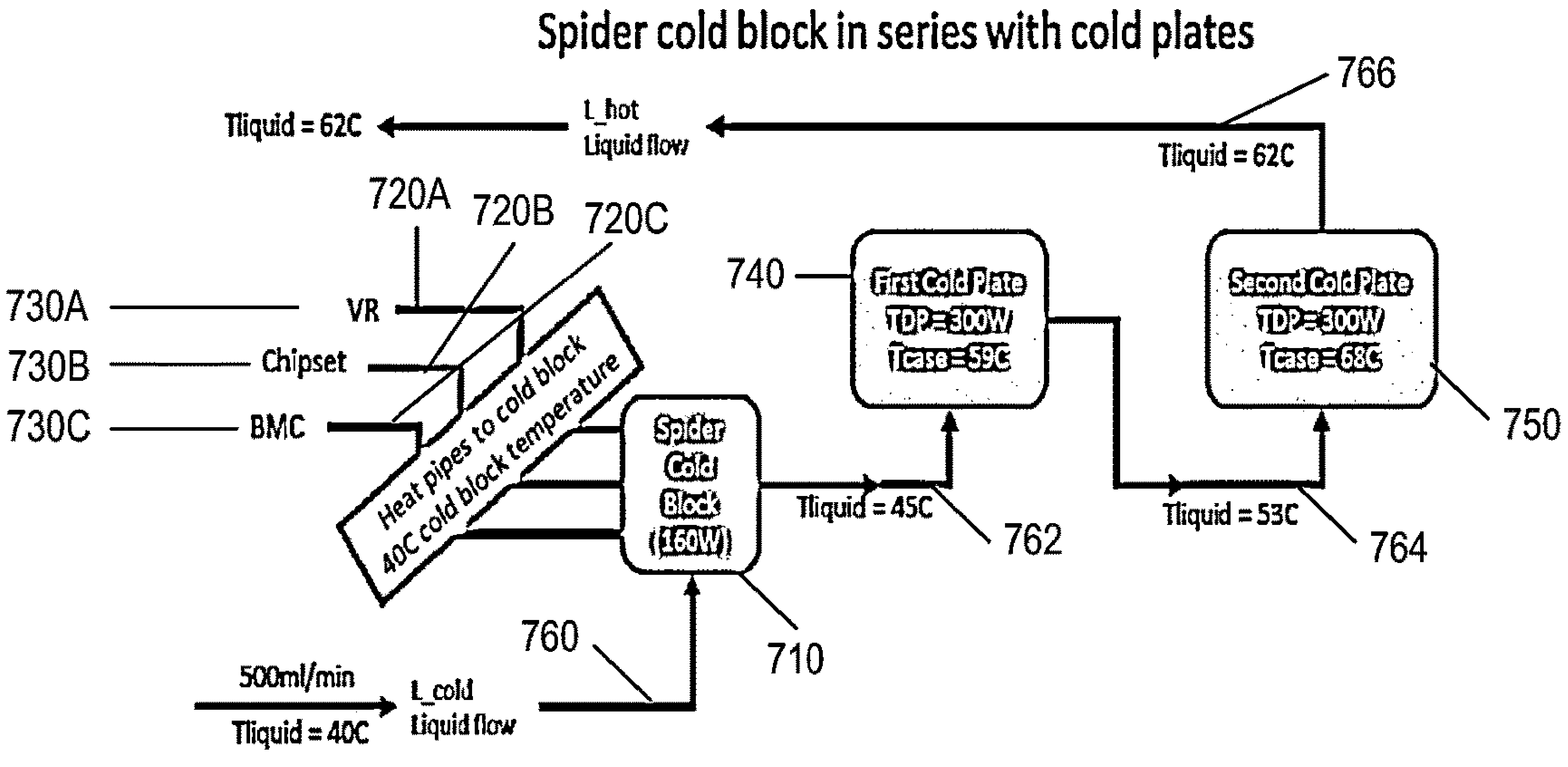

Spider cold block in series with cold plates
766
Tliquid = 62C
L_hot
Liquid flow
Tliquid = 62C
720A
720B
720C
730A
730B
730C
VR
Chipset
BMC
Heat pipes to cold block
40C cold block temperature
740
First Cold Plate
TDP=300W
Tcase=59C
Second Cold Plate
TDP=300W
Tcase=68C
750
Spider
Cold
Block
(160W)
Tliquid = 45C
762
Tliquid = 53C
764
710
760
500ml/min
Tliquid = 40C
L_cold
Liquid flow

FIG. 7B

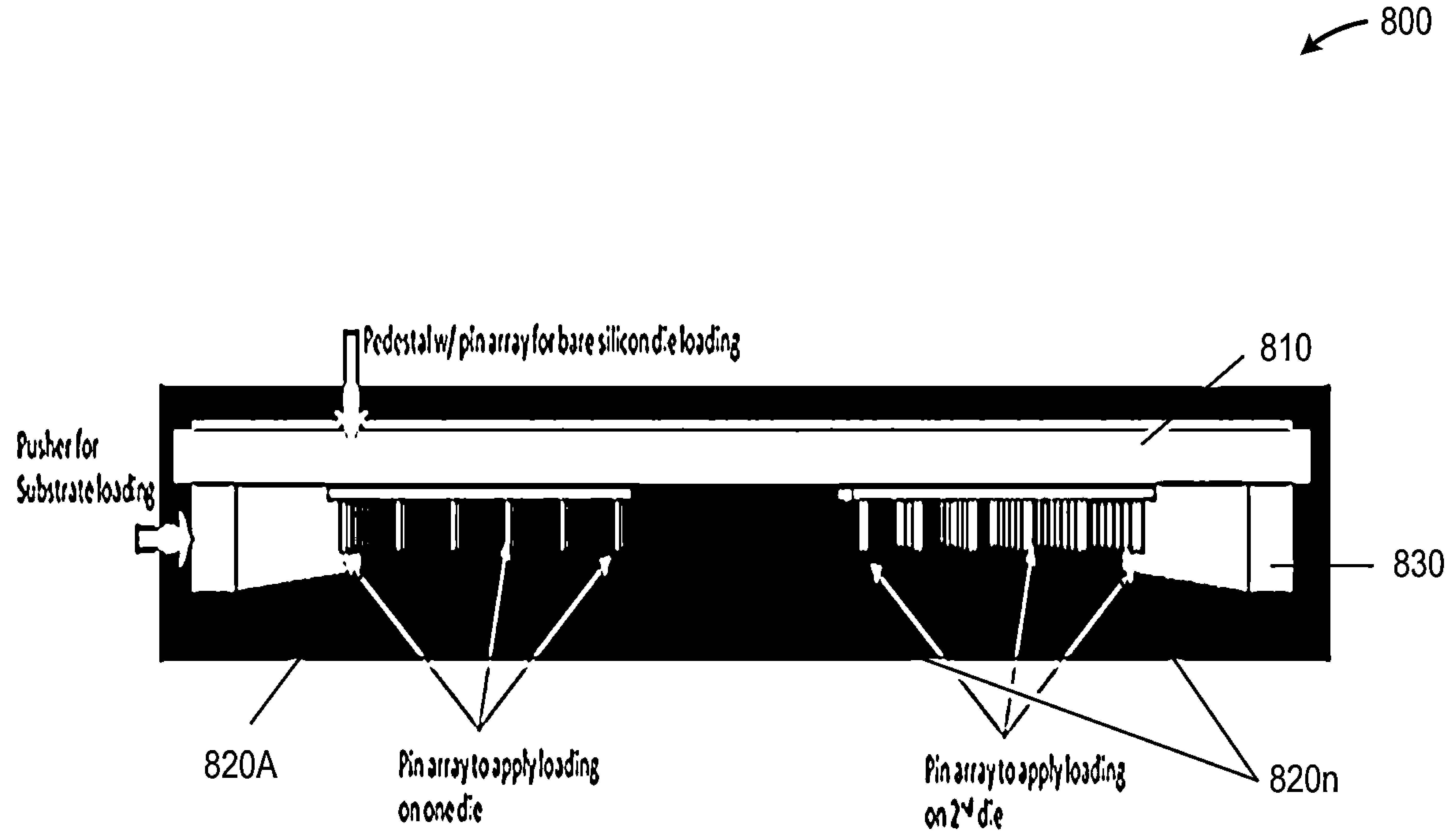

800
Pedestal w/ pin array for bare silicon die loading
810
Pusher for Substrate loading
830
820A
Pin array to apply loading on one die
Pin array to apply loading on 2nd die
820n

FIG. 8A

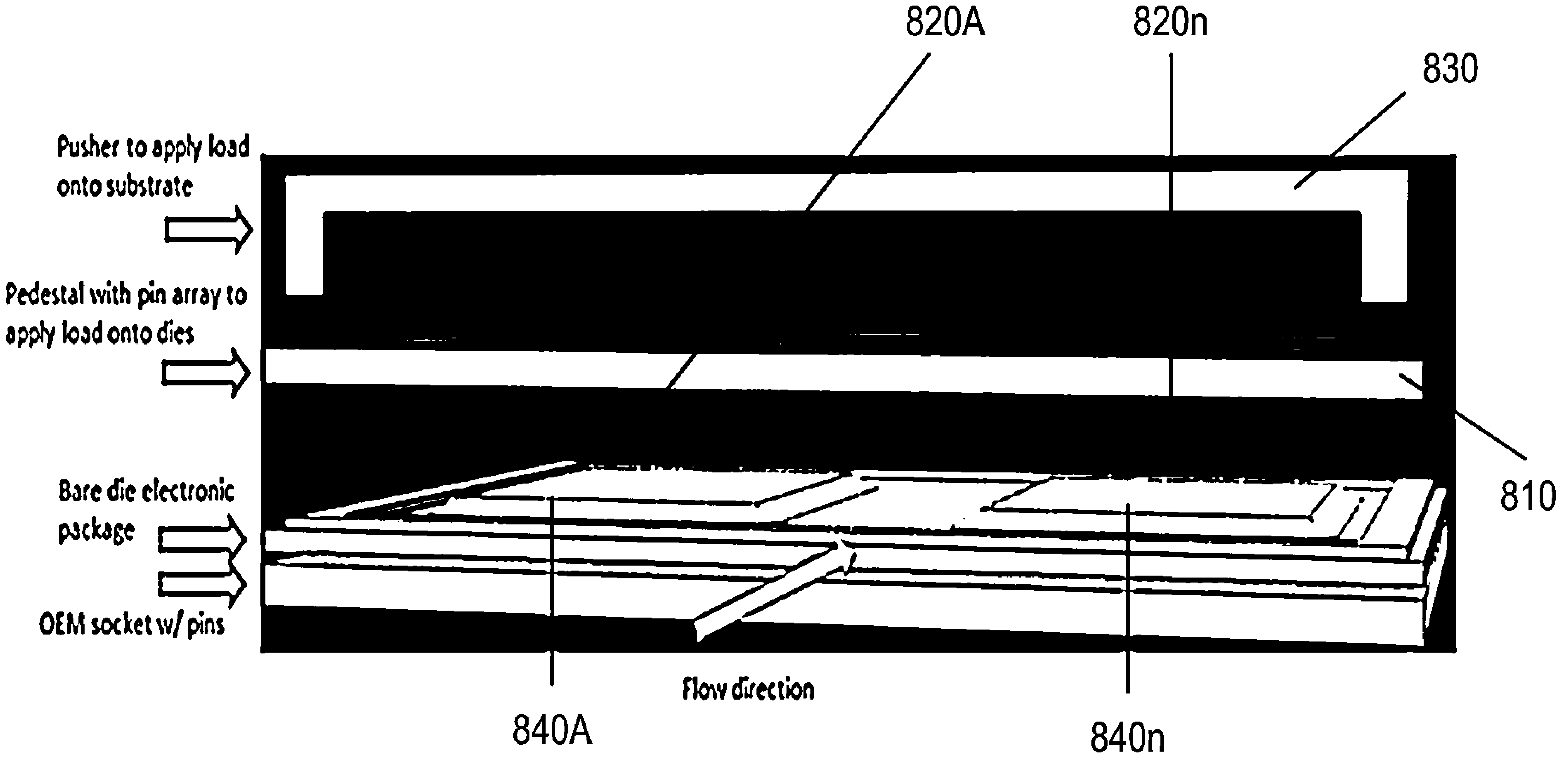

820A
820n
830
Pusher to apply load onto substrate
Pedestal with pin array to apply load onto dies
810
Bare die electronic package
OEM socket w/ pins
Flow direction
840A
840n

FIG. 8B

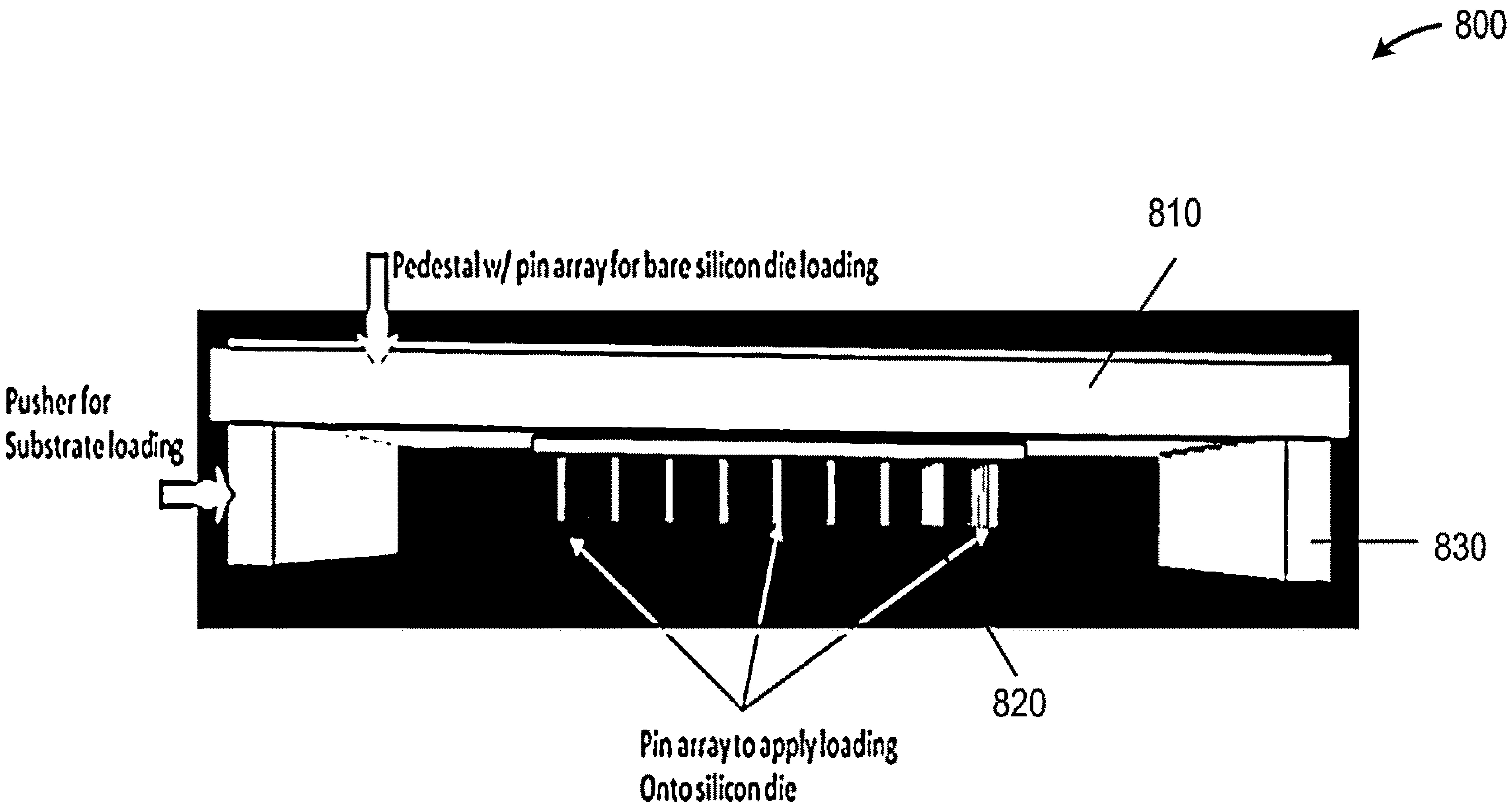

800
810
Pedestal w/ pin array for bare silicon die loading
Pusher for
Substrate loading
830
820
Pin array to apply loading
Onto silicon die

FIG. 8C

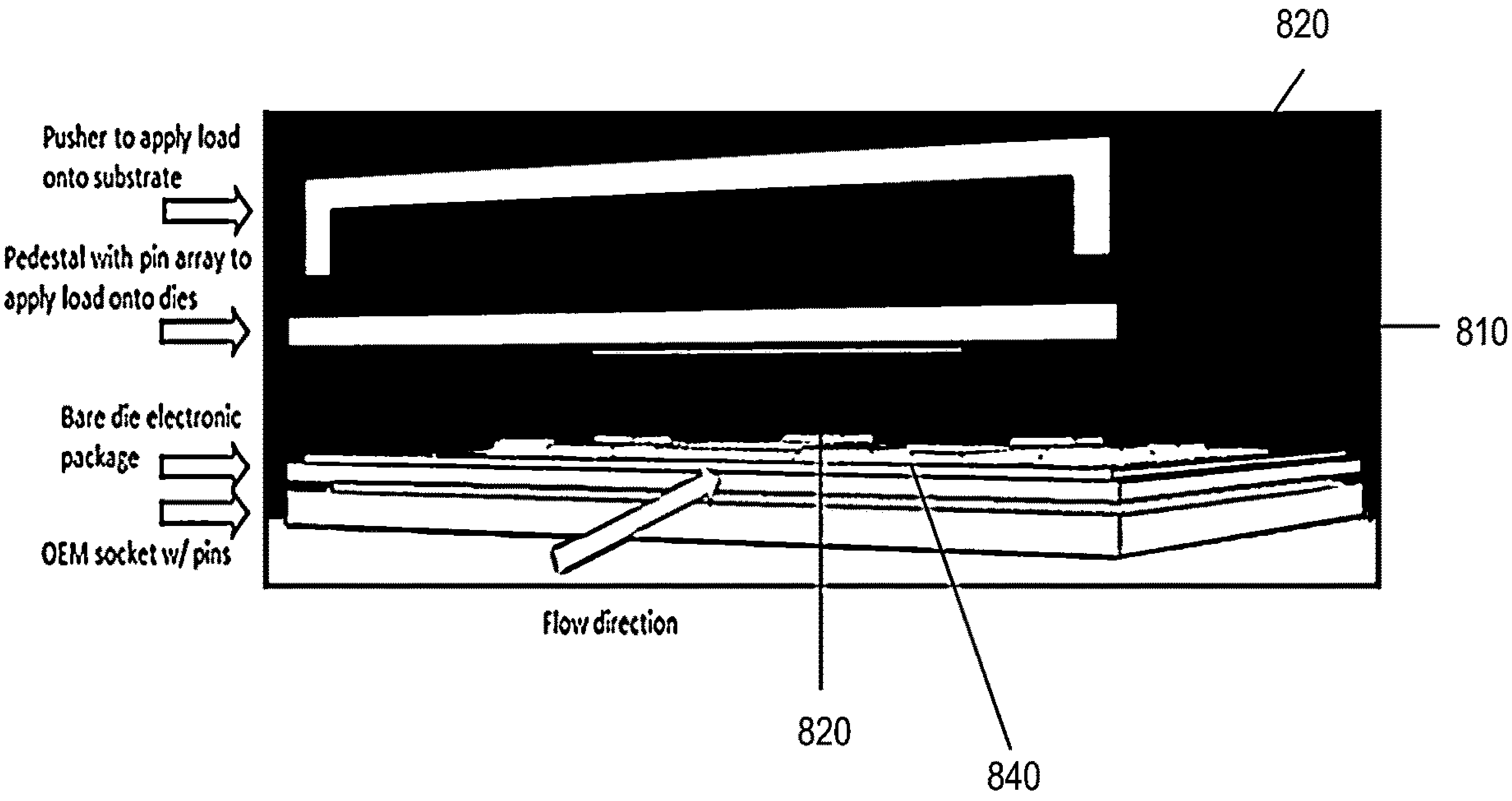
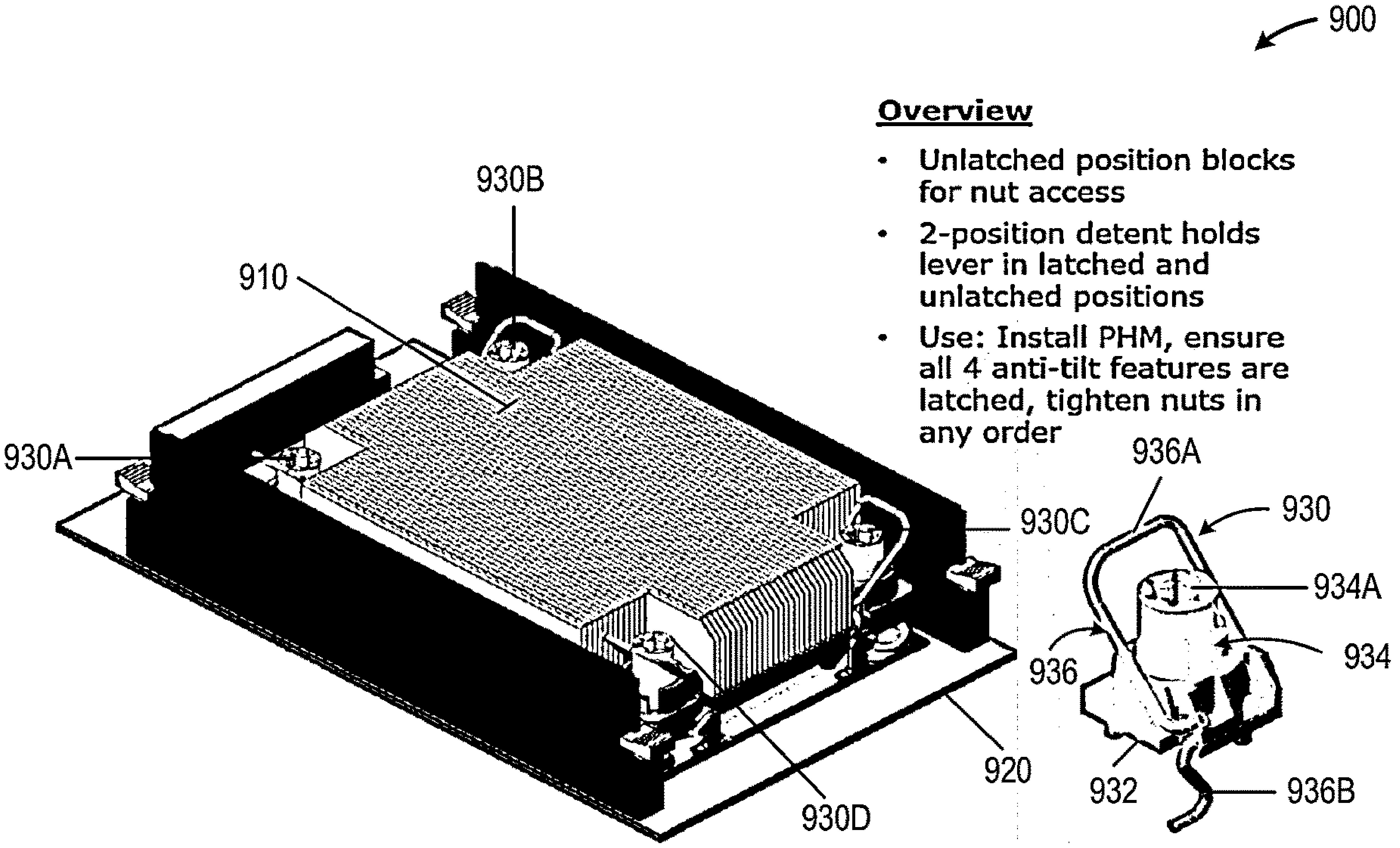

820
Pusher to apply load
onto substrate
Pedestal with pin array to
apply load onto dies
810
Bare die electronic
package
OEM socket w/ pins
Flow direction
820
840

FIG. 8D



Overview

- Unlatched position blocks for nut access
- 2-position detent holds lever in latched and unlatched positions
- Use: Install PHM, ensure all 4 anti-tilt features are latched, tighten nuts in any order

FIG. 9A

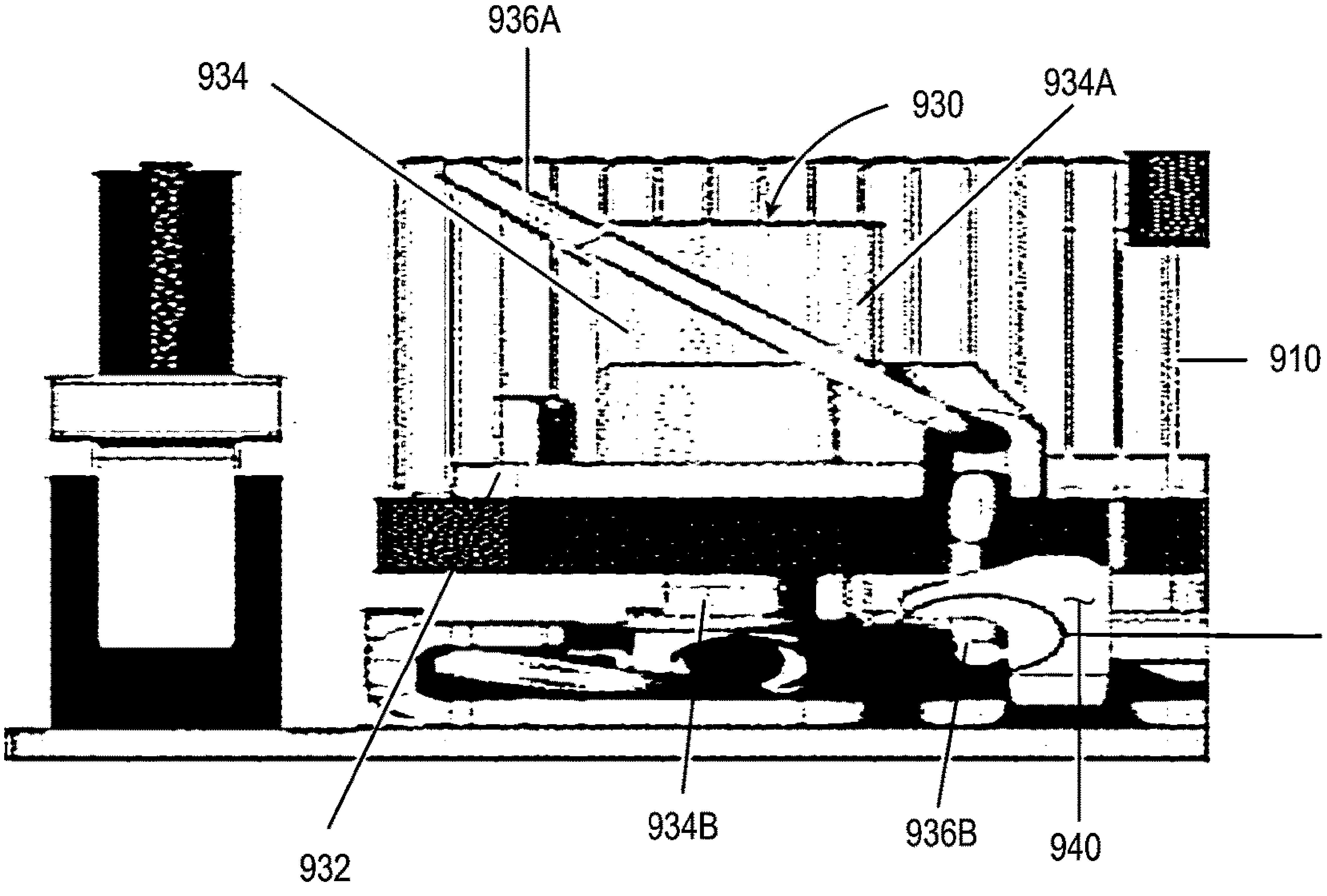


FIG. 9B

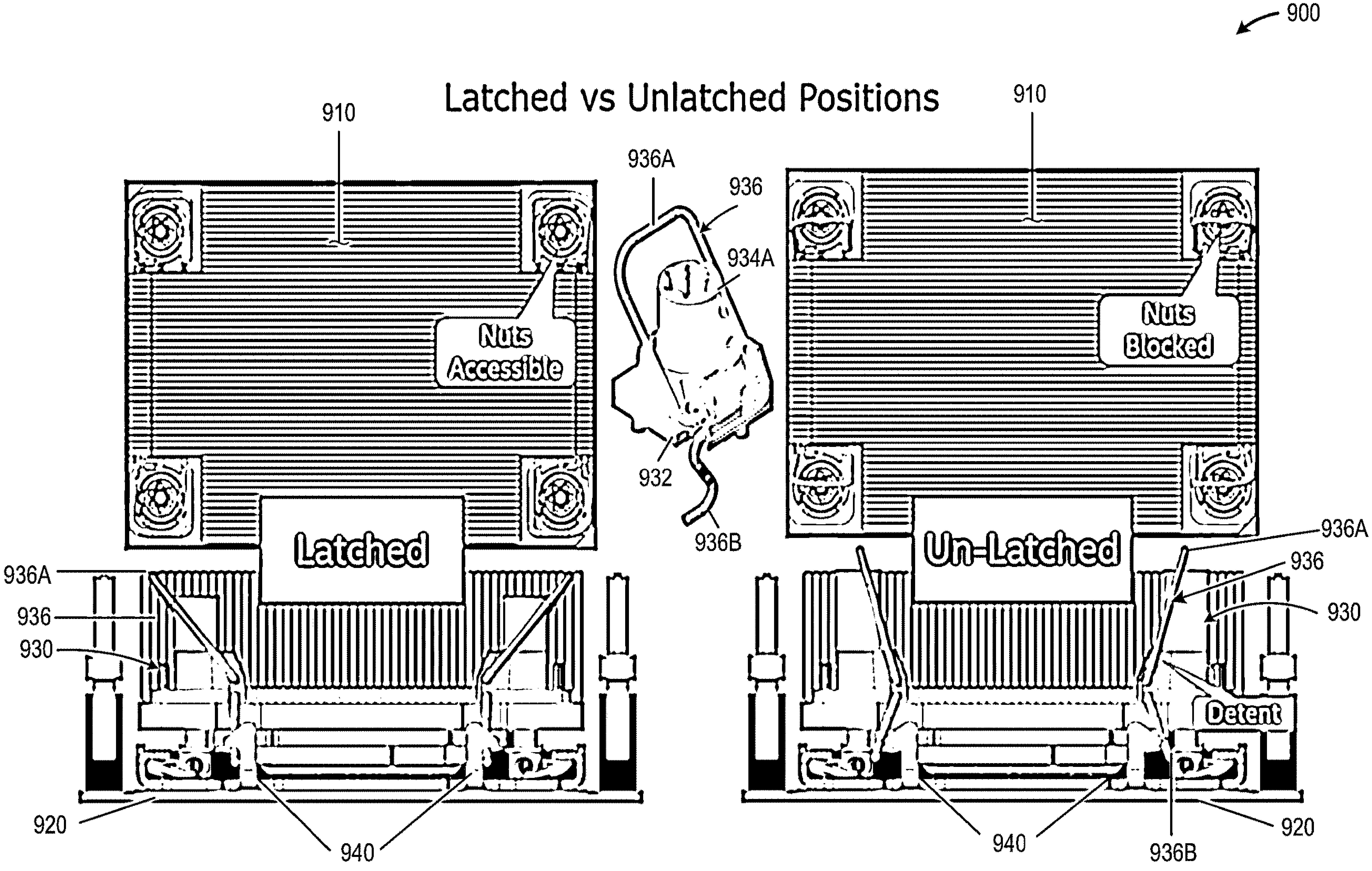

900
Latched vs Unlatched Positions
910
Nuts Accessible
Latched
936A
936
930
920
940
936A
936
934A
932
936B
910
Nuts Blocked
Un-Latched
936A
936
930
Detent
940
936B
920

FIG. 9C

FIG. 9D

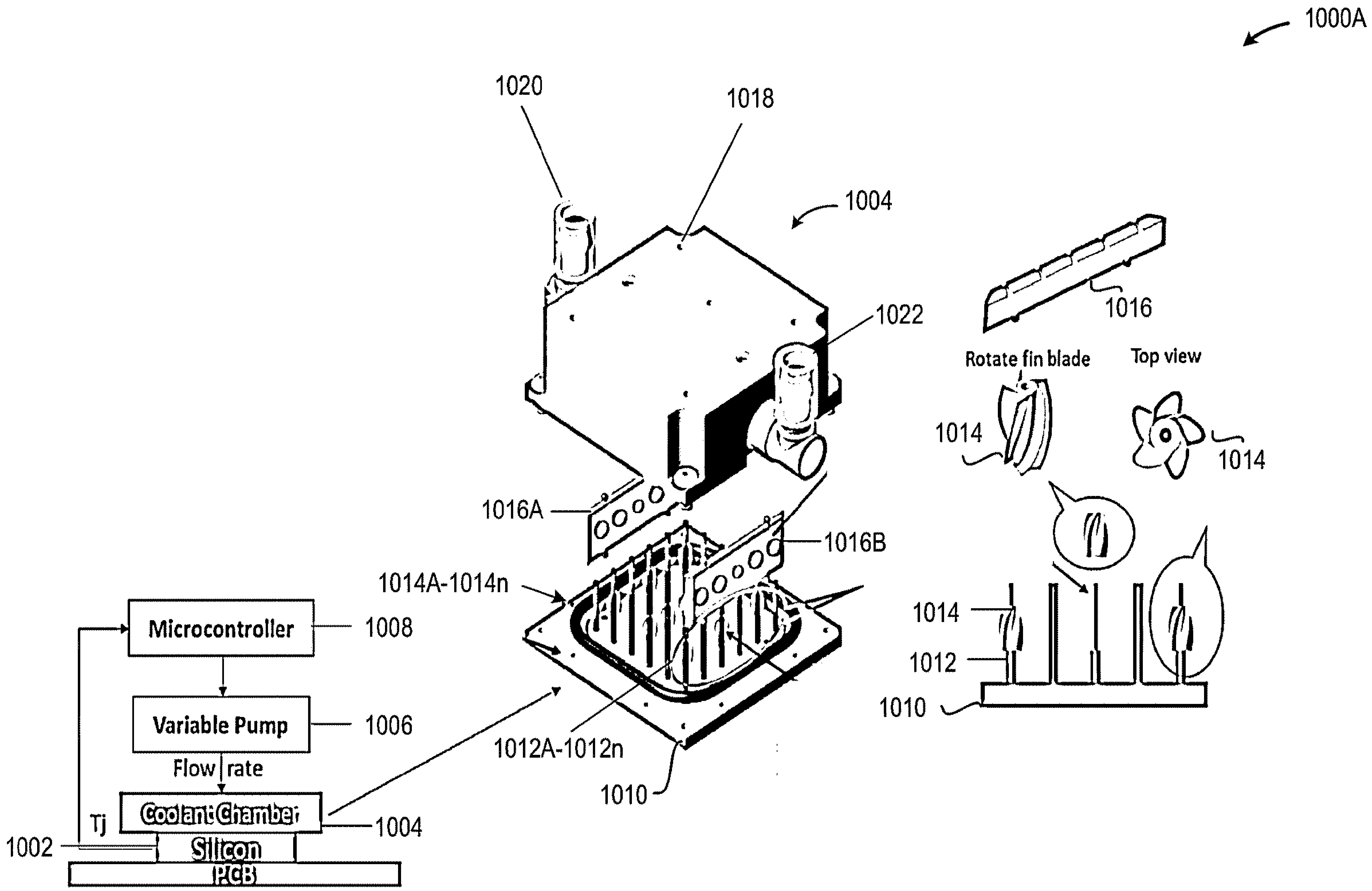

1000A
1020
1018
1004
1022
1016
Rotate fin blade
Top view
1014
1014
1016A
1016B
1014A-1014n
Microcontroller
1008
1014
1012
1010
Variable Pump
1006
1012A-1012n
Flow rate
1010
Coolant Chamber
Tj
1004
1002
Silicon
PCB

FIG. 10A

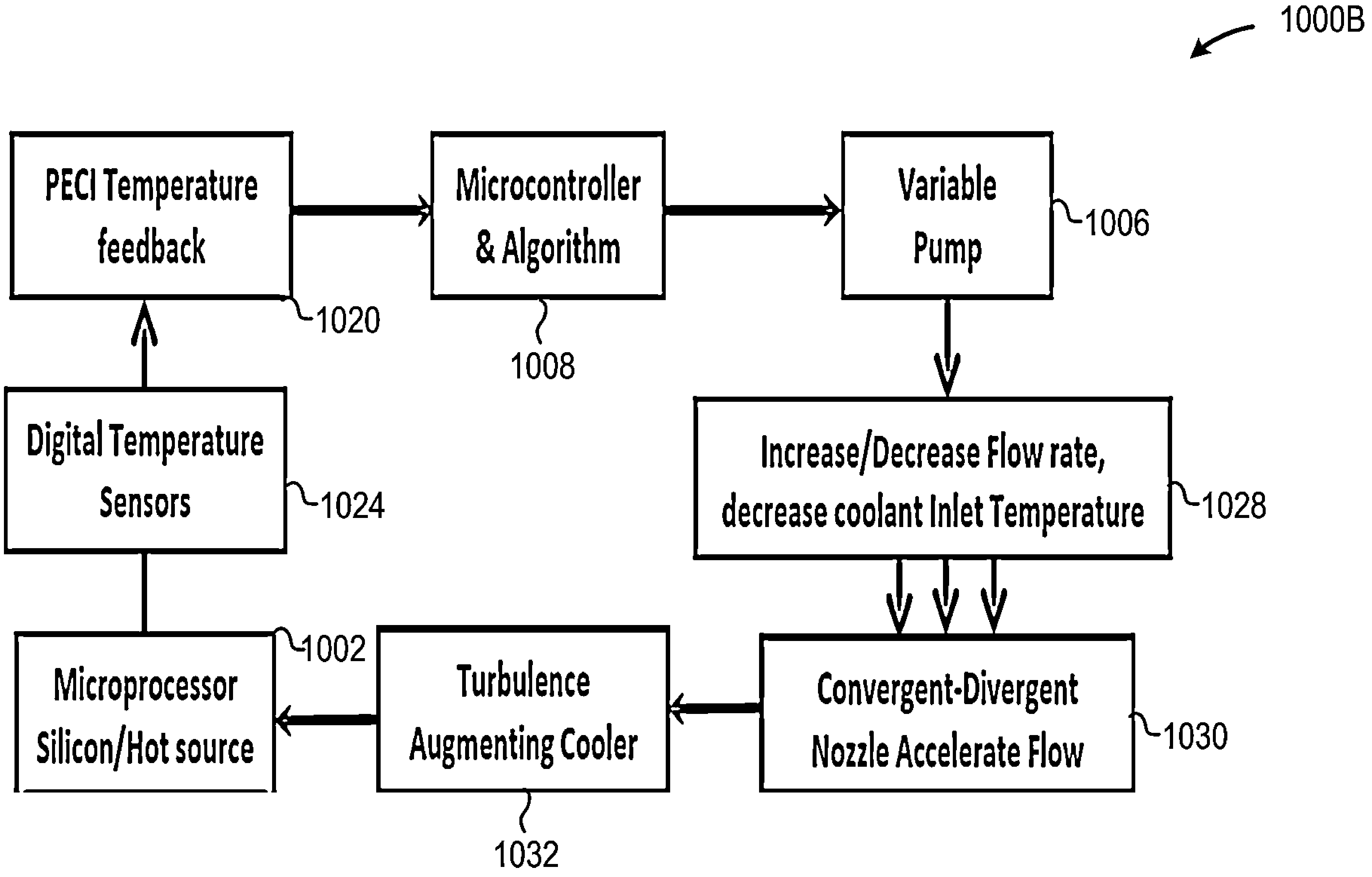


FIG. 10B

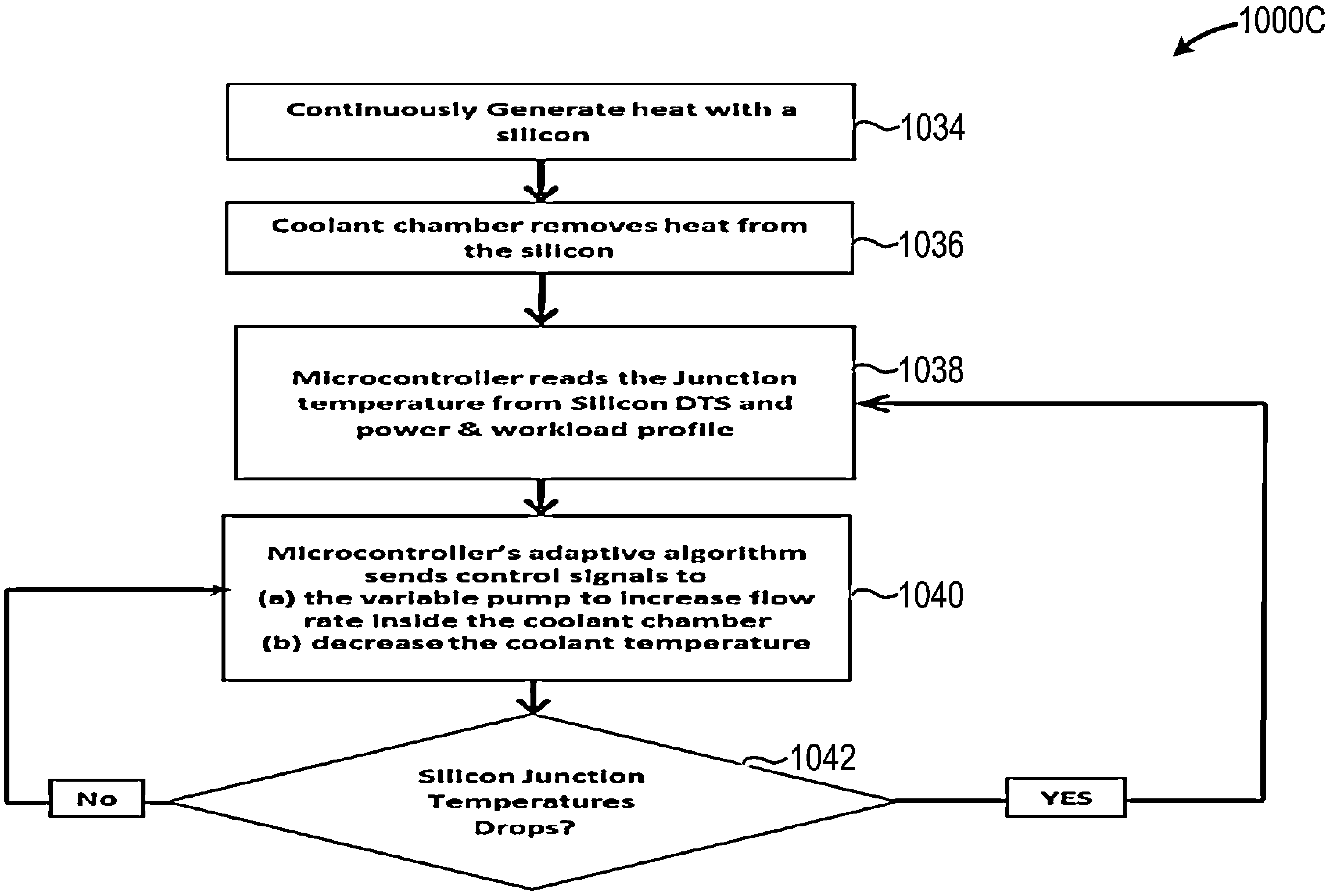


FIG. 10C

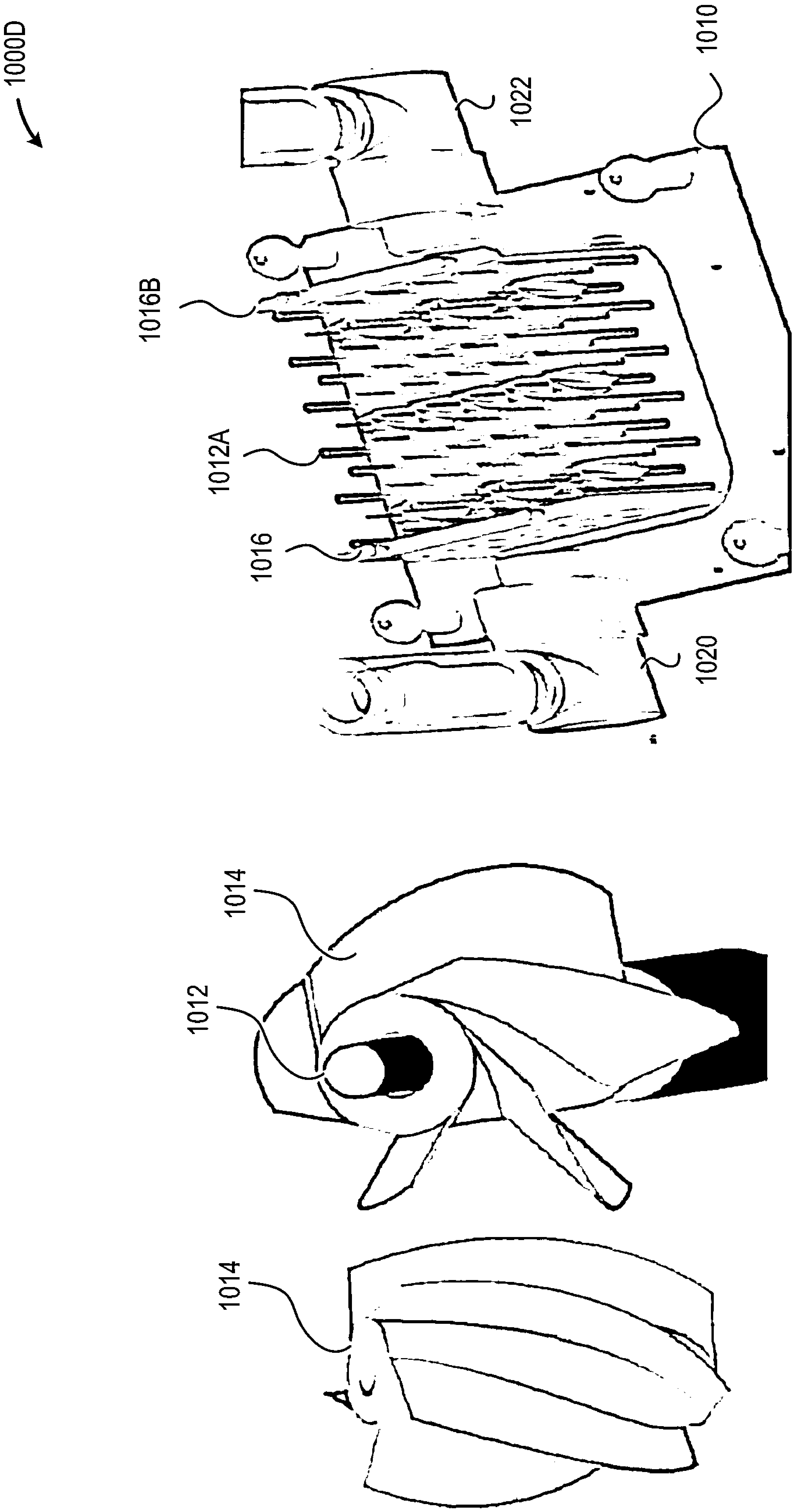


FIG. 10D

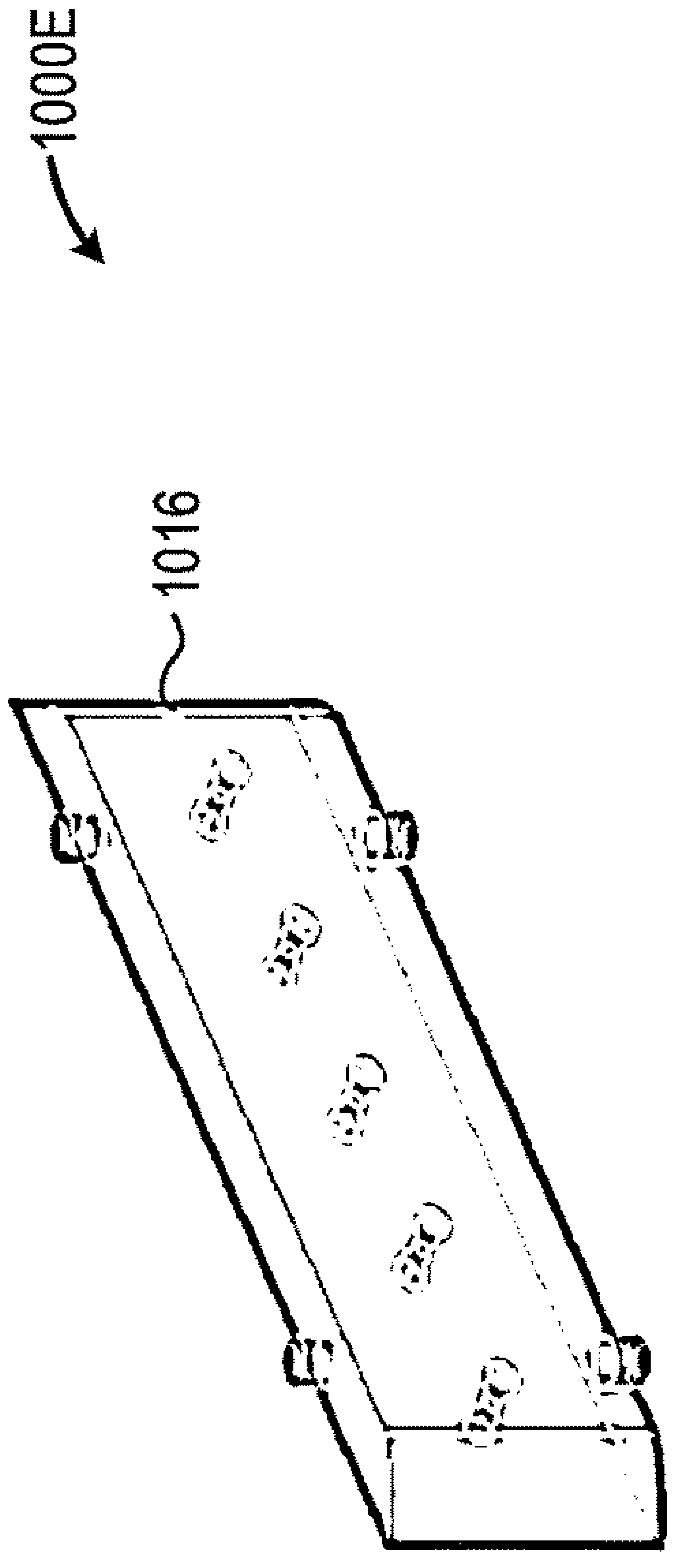


FIG. 10E

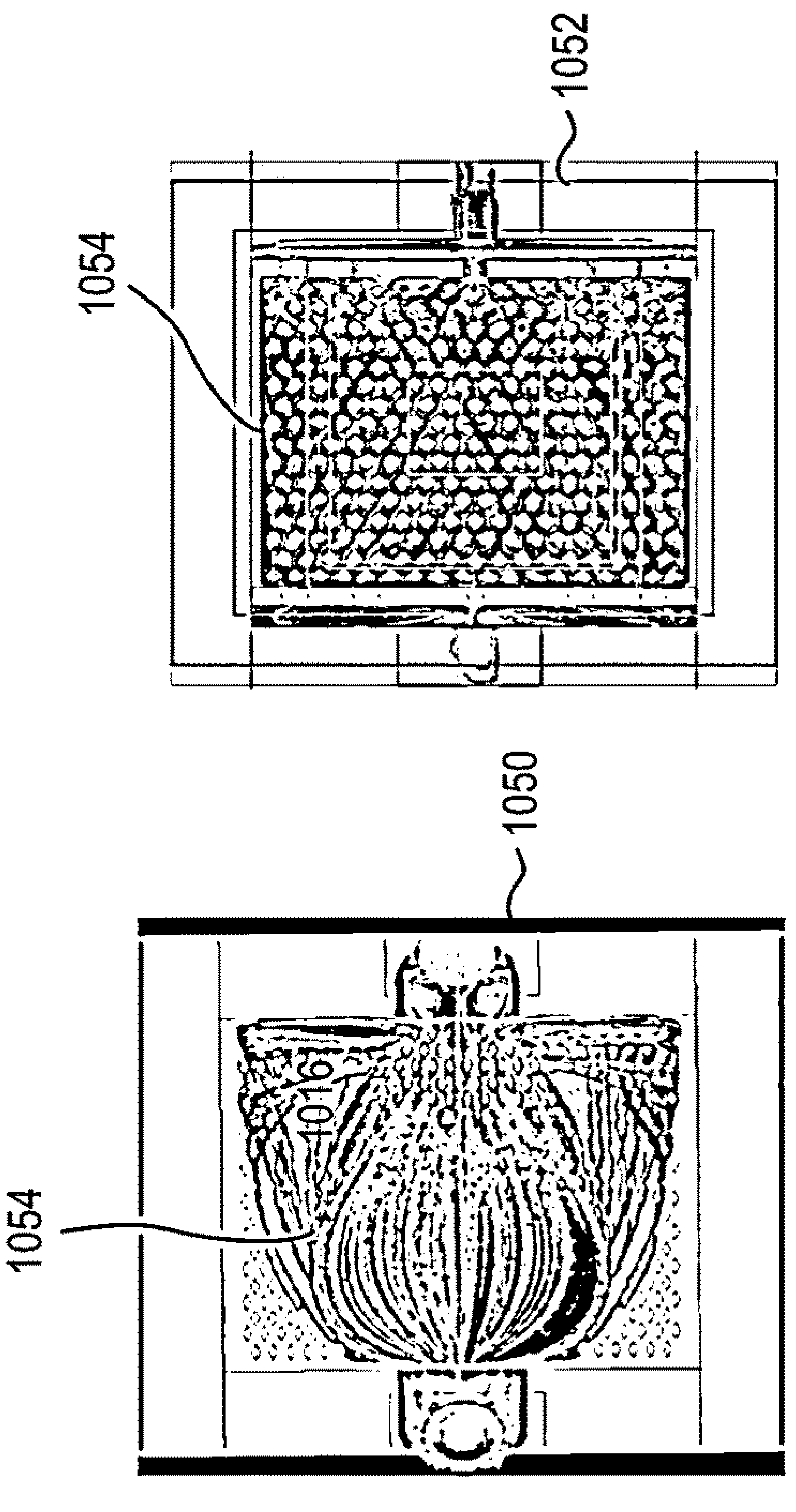


FIG. 10F

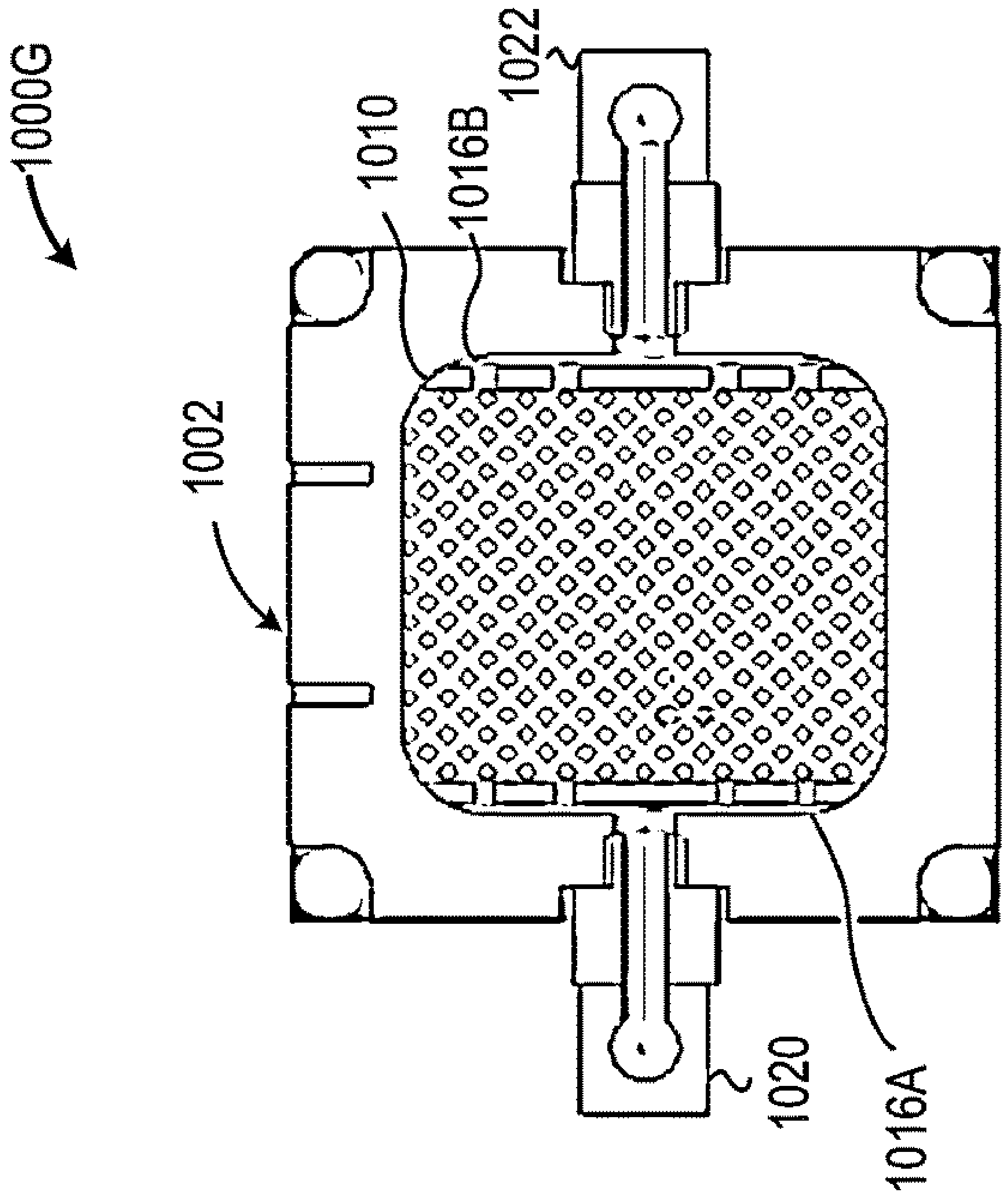


FIG. 10G

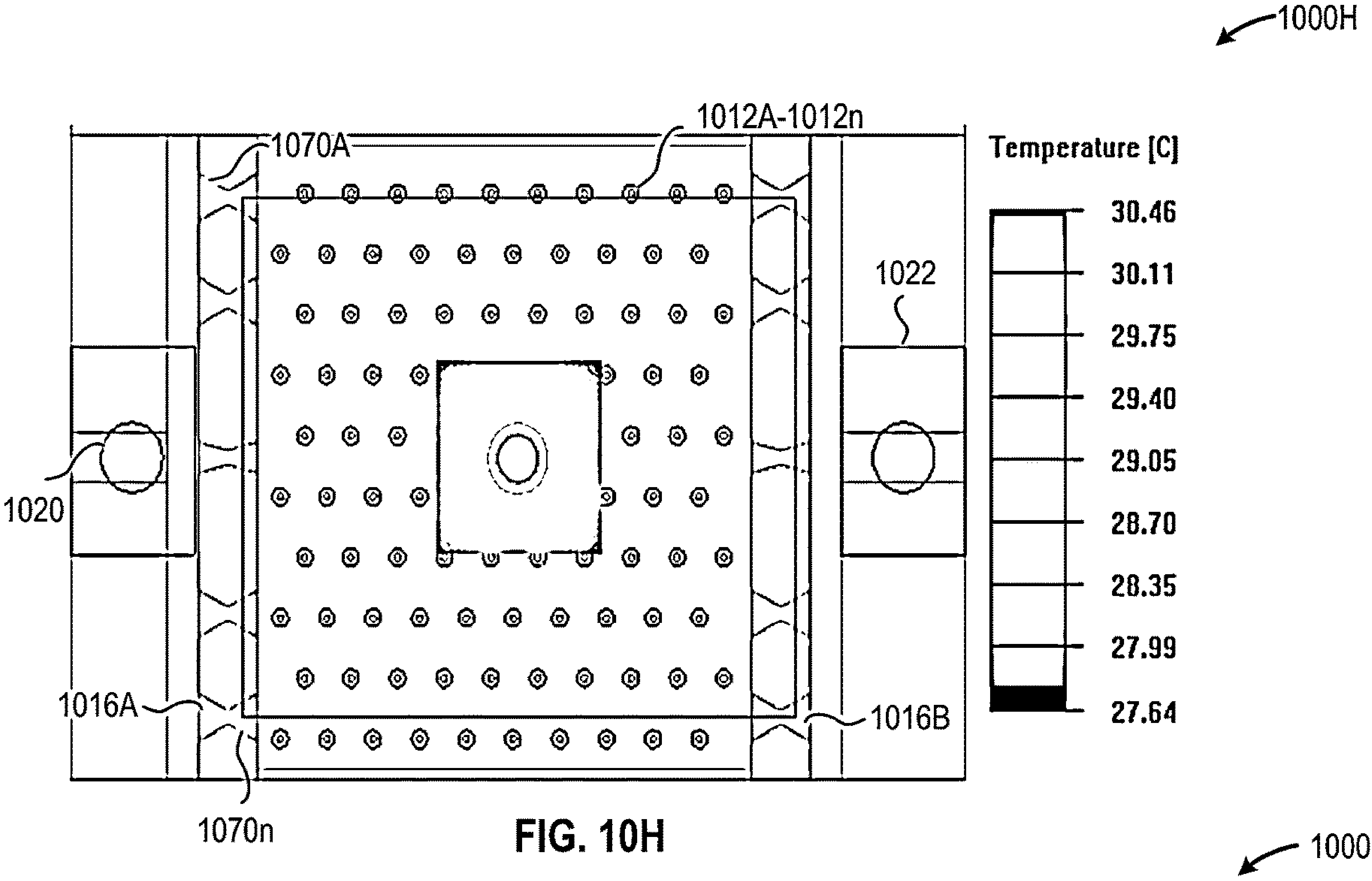


FIG. 10H

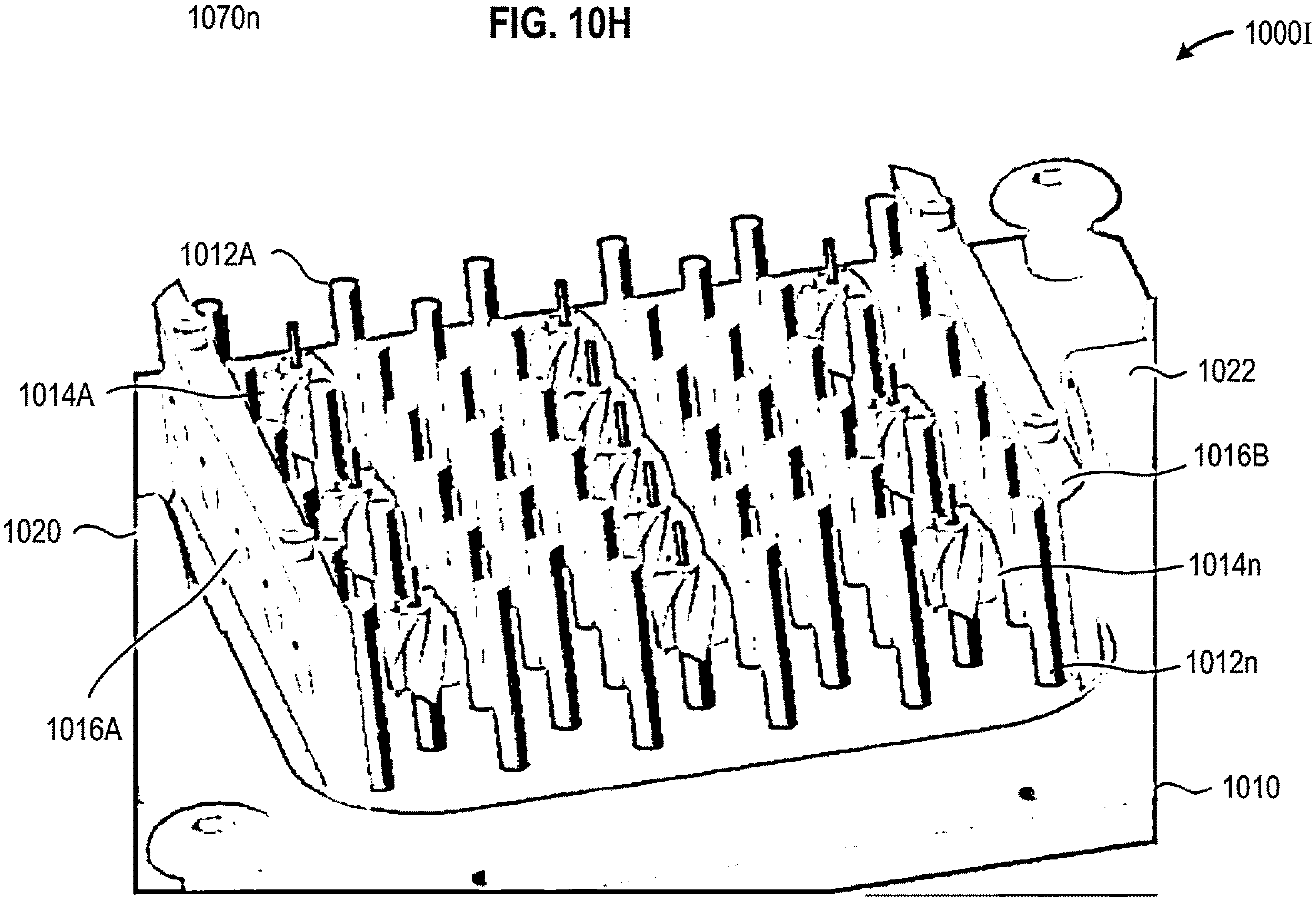


FIG. 10I

THERMAL CONTROL FOR PROCESSOR-BASED DEVICES

BACKGROUND

[0001] There is market pressure for processor-based device manufacturers to reduce the size of portable devices while at the same time improving system performance and responsiveness. Such system performance and responsiveness may be improved through the use of single- or multi-core microprocessors having extremely high component density. Such microprocessors, however, produce considerable thermal output that, when combined with a small form factor electronic device, lead to heating that can compromise the performance and/or life expectancy of the processor-based device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Features and advantages of various embodiments of the claimed subject matter will become apparent as the following Detailed Description proceeds, and upon reference to the Drawings, wherein like numerals designate like parts, and in which:

[0003] FIG. **1**A is a perspective view of an illustrative system that depicts a thermal solution including cold plate bracket coupled to a cold plate and a voltage regulator (VR) thermal solution that includes thermal channels fluidly coupling a VR cooler block to a VR cooler retention block thermally coupled to the cold plate, in accordance with at least one embodiment described herein;

[0004] FIG. **1**B is a side elevation of the illustrative system depicted in FIG. **1**A, in accordance with at least one embodiment described herein;

[0005] FIG. **1**C is another perspective view of an example embodiment of the illustrative system depicted in FIG. **1**A, in accordance with at least one embodiment described herein;

[0006] FIG. **1**D is another perspective view of another example embodiment of the illustrative system **100** depicted in FIG. **1**A, in accordance with at least one embodiment described herein;

[0007] FIG. **2**A is an illustrative CPU carrier that includes a frame member having a plurality of short stopper members and a plurality of long stopper members, in accordance with at least one embodiment described herein;

[0008] FIG. **2**B is a perspective view of the CPU carrier from FIG. **2**A being physically coupled to a heatsink, in accordance with at least one embodiment described herein;

[0009] FIG. **2**C is a perspective view of a central processing unit (CPU) being physically coupled to the assembled CPU carrier and heatsink depicted in FIG. **2**B, in accordance with at least one embodiment described herein;

[0010] FIG. **2**D is a perspective view of the assembled CPU, CPU carrier and heatsink being coupled to a board via a plurality of loading studs, in accordance with at least one embodiment described herein;

[0011] FIG. **2**E is a plan view of the heat sink and CPU coupled to the board via the CPU carrier, in accordance with at least one embodiment described herein;

[0012] FIG. **3**A is an exploded view of an illustrative spring cell, in accordance with at least one embodiment described herein;

[0013] FIG. **3**B is an elevation view of an illustrative assembled spring cell such as depicted in FIG. **3**A, in accordance with at least one embodiment described herein;

[0014] FIG. **3**C is an elevation view depicting assembly of the illustrative spring cell, in accordance with at least one embodiment described herein;

[0015] FIG. **3**D is a cut-away elevation depicting the assembly of the illustrative spring cell depicted in FIG. **3**A, in accordance with at least one embodiment described herein;

[0016] FIG. **3**E is an elevation view depicting further assembly of the illustrative spring cell, in accordance with at least one embodiment described herein;

[0017] FIG. **3**F is a perspective view of insertion of the illustrative spring cell into the base of a heat sink or similar thermal solution, in accordance with at least one embodiment described herein;

[0018] FIG. **3**G is a perspective view of the final position of the illustrative spring cell within the base of a heat sink or similar thermal solution, in accordance with at least one embodiment described herein;

[0019] FIG. **4**A is an exploded view of an illustrative system that includes a heatsink integrated backplate thermally coupled to all or a portion of a lower surface of a semiconductor package using a thermally conductive material and a thermal solution thermally coupled to all or a portion of an upper surface of the semiconductor package, in accordance with at least one embodiment described herein;

[0020] FIG. **4**B is a side elevation of the illustrative system depicted in FIG. **4**A in an assembled state in which the heatsink integrated backplate is thermally coupled to a voltage regulator module (VRM) disposed beneath the semiconductor package and the thermal solution is disposed proximate the upper surface of the semiconductor package, in accordance with at least one embodiment described herein;

[0021] FIG. **4**C is a perspective view of an illustrative heatsink integrated backplate, in accordance with at least one embodiment described herein;

[0022] FIG. **4**D is an enlarged cross-sectional elevation of the illustrative system depicted in FIGS. **4**A and **4**B, in accordance with at least one embodiment described herein;

[0023] FIG. **5**A includes perspective, plan, and elevation views of an illustrative two part, rotatable heat sink system that includes a relatively small, lower, fixed position, heat sink and a relatively large, upper, heat sink that is rotatable with respect to the lower heat sink, in accordance with at least one embodiment described herein;

[0024] FIG. **5**B is a perspective view of the illustrative two-part, rotatable heat sink system, including a rotatable mount and locking mechanism, in accordance with at least one embodiment described herein;

[0025] FIG. **5**C is an exploded view of an illustrative upper heat sink, in accordance with at least one embodiment described herein;

[0026] FIG. **5**D is a perspective view of an illustrative lower heat sink, in accordance with at least one embodiment described herein;

[0027] FIG. **5**E includes an exploded view and a cross-sectional view of an illustrative fixed pin set, in accordance with at least one embodiment described herein;

[0028] FIG. **5**F includes an exploded view and a cross-sectional view of an illustrative rotatable mount **540**, in accordance with at least one embodiment described herein;

[0029] FIG. **6**A includes perspective, plan, and elevation views of an illustrative two part, detachable, heat sink system that includes a relatively small, lower, fixed position, heat sink thermally coupled to a relatively large, upper, heat sink that is removable from the lower heat sink, in accordance with at least one embodiment described herein;

[0030] FIG. **6**B is a side elevation of the detachable heat sink system depicted in FIG. **6**A demonstrating the overhang of the upper heat sink over components mounted on a substrate, in accordance with at least one embodiment described herein;

[0031] FIG. **6**C is a perspective view of the detachable heat sink system depicted in FIG. **6**A demonstrating the overhang of the upper heat sink over components mounted on a substrate, in accordance with at least one embodiment described herein;

[0032] FIG. **6**D includes perspective and exploded views of an illustrative embodiment of the detachable heat sink system using a plurality of fasteners to physically and thermally couple the upper heat sink to the lower heat sink, in accordance with at least one embodiment described herein;

[0033] FIG. **6**E includes perspective and exploded views of an illustrative embodiment of the detachable heat sink system using a plurality of clamps to physically and thermally couple the upper heat sink to the lower heat sink, in accordance with at least one embodiment described herein;

[0034] FIG. **6**F includes perspective and exploded views of an illustrative embodiment of the detachable heat sink system using a a spring clip to physically and thermally couple the upper heat sink to the lower heat sink, in accordance with at least one embodiment described herein;

[0035] FIG. **7**A is a perspective view of an illustrative distributed thermal control system that includes a chilled distribution block coupled to a plurality of geographically distributed heat producing components by a plurality of thermal conduits, in accordance with at least one embodiment described herein;

[0036] FIG. **7**B is a schematic diagram that includes the distributed thermal control system depicted in FIG. **7**A, in accordance with at least one embodiment described herein;

[0037] FIG. **8**A is an elevation view of an illustrative die loading apparatus for use with multiple semiconductor dies, the loading apparatus including a pedestal member, one or more pin arrays coupled to the pedestal member, and one or more pusher members, in accordance with at least one embodiment described herein;

[0038] FIG. **8**B is a perspective view of an illustrative system that includes a plurality of semiconductor dies that are seated to a socket disposed on a substrate using a die loading apparatus such as depicted in FIG. **8**A and in which, after installation, the pin arrays create a fluid channel between the upper surface of the semiconductor dies and the lower surface of the pedestal member, in accordance with at least one embodiment described herein;

[0039] FIG. **8**C is an elevation view of an illustrative single die loading apparatus **800** that includes a pedestal member, a single pin array coupled to the pedestal member **810**, and one or more pusher members, in accordance with at least one embodiment described herein;

[0040] FIG. **8**D is a perspective view of an illustrative system that includes a single semiconductor die that is seated using a single loading apparatus such as depicted in FIG. **8**C and in which the pin array creates a fluid channel between the upper surface of the semiconductor die and the lower surface of the pedestal member, in accordance with at least one embodiment described herein;

[0041] FIG. **9**A is a perspective view of a system that includes a thermal solution secured to a substrate using a plurality of detent fasteners rotatably positionable between an UNLATCHED position in which the detent fastener does not engage a surface feature coupled to the substrate and a LATCHED position in which the detent fastener engages a surface feature coupled to the substrate, in accordance with at least one embodiment described herein;

[0042] FIG. **9**B is a cross-sectional view of an illustrative system in which the detent fastener is disposed in the LATCHED position in which the rotating member coupled to the detent fastener engages a surface feature coupled to the substrate, in accordance with at least one embodiment described herein;

[0043] FIG. **9**C includes a plan view and a cross-sectional view of an illustrative system in which the detent fastener is disposed in the LATCHED position in which the rotating member coupled to the detent fastener engages a surface feature coupled to the substrate, in accordance with at least one embodiment described herein;

[0044] FIG. **9**D is a cross-sectional view of an illustrative system in which the detent fastener is disposed in the UNLATCHED position in which the rotating member coupled to the detent fastener does not engage the surface feature coupled to the substrate, in accordance with at least one embodiment described herein;

[0045] FIG. **10**A is a perspective view of a thermal solution that includes a flow-through coolant chamber incorporating an internal distribution header, an internal collection header **1**, a plurality of extended thermal members, and a plurality of turbulence elements disposed about at least a portion of the thermal members and, in which, the thermal solution thermally couples to one or more heat producing devices **1002**, in accordance with at least one embodiment described herein;

[0046] FIG. **10**B is a flow diagram of an illustrative method of cooling a heat producing device using a thermal solution such as described in detail in FIG. **10**A, in accordance with at least one embodiment described herein;

[0047] FIG. **10**C is a flow diagram of an illustrative method of cooling a heat-producing device with a thermally coupled thermal solution such as described in FIG. **10**A, in accordance with at least one embodiment described herein;

[0048] FIG. **10**D is a perspective view of an illustrative turbulence element and an illustrative thermal solution, in accordance with at least one embodiment described herein;

[0049] FIG. **10**E is a perspective view of an illustrative distribution header and/or collection header, in accordance with at least one embodiment described herein;

[0050] FIG. **10**F is a hypothetical model depicting a comparison of coolant flow through a thermal solution without distribution and collection headers and coolant flow through a thermal solution equipped with distribution and collection headers, in accordance with at least one embodiment described herein;

[0051] FIG. **10**G is a plan view of an illustrative thermal solution that includes a base member, a plurality of thermal members physically and thermally coupled to the base member, turbulence elements disposed about at least a portion of the thermal members, in accordance with at least one embodiment described herein;

[0052] FIG. **10**H is a plan view of an illustrative thermal solution that illustrates the thermal distribution of a heat-producing device disposed proximate the base member of the thermal solution and also depicts the relative sizes and/or locations of a plurality of convergent/divergent nozzles disposed in the distribution header and the collection header, in accordance with at least one embodiment described herein; and

[0053] FIG. **10**I is a perspective view of an illustrative thermal solution that include a plurality of turbulence elements disposed on at least a portion of the thermal members, in accordance with at least one embodiment described herein.

[0054] Although the following Detailed Description will proceed with reference being made to illustrative embodiments, many alternatives, modifications and variations thereof will be apparent to those skilled in the art.

DETAILED DESCRIPTION

[0055] The systems and methods disclosed herein improve the thermal performance of heat-producing devices disposed within processor-based devices, such as data servers. Such thermal performance improvements may include increasing the thermal performance of a system by adding a heat transfer area. Such thermal performance improvements may include providing dedicated thermal solutions for voltage regulation circuitry used by processor-based devices. Such thermal performance improvements may include improving the flow of cooling media around components in a direct-contact or immersed cooling environment.

[0056] An electronic device cooling system is provided. The cooling system may include: a cold plate thermally and physically couplable to a first heat-producing semiconductor device; a thermal retention block member thermally and physically couplable to the cold plate; a remote device cooler block thermally and physically couplable to a second heat-producing device, the second heat-producing device disposed remote from the first heat-producing semiconductor device; and one or more thermal channels, each of the one or more thermal channels having a first end and a second end, the first end of each of the one or more thermal channels thermally coupled to the remote device cooler block and the second end of each of the one or more thermal channels thermally coupled to the thermal retention block member.

[0057] A semiconductor device carrier apparatus is provided. The apparatus may include: a frame member having an upper surface couplable to a thermal solution and a lower surface couplable to a heat-producing semiconductor device; where the frame member includes a plurality of apertures, each of the plurality of apertures to accommodate the passage of at least one fastener to couple the frame member to a substrate that includes the heat-producing semiconductor device; a plurality of short stopper members disposed on the lower surface of the frame member and about the periphery of the frame member; where each of the plurality of short stopper members includes a first material having a first durometer value; and a plurality of long stopper members disposed on the lower surface of the frame member and about the periphery of the frame member; wherein each of the plurality of long stopper members includes a second material having a second durometer value, the second durometer value less than the first durometer value.

[0058] A thermal solution spring cell is provided. The spring cell may include: a fastener head; a fastener body coupled to the fastener head that includes: an upper portion coupled to the fastener head, the upper portion including a cylindrical member having a first diameter; a lower portion coupled to the upper portion, the lower portion including: a cylindrical portion having a second diameter greater than the first diameter, to form a shoulder between the upper portion and the lower portion; and a groove to receive a clip member, the groove formed at least partially about the periphery of the lower cylindrical portion, the groove disposed proximate an end of the lower portion of the fastener body distal from the upper portion of the fastener body; a compressible element disposed proximate at least a portion of the upper portion of the fastener body; and a retaining ring to at least partially compress the compressible element about the upper portion of the fastener body and physically engage the shoulder between the upper portion of the fastener body and the lower portion of the fastener body.

[0059] A central processing unit (CPU) backplate apparatus is provided. The apparatus may include: a backplate to couple to a first surface of a printed circuit board opposite a CPU disposed on a second surface of the printed circuit board, the first surface transversely opposed across a thickness of the printed circuit board from the second surface; an extended heat transfer surface physically and thermally coupled to a first surface of the backplate, the first surface of the backplate transversely opposed across a thickness of the backplate from a second surface of the backplate, the second surface of the backplate proximate the first surface of the printed circuit board.

[0060] A semiconductor device extended surface heat transfer apparatus is provided. The heat transfer apparatus may include: a first extended surface heat transfer device that includes a baseplate having an upper surface and a lower surface and a plurality of fins physically and thermally coupled to the upper surface of the baseplate, the first extended surface heat transfer device having a first longitudinal axis; a thermally conductive rotatable mount having a first end and a second end, wherein the first end of the thermally conductive rotatable mount attaches to the upper surface of the baseplate of the first extended surface heat transfer device; and a second extended surface heat transfer device that includes a baseplate having an upper surface and a lower surface and a plurality of fins physically and thermally coupled to the upper surface of the baseplate, the second extended surface heat transfer device having a second longitudinal axis; wherein the second end of the thermally conductive rotatable mount attaches to the lower surface of the baseplate of the second extended surface heat transfer device; and wherein the thermally conductive rotatable mount permits the second longitudinal axis of the second extended surface heat transfer device to rotate through an angle of at least 90 degrees with respect to the first longitudinal axis of the first extended surface heat transfer device.

[0061] A thermal transfer system is provided. The thermal transfer system may include: a distribution block including at least one cooling medium inlet to receive a cooling medium and at least one cooling medium outlet; a cold block physically and thermally couplable to a first heat-producing, board-mounted device, the cold block including at least one cooling medium inlet fluidly coupled to the at least one cooling medium outlet of the distribution block to receive the cooling medium from the distribution block; at least one remote cold block physically and thermally couplable to at least one heat producing board mounted device; and at least one thermal conduit having a first end and a second end, the first end thermally couplable to the distribution block and the second end thermally couplable to the remote cold block.

[0062] A two-part, detachable heat sink system is provided. The system may include: a first extended surface heat transfer device having a first heat transfer area, an upper surface, and a lower surface, the lower surface disposed proximate a heat-producing device coupled to a substrate; a thermal interface member thermally coupled to the upper surface of the first extended surface heat transfer device; a second extended surface heat transfer device having a second heat transfer area, an upper surface, and a lower surface, the lower surface, the second extended surface heat transfer device disposed proximate and thermally coupled to the thermal interface member; and one or more fasteners to detachably attach the second extended surface heat transfer device to the thermal interface member and to the first extended surface heat transfer device

[0063] A semiconductor die insertion system is provided. The system may include: a pedestal member having a thickness, an upper surface, and a lower surface; at least one pin array that includes a plurality of pin members extending from the lower surface of the pedestal member, the at least one pin array disposed across at least a portion of the lower surface of the pedestal member; wherein each of the plurality of pin members extend a first distance from the lower surface of the pedestal member; and a pusher member having a upper surface and a lower surface, the pusher member including at least one extension member that projects a second distance from the lower surface of the pusher member; wherein the second distance is greater than the sum of the pedestal member thickness and the first distance.

[0064] A thermal solution fastener is provided. The fastener may include: a fastener member having a head portion and a body portion; a fastener housing disposed about at least a portion of the body portion of the fastener member, the fastener slidably displaceable through an aperture formed in the fastener housing; and a rotatable member rotatably coupled to the fastener housing, the rotatable member including: an upper portion that in a first position is disposed proximate the head portion of the fastener member and in a second position is disposed remote from the head portion of the fastener member; and a lower portion that in the first position disengages from a surface feature coupled to an upper surface of a substrate and in the second position engages the surface feature coupled to the upper surface of the substrate.

[0065] A thermal solution is provided. The thermal solution may include: an enclosed chamber that includes: a thermally conductive lower surface to dispose proximate at least a portion of a surface of a heat-producing electronic component; at least one coolant inlet to receive a coolant flow; and at least one coolant outlet to discharge the received coolant flow; and a plurality of turbulence elements to cause a coolant flowing through the enclosed chamber to flow in a turbulent flow regime across at least a portion of the thermally conductive lower surface.

[0066] A thermal solution system is provided. The system may include: at least one sensor to measure a thermal output of at least one heat-producing electronic component; a variable flow output fluid mover to discharge a coolant; an enclosed chamber that includes: a thermally conductive lower surface to dispose proximate at least a portion of a surface of a heat-producing electronic component; at least one coolant inlet to receive a coolant flow; and at least one coolant outlet to discharge the received coolant flow; and a plurality of turbulence elements to cause a coolant flowing through the enclosed chamber to flow in a turbulent flow regime across at least a portion of the thermally conductive lower surface; and control circuitry communicatively coupled to the at least one sensor and the variable flow output fluid mover, the control circuitry to: adjust the coolant flow provided by the variable flow output fluid mover based on the thermal output of the at least one heat-producing electronic component.

[0067] A method for cooling a heat producing electronic device is provided. The method may include: receiving, from at least one sensor by control circuitry, data representative of a thermal output of at least one heat-producing electronic component; distributing via one or more nozzles a coolant flow through an enclosed chamber thermally coupled to the heat-producing electronic device; adjusting, by control circuitry, a coolant flow rate through the enclosed chamber; and causing the coolant flow through the enclosed chamber to flow in a turbulent flow regime.

[0068] A controller is provided. The controller may include: an input/output interface; and control circuitry to: receive, from at least one sensor, data representative of a thermal output of at least one heat-producing electronic component; receive, via the I/O interface, data representative of a future expected computational load on the at least one heat-producing electronic component; and adjust, using a variable output fluid mover, a turbulent coolant flow rate through an enclosed chamber thermally coupled to a heat-producing electronic device based at least in part the received data representative of a thermal output of at least one heat-producing electronic component and the received data representative of a future expected computational load on the at least one heat-producing electronic component.

[0069] FIG. **1**A is a perspective view of an illustrative system **100** that depicts a thermal solution including cold plate bracket **110** coupled to a cold plate **120** and a voltage regulator (VR) thermal solution that includes thermal channels **130** fluidly coupling a VR cooler block **140** to a VR cooler retention block **150** thermally coupled to the cold plate **120**, in accordance with at least one embodiment described herein. FIG. **1**B is a side elevation of the illustrative system **100** depicted in FIG. **1**A, in accordance with at least one embodiment described herein. FIG. **1**C is another perspective view of an example embodiment of the illustrative system **100** depicted in FIG. **1**A, in accordance with at least one embodiment described herein. FIG. **1**D is another perspective view of another example embodiment of the illustrative system **100** depicted in FIG. **1**A, in accordance with at least one embodiment described herein.

[0070] In embodiments, the cold plate **120** may be physically and/or thermally affixed to the cold plate bracket **110** to form a cold plate assembly. Similarly, the VR cooler block **140**, VR retention block **150** and the thermal channels **130** form a VR cooling solution. The VR retention block **150** physically and/or thermally couples to the cold plate **120**. Thus, as depicted in FIGS. **1**A-**1**D, the cold plate **120** receives thermal energy from one or more components disposed proximate the cold plate **120** as well as thermal energy from one or more voltage regulators disposed remote from the cold plate **120**. Beneficially, the VR cooler block **140** may be positioned in any location relative to the cold plate **120** simply by lengthening, shortening, or otherwise reconfiguring the thermal channels **130** that fluidly couple the VR cooler block **140** to the VR cooler retention block **150**. In embodiments, the thermal channels **130** may include one or more heat pipes or similar thermally conductive structures. In embodiments, one or more thermal transfer or phase change fluids may flow between the VR cooler block **140** and the VR cooler retention block via the thermal channels **130**.

[0071] In embodiments, the cold plate **120** may include a structure fabricated using any material having a high thermal conductivity—such as copper, stainless steel, aluminum, graphene, or combinations thereof. In embodiments, the cold plate may have a thermal conductivity of: about 50 BTU/hr-ft-° F. or greater; about 100 BTU/hr-ft-° F. or greater; about 150 BTU/hr-ft-° F. or greater; about 200 BTU/hr-ft-° F. or greater; about 250 BTU/hr-ft-° F. or greater; about 300 BTU/hr-ft-° F. or greater. In embodiments, the cold plate **120** may include one or more fluid connections **122**A-**122***n*, for example one or more fluid inlet connections **122**A and one or more fluid outlet connections **122**B. In embodiments, the cold plate **120** may include one or more structures or surface features to increase the thermal transfer area. In embodiments, the cold plate bracket **110** may be beneficially modified, adjusted, or altered to correspond to a wide variety of processor and/or system layouts. In embodiments, all or a portion of the VR retention block **150** may be integrally formed with the cold plate **120**. In other embodiments, the VR retention block **150** may be formed separate from the cold plate **120** and thermally and/or physically coupled to the cold plate **120** during system assembly.

[0072] In embodiments, the thermal solution may include a copper cold plate **120** having an extended thermal transfer surface (e.g., fin area covering the die area) of all package types. The rigidity of the copper cold plate may be increased using a cold plate bracket **110** fabricated from a structurally stiffer material, such as stainless steel. A cooling media may be introduced to the copper cold plate **120** via one or more fluid inlets **122**A and removed from the copper cold plate via one or more fluid outlets **122**B. In embodiments, the one or more fluid connections **122**A-**122***n* may be directly brazed to the cold plate **120** or may be attached to the cold plate **120** using connectors with seal mechanisms such as NPT threads or O-rings.

[0073] The system **100** beneficially provides a modular solution that permits independent modification of the CPU cooling solution (via the cold plate **120**) and the VR cooler block **140**. As depicted in FIGS. **1**A-**1**D, the system **100** includes a separate VR cooler block **140** in which the heat pipes are embedded in a thermally conductive material, such as an aluminum, stainless steel, or copper member, disposed proximate the power consuming components forming the voltage regulator circuitry. In embodiments, the VR cooler block **140** may be thermally coupled to the voltage regulators. For example, the VR cooler block **140** may be thermally coupled to the voltage regulators using a phase change thermal interface material or gap pad. The fluid channels **130** that thermally couple the VR cooler block **140** to the VR cooler retention block **150** may exit the upper surface of the VR cooler block **140**.

[0074] The thermal channels **130** physically and thermally couple to corresponding apertures formed in the VR cooler retention block **150**. For example, as depicted in FIGS. **1**A-**1**D, the VR cooler retention block **150** may include two separate apertures to receive thermal channels **130**. In embodiments, a thermally conductive material, such as a thermal grease, may be used to thermally couple the thermal channels **130** to the VR cooler retention block **150**.

[0075] FIG. **2**A is an illustrative CPU carrier **200** that includes a frame member **210** having a plurality of short stopper members **220**A-**210***n* (four shown, collectively "short stopper members **220**") and a plurality of long stopper members **230**A-**220***n* (four shown, collectively, "long stopper members **230**"), in accordance with at least one embodiment described herein. FIG. **2**B is a perspective view of the CPU carrier **200** from FIG. **2**A being physically coupled to a heatsink **250**, in accordance with at least one embodiment described herein. FIG. **2**C is a perspective view of a central processing unit (CPU) **260** being physically coupled to the assembled CPU carrier **200** and heatsink **250** depicted in FIG. **2**B, in accordance with at least one embodiment described herein. FIG. **2**D is a perspective view of the assembled CPU **260**, CPU carrier **200** and heatsink **250** being coupled to a board **270** via a plurality of loading studs **272**A-**272***n* (four shown, collectively, "loading studs **272**"), in accordance with at least one embodiment described herein. FIG. **2**E is a plan view of the heat sink **250** and CPU **260** coupled to the board **270** via the CPU carrier **200**, in accordance with at least one embodiment described herein.

[0076] The frame member **210** has an upper surface and a lower surface. The upper surface of the frame member **210** may be disposed proximate a thermal solution, such as an extended surface heat sink **250** and the lower surface of the frame member **210** may be disposed proximate a semiconductor package or similar heat-producing semiconductor device. In embodiments, a plurality of thermal solution attachment features **212**A-**212***n* may extend from the upper surface of the frame member **210**. The thermal solution attachment features **212** permit the detachable attachment of the thermal solution **250** to the upper surface of the frame member **210**.

[0077] Referring to FIGS. **2**A-**2**D, the CPU carrier **200** beneficially provides a carrier for the CPU **260** that limits the tilt and load placed upon the CPU **260** when the heat sink **250**/CPU **260**/CPU carrier **200** assembly is inserted into a socket on a board **270**. As depicted in FIG. **2**A, for a four corner loading heat sink/loading mechanism, the degree of tilt experienced by the CPU **260** as the heat sink **250**/CPU **260**/CPU carrier **200** assembly is inserted into the socket may be controlled to minimize the likelihood of socket damage. The short stoppers **220** and the long stoppers **230** beneficially limit the amount of tilt experienced by the CPU **260** during insertion to effectively prevent socket damage. For example, when loading one corner of the heat sink **250**/CPU **260**/CPU carrier **200** assembly, the long stopper **230** may contact the board **270** and limit the amount of tilt experienced by the CPU **260**. Referring to FIG. **2**D, by limiting the amount of tilt experienced by the CPU **260**, the assembler may beneficially attach each of a plurality of load nuts **252**A-**252***n* (four shown, collectively, "load nuts **252**") to a respective one of a plurality of loading studs **272**A-**272***n* (four shown, collectively, "loading studs **272**") in any sequence. In embodiments, the CPU carrier

[0078] Adding the short stoppers **220** and the long stoppers **230** to the CPU carrier **200**, eliminates the need for anti-tilt nut on heatsink **250**. Elimination of the anti-tilt nut on the heatsink **250** beneficially permits the region of the heatsink occupied by the anti-tilt nut to receive additional extended surface area improving the performance and/or thermal efficiency of the heatsink **250**. In embodiments, the short stoppers **220** and the long stoppers **230** may be fabricated from a compressible material, such as an elastomeric or polymeric material. In embodiments, the length of the short stoppers **220** may be about: 10% or less; 20% or less; 30% or less; 40% or less; 50% or less; 60% or less; 70% or less; 80% or less; or 90% or less of the length of the long stoppers **230**. In embodiments, each of the long stoppers **230** may have a length of about: 0.5 millimeter (mm) or less; 1 mm or less; 2 mm or less; 3 mm or less; 4 mm or less; 5 mm or less; 7 mm or less; 9 mm or less; 12 mm or less; or 15 mm or less.

[0079] After installation of the heat sink **250**/CPU **260**/CPU carrier **200** assembly, the short stoppers **220** and the long stoppers **230** contact the board **270** and absorb any excess load that is above the load limit of the socket caused by tightening the load nuts **252**. The short stoppers **220** and the long stoppers **230** provide a compressible members positioned parallel to the socket on the board **270** to absorb only the excess load created by tightening the load nuts **252** on the loading studs **272**. Because of this inherent flexibility, the CPU carrier **200** is beneficially able to accommodate a wide range of CPU heights.

[0080] As depicted in FIG. 2B, the CPU carrier **200** is first physically coupled and/or bonded to the heatsink **250** using one or more fasteners, one or more chemical bonding agent or adhesives, or one or more thermal bonding agents or adhesives. In embodiments, the CPU carrier **200** may be detachably attached to the heatsink **250**. In embodiments, the CPU carrier **200** may be permanently affixed or attached to the heatsink **250**.

[0081] As depicted in FIG. 2C, the CPU **260** is physically coupled to the CPU carrier **200** on the side of the CPU carrier **200** opposite the heatsink **250**. In embodiments, one or more thermally conductive materials may be disposed between the CPU **260** and the heatsink **250** to facilitate the transfer of thermal energy from the CPU **260** to the heatsink **250**. In embodiments, the CPU **260** may be physically bonded to the CPU carrier **200** using one or more fasteners, one or more chemical bonding agent or adhesives, or one or more thermal bonding agents or adhesives. In embodiments, the CPU **260** may be detachably attached to the CPU carrier **200**. In other embodiments, the CPU **260** may be may be permanently affixed or attached to the CPU carrier **200**.

[0082] As depicted in FIG. 2D, the completed heat sink **250**/CPU **260**/CPU carrier **200** assembly may be affixed to a board **270** such that the CPU **260** is seated in a socket or similar attachment feature(s) disposed on a surface of the board **270**. In embodiments, to secure the heat sink **250**/CPU **260**/CPU carrier **200** assembly, a plurality of load nuts **252** may be threadedly coupled to a corresponding plurality of loading studs **272** physically coupled to the board **270**. The short stoppers **220** and the long stoppers **230** beneficially compress as the load nuts are tightened to absorb any excess load placed on the completed heat sink **250**/CPU **260**/CPU carrier **200** assembly and to minimize the likelihood of damage to the socket. The attachment of the completed heat sink **250**/CPU **260**/CPU carrier **200** assembly to the board **270** and socket is depicted in FIG. 2E. As depicted in FIG. 2E each of the plurality of load nuts **252** threadedly engages a corresponding one of the plurality of loading studs **272**. Although other fixing mechanisms are also possible to affix the load nuts **252** to the load studs **272**.

[0083] FIG. 3A is an exploded view of an illustrative spring cell **300**, in accordance with at least one embodiment described herein. FIG. 3B is an elevation view of an illustrative assembled spring cell **300** such as depicted in FIG. 3A, in accordance with at least one embodiment described herein. FIG. 3C is an elevation view depicting assembly of the illustrative spring cell **300**, in accordance with at least one embodiment described herein. FIG. 3D is a cut-away elevation view depicting the assembly of the illustrative spring cell **300** depicted in FIG. 3A, in accordance with at least one embodiment described herein. FIG. 3E is an elevation view depicting further assembly of the illustrative spring cell **300**, in accordance with at least one embodiment described herein. FIG. 3F is a perspective view of insertion of the illustrative spring cell **300** into the base of a heat sink or similar thermal solution, in accordance with at least one embodiment described herein. FIG. 3G is a perspective view of the final position of the illustrative spring cell **300** within the base of a heat sink or similar thermal solution, in accordance with at least one embodiment described herein. The spring cell **300** depicted in FIGS. 3A-3F may be used to physically couple a thermal solution, such as a heat sink, to a printed circuit board, such as a CPU motherboard. The spring cell **300** maintains a defined pressure on the thermal solution, thereby improving the transfer of thermal energy from one or more components mounted on the printed circuit board to the ambient environment.

[0084] As depicted in FIG. 3A, the spring cell **300** includes a fastener body **310** having a relatively smaller diameter upper portion **312** and a relatively larger diameter lower portion **314**, forming a shoulder, ridge or similar surface feature **316** therebetween. The fastener body **310** also includes a grooved portion **318** to receive an e-ring/C-clip **320** used to retain the spring cell **300** on the printed circuit board. The spring cell **300** also includes a compressible element **330**, a retaining ring **340** to retain and compress the compressible element **330**, and a spacer element **350**. The retaining ring **340** may include one or more metallic (e.g., spring steel, stainless steel, aluminum), non-metallic (e.g., carbon fiber), or combinations of materials. The compressible element **330** may include a helical coil spring as depicted in FIG. 3A. The compressible element **330** may include any number, type, or composition capable of providing a tensile biasing force along the axis of the fastener body. Other types of compressible elements include but are not limited to: leaf springs, conical springs, barrel springs, hourglass springs, constant pitch springs, variable pitch springs, and similar. In embodiments, the helical coil spring may have a spring constant selected based, at least in part, on the desired pressure to apply to the thermal solution. In embodiments, the compressible element **330** may have a spring constant of: 0.01 Newtons per meter (N/m) or less; 0.1 N/m or less; 0.25 N/m or less; 0.5 N/m or less; 0.75 N/m or less; 1 N/m or less; 5 N/m or less; 10 N/m or less; 25 N/m or less; 50 N/m or less; 75 N/m or less; or 100 N/m or less.

[0085] FIG. 3B depicts an assembled spring cell **300**. As depicted in FIG. 3B, the compressible element **330** is positioned proximate the relatively smaller diameter portion **312** of the fastener body **310**. The retaining ring **340** slides over the relatively larger diameter portion **314** of the fastener body **310**, compresses the compressible element **330** and "catches" on the shoulder **316**, maintaining the compressible element **330** in a partially compressed state. The spacer element **350** slides over the relatively larger diameter portion **314** of the fastener body **310** and is disposed proximate the retaining ring **340**. The e-ring/C-clip **320** is disposed in the groove **318** and retains the spring cell **300** on the printed circuit board. During assembly, the e-ring/C-clip **320** is removed and the spring cell **300** passed through aligned apertures in the thermal solution and the printed circuit board. Pressure is applied to the spring cell **300** to compress the compressible member **330** to apply the desired pressure to the thermal solution/printed circuit board assembly and the e-ring/C-clip **320** is slipped over the grove **318** to retain the spring cell **300** and maintain the pressure on thermal solution. In embodiments the relatively smaller diameter portion **312** of the fastener body **310** may have a diameter of: 10% or less; 20% or less; 30% or less; 40% or less; 50% or less; 60% or less; 70% or less; 80% or less; 90% or less; or 95% or less of the diameter of the relatively larger diameter portion **314** of the fastener body **310**. In embodiments, the relatively larger diameter portion **314** of the fastener body **310** may have a diameter of about: 1 millimeter (mm) or less; 2 mm or less; 3 mm or less; 4 mm or less; 5 mm or less; 6 mm or less; 7 mm or less; 8 mm or less; 9 mm or less; 10 mm or less; llmm or less; or 12 mm or less. In embodiments, the fastener body **310** may have a length of about: 5 millimeters (mm) or less; 7.5 mm or less; 10 mm or less; 12.5 mm or less; 15 mm or less; 17.5 mm or less; 20 mm or less; 25 mm or less; or 50 mm or less.

[0086] FIG. 3C depicts the initial assembly step for an illustrative spring cell **300**. As depicted in FIG. 3C, the compressible element **300** is slipped over the relatively larger diameter lower portion **314** of the fastener body **310** and is positioned proximate the relatively smaller diameter upper portion **312** of the fastener body **310**. The retaining ring **340** passes over the relatively larger diameter lower portion **314** of the fastener body **310** and compresses the compressible element **330**.

[0087] FIG. 3D depicts a subsequent assembly step for an illustrative spring cell **300**. As depicted in FIG. 3D, the retaining ring **340** passes over the relatively larger diameter lower portion **314** of the fastener body **310** and catches on the shoulder **316** that separates the relatively smaller diameter upper portion **312** and the relatively larger diameter lower portion **314**, maintaining the compressible element in a partially compressed state.

[0088] FIG. 3E depicts a subsequent assembly step for an illustrative spring cell **300**. As depicted in FIG. 3E, the spacer element **350** slides over the relatively larger diameter lower portion **314** of the fastener body **310** and is disposed proximate the retaining ring **340**.

[0089] FIG. 3F depicts the insertion of an illustrative spring cell **300** through a printed circuit board **360**. As depicted in FIG. 3F, the relatively larger diameter lower portion **314** of the fastener body **310** passes through an aperture **362** in the printed circuit board **360**.

[0090] FIG. 3G depicts the completed assembly of an illustrative spring cell **300** with a printed circuit board **360**. As depicted in FIG. 3G, after passing the relatively larger diameter lower portion **314** of the fastener body **310** through the aperture **362** in the printed circuit board **360**, the retaining ring **340** slips over the groove **318** in the fastener body **310**.

[0091] FIG. 4A is an exploded view of an illustrative system **400** that includes a heatsink integrated backplate **410** thermally coupled to all or a portion of a lower surface of a semiconductor package **420** using a thermally conductive material **430** and a thermal solution **440** thermally coupled to all or a portion of an upper surface of the semiconductor package **420**, in accordance with at least one embodiment described herein. FIG. 4B is a side elevation of the illustrative system **400** depicted in FIG. 4A in an assembled state in which the heatsink integrated backplate **410** is thermally coupled to a voltage regulator module (VRM) **450** disposed beneath the semiconductor package **420** and the thermal solution **440** is disposed proximate the upper surface of the semiconductor package **420**, in accordance with at least one embodiment described herein. FIG. 4C is a perspective view of an illustrative heatsink integrated backplate **410**, in accordance with at least one embodiment described herein. FIG. 4D is an enlarged cross-sectional elevation of the illustrative system **400** depicted in FIGS. 4A and 4B, in accordance with at least one embodiment described herein.

[0092] As depicted in FIGS. 4A, 4B, and 4D, the system **400** includes an upper thermal solution **440**, such as an extended surface heatsink, thermally coupled to a semiconductor package **420**, such as a central processing unit (CPU). The semiconductor package **420** is physically coupled to the upper surface of a substrate **460**, such as a printed circuit board. A relatively high power consumption voltage regulator module (VRM) **460** provides power to the semiconductor package **420** and is physically coupled to the lower surface of the substrate **460** in a location that may be proximate the semiconductor package **420**. The heatsink integrated backplate **410** is disposed proximate the lower surface of the substrate **460** and may be physically coupled to the lower surface of the substrate **460** using a thermally conductive material **430**, such as a thermally conductive tape or adhesive material. The heatsink integrated backplate **410** beneficially performs at least two functions; first, securely mounting the semiconductor package **420**, and second, transferring at least a portion of the thermal energy (i.e., heat) generated by the VRM **450** away from the semiconductor package **420**.

[0093] FIG. 4A illustrates the basic assembly of the system **400**. Note the substrate **460** does not appear in FIG. 4A. The system **400** includes a backplate **410** disposed proximate the lower surface of the substrate **460**, proximate one or more voltage regulator modules **450**. The backplate **410** may include an extended surface heatsink, such as a finned heatsink, sufficiently shallow to meet backside Keep-in-Zone requirements (i.e., the distance the heatsink extends from the back side of the substrate **460**, such as <0.1 mm, <0.2 mm, <0.5 mm, <1 mm, <1.5 mm, <2 mm, or <5 mm) Although typical backplates may be fabricated using a relatively rigid material such as steel, in system **400** may include a heatsink integrated backplate **410** fabricated using a material such as copper, aluminum, or alloys thereof that provide sufficient rigidity to serve as a backplate and sufficient thermal conductivity to provide an effective thermal solution/heatsink. In embodiments, one or more thermal interface materials may be disposed between the VRM **450**

and the heatsink integrated backplate **410** to isolate and/or protect the VRM **450** from damage caused by dynamic shock and/or vibration.

[0094] The semiconductor package **420** may include any type of system or device. In at least some embodiments, the semiconductor package **420** may include a central processing unit (CPU), graphics processing unit (GPU); vector processing unit; or tensor processing unit. The upper thermal solution **440** may include an extended surface heatsink. The upper thermal solution may be disposed proximate all or a portion of the upper surface of the semiconductor package **420**.

[0095] In embodiments, a thermally conductive material **430** is disposed between at least a portion of the heatsink integrated backplate **410** and the lower surface of the substrate **460**. The thermally conductive material **430** may include one or more dielectric materials having a relatively high thermal conductivity to thermally couple and electrically isolate the heatsink integrated backplate **410** from the substrate. In at least some embodiments, the thermally conductive material may include a material such as 3M 8805 thermally conductive adhesive tape manufactured by 3M Corporation (Maplewood, Minn.).

[0096] FIGS. **4**B and **4**D are cross-sectional elevations of an illustrative system **400** that includes a heatsink integrated backplate **410**. As depicted in FIGS. **4**B and **4**D, in embodiments a thermal interface material may be disposed between the heatsink integrated backplate **410** and the VRM **450** to isolate the VRM **450** from shock and/or vibration. In at least some embodiments, a two-part thermal interface material may be disposed between the VRM **450** and the heatsink integrated backplate **410**. An example two-part thermal interface material is Bergquist 3500S35 manufactured by Henkel Corporation (Dusseldorf, Germany), or any similar, thermally conductive, shock absorbing material may be used.

[0097] FIG. **4**C is an illustrative heatsink integrated backplate **410** that includes an extended surface heatsink portion. In embodiments, the heatsink integrated backplate **410** may include one or more materials having a thermal conductivity of at least 200 Watts/meter-Kelvin (W/m-K). Example materials include but are not limited to copper, copper containing alloys, aluminum, and aluminum containing alloys. In embodiments, where the heatsink integrated backplate **410** includes an extended surface heatsink, the extended surfaces may project a distance beneath the substrate **460**. In such embodiments, the extended surfaces may project a distance less than backside Keep-in-Zone requirements between the substrate and the device chassis as depicted in FIG. **4**D.

[0098] FIG. **5**A includes perspective, plan, and elevation views of an illustrative two part, rotatable heat sink system **500** that includes a relatively small, lower, fixed position, heat sink **510** and a relatively large, upper, heat sink **520** that is rotatable with respect to the lower heat sink **510**, in accordance with at least one embodiment described herein. FIG. **5**B is a perspective view of the illustrative two part, rotatable heat sink system **500**, including a rotatable mount **540** and locking mechanism **550**, in accordance with at least one embodiment described herein. FIG. **5**C is an exploded view of an illustrative upper heat sink **520**, in accordance with at least one embodiment described herein. FIG. **5**D is a perspective view of an illustrative lower heat sink **510**, in accordance with at least one embodiment described herein. FIG. **5**E includes an exploded view and a cross-sectional view of an illustrative fixed pin set **550**, in accordance with at least one embodiment described herein. FIG. **5**F includes an exploded view and a cross-sectional view of an illustrative rotatable mount **540**, in accordance with at least one embodiment described herein.

[0099] As depicted in FIG. **5**A, when in an operating mode, the upper heat sink **520** may be disposed in a position overhanging the memory circuitry **530**. In the memory maintenance mode, the upper heat sink **520** may be rotated about 90 degrees, exposing the memory circuitry **530**. Thus, the rotatable heat sink system **500** beneficially increases the available extended surface area for heat transfer by extending above other components co-located on a substrate with one or more heat producing devices. For example, the lower heat sink **510** of the rotatable heat sink system **500** may be thermally coupled to a central processing unit (CPU) and the upper heat sink **520** may be rotated to occupy space above memory circuitry **530** disposed adjacent to the CPU. To maintain the memory circuitry **530**, the upper heat sink **520** may be pivoted on the rotatable mount **540**.

[0100] As depicted in FIG. **5**B, a rotatable mount **540** physically, thermally, and rotatably couples the lower heat sink **510** with the upper heat sink. The fixed pin set **550** locks and/or detachably attaches the upper heat sink in position and, when the upper heat sink **520** is disposed in the operating mode, compresses the upper heat sink against the rotatable mount **540** to improve conductive heat transfer from the base **512** of the lower heat sink **510** to the heat pipes **526** disposed in, on, or about the base **522** of the upper heat sink **520**.

[0101] FIG. **5**C is an exploded view of an illustrative upper heat sink **520**. As depicted in FIG. **5**C, the upper heat sink **520** may include a base member **522**, a thermal transfer block **524** fabricated using a material having a thermal conductivity greater than about: 50 Watts/meter-Kelvin (W/m-K); 100 W/m-K; 150 W/m-K; 200 W/m-K; 250 W/m-K; or 300 W/m-K may be thermally coupled to the base member **522**, one or more heat pipes **526** thermally coupled to the thermal transfer block **524** and/or the base member **522**, and an extended surface portion **528** that may include a plurality of fins or similar structures. As depicted in FIG. **5**C, a portion of the rotatable mount **540** may be fabricated using a thermally conductive material to conductively transfer heat from the base **512** of the lower heat sink **510** to the base **522** of the upper heat sink **520**.

[0102] FIG. **5**D depicts an illustrative lower heat sink **510**. The lower heat sink **510** includes a void space **514** where the rotatable mount **540** physically and thermally couples to the base member **512** of the lower heat sink **510**. The lower heat sink **510** includes one or more attachment devices **516**A-**516***n* (four depicted, collectively "attachment devices **516**") used to physically couple the rotatable heat sink system **500** to a substrate.

[0103] FIG. **5**E depicts an illustrative fixed pin set **550** that includes a compression element **552**, a support member **554**, and a pin **556**. As depicted in FIG. **5**E, the pin **556** is vertically displaceable to permit the withdrawal of the pin **556** from a receiver in the rotatable mount **540**. The compression element **552** may bias the pin **556** toward the rotatable mount **540** such that when the upper heat sink **520** is disposed transverse to the lower heat sink **510**, the compression element **552** biases the pin **556** into a corresponding hole, void, or aperture on the rotatable member **540**, thereby locking the upper heat sink **520** into a transverse or orthogonal position relative to the lower heat sink **510**. Conversely, when the pin **556** is vertically withdrawn from the hole, void, or aperture on the rotatable member **540**, the upper heat sink **520** may be rotated to access the circuitry positioned beneath the send heat sink **520** when the second heat sink **520** is disposed in the operating mode.

[0104] FIG. **5**F depicts an illustrative rotatable member **540** that includes a thermally conductive roller member **542**, a biasing element **544**, and a support sleeve **546**. As depicted in FIG. **5**F, the biasing element **544** is disposed about all or a portion of the roller member **542**. The support sleeve **546** is rigidly anchored to the base member **512** of the lower heat sink **510** and is disposed about the biasing element **544**. Trapped by the support sleeve **546**, the biasing member **544** exerts a downward force on the roller member **542** causing the roller member to physically contact and thermally coupled to the base member **512** of the lower heat sink **510**. In embodiments, the roller member **542** may be physically and thermally affixed to the thermal transfer block **524** coupled to the base member **522** of the upper heat sink **520**. Thus, as the upper heat sink **520** is manually or autonomously rotated, the roller member **542** is rotating on the upper surface of the base member **512** of the lower heat sink **510**. In embodiments, a thermally conductive grease or similar lubricant may be disposed between the roller member **542** and the upper surface of the base member **512** of the lower heat sink **510**.

[0105] FIG. **6**A includes perspective, plan, and elevation views of an illustrative two part, detachable, heat sink system **600** that includes a relatively small, lower, fixed position, heat sink **610** thermally coupled to a relatively large, upper, heat sink **620** that is removable from the lower heat sink **610**, in accordance with at least one embodiment described herein. The detachable heatsink system **600** beneficially permits the removal of the upper heat sink portion **620** to access components disposed proximate the lower, fixed, heat sink portion **610**. FIG. **6**B is a side elevation of the detachable heat sink system **600** depicted in FIG. **6**A demonstrating the overhang of the upper heat sink **620** over components mounted on a substrate, in accordance with at least one embodiment described herein. FIG. **6**C is a perspective view of the detachable heat sink system **600** depicted in FIG. **6**A demonstrating the overhang of the upper heat sink **620** over components mounted on a substrate, in accordance with at least one embodiment described herein. FIG. **6**D includes perspective and exploded views of an illustrative embodiment of the detachable heat sink system **600** using a plurality of fasteners **640**A-**640***n* (four shown, collectively, "fasteners **640**") to physically and thermally couple the upper heat sink **620** to the lower heat sink **610**, in accordance with at least one embodiment described herein. FIG. **6**E includes perspective and exploded views of an illustrative embodiment of the detachable heat sink system **600** using a plurality of clamping systems **650**A-**650***n* (two shown, collectively, "clamping systems **650**") to physically and thermally couple the upper heat sink **620** to the lower heat sink **610**, in accordance with at least one embodiment described herein. FIG. **6**F includes perspective and exploded views of an illustrative embodiment of the detachable heat sink system **600** using a spring clip **660** to physically and thermally couple the upper heat sink **620** to the lower heat sink **610**, in accordance with at least one embodiment described herein.

[0106] Referring first to FIG. **6**A, the lower heat sink **610** may have a first heat transfer area and the upper heat sink **620** may have a second heat transfer area. In embodiments, the second heat transfer area may be greater than or equal to the first heat transfer area. A longitudinal axis of the lower heat sink **610** is disposed at an angle to the longitudinal axis of the upper heat sink **620**. In embodiments, the longitudinal axis of the lower heat sink **610** may be disposed orthogonal to the longitudinal axis of the upper heat sink **620**. A thermal interface member **630** thermally couples the lower heat sink **610** to the upper heat sink **620**. In embodiments, the thermal interface member **630** detachably attach and/or physically couple the upper heat sink **620** to the lower heat sink **610**. Beneficially, since the upper heat sink **620** is spaced a distance above the upper surface of the substrate to which the lower heat sink **610** is mounted, the upper heat sink **620** may overhang one or more components disposed on the upper surface of the substrate that are positioned proximate the lower heat sink **610**. In embodiments, the height of one or more extended thermal transfer surfaces (e.g., fins) on the lower heat sink **610** may be determined based, at least in part, upon the projection from the upper surface of the substrate of one or more components positioned adjacent to the lower heat sink **610**. For example, the height of the fins on the lower heat sink **610** may be selected or based, at least in part, on the height of one or more Dual-Inline Memory Modules (DIMMs) disposed proximate the lower heat sink **610**. The thermal interface member **630** may be fabricated using one or more materials having a high thermal conductivity. For example, the thermal interface member **630** may be fabricated using copper, a copper containing alloy, aluminum, or an aluminum containing alloy—each having a thermal conductivity in excess of 200 Watts/meter-Kelvin (W/m-K).

[0107] FIG. **6**B is an elevation view depicting the lower heat sink **610**, the upper heat sink **620** and the thermal interface member **630** that thermally couples the lower heat sink **610** to the upper heat sink **620** to beneficially increase the available thermal transfer area of the assembled dual-layer heat sink system **600**. As depicted in FIG. **6**B, one or more DIMMs **640**A-**640***n* may be disposed proximate the lower heat sink **610** and may be positioned, in whole or in part, beneath the upper heat sink **620**. In embodiments, the lower heat sink **610** may be physically and/or thermally coupled to one or more heat producing components **650**. For example, the lower heat sink **610** may be positioned proximate one or more central processing units (CPUs), one or more graphical processing units (GPUs), or combinations thereof.

[0108] FIG. **6**C is a perspective view depicting two dual-layer heat sink systems **600**, each including a lower heat sink **610**, a detachably attached upper heat sink **620**, and a thermal interface member **630** thermally coupling the lower heat sink **610** and upper heat sink **620**. As depicted in FIG. **6**C, the longitudinal axis of the upper heat sink **620** arranged orthogonal to the longitudinal axis of the lower heat sink **610** and the upper heat sink extends over one or more DIMMs **640**A-**640***n*.

[0109] FIG. **6**D includes perspective views of an assembled and an exploded dual-layer heat sink system **600** in which a plurality of fasteners **660**A-**660***n* (four shown, collectively, "fasteners **660**") detachably attach the upper heat sink **620** to the thermal interface member **630** and to the lower heat sink **610**. In embodiments, the fasteners **660** may include fasteners such as spring and shoulder screws that include a biasing device to increase the pressure on the upper heat sink **620** such that the contact with the thermal interface member **630** is increased, thereby increasing the transfer of thermal energy from the lower heat sink **610** to the upper heat sink **620**. Other fasteners may also be used. In embodiments, the fasteners **660** may engage or pass through one or more complimentary receivers physically coupled to the lower heat sink **610**.

[0110] FIG. **6**E includes perspective views of an assembled and an exploded dual-layer heat sink system **600** in which a plurality of clamp members **670**A-**670***n* (two shown, collectively, "clamp members **670**") detachably attach the upper heat sink **620** to the thermal interface member **630** and to the lower heat sink **610**. In embodiments, the retaining members **670** may include bars or similar structures, each having one or more fasteners or similar devices to couple to the lower heats sink **610** and increase the pressure on the upper heat sink **620** such that the contact with the thermal interface member **630** is increased. Increasing the pressure and contact between the upper heat sink **620** and the thermal interface member **630** increases the transfer of thermal energy from the lower heat sink **610** to the upper heat sink **620**. In embodiments, the fasteners **660** may engage or pass through one or more complimentary receivers physically coupled to the lower heat sink **610**.

[0111] FIG. **6**F includes perspective views of an assembled and an exploded dual-layer heat sink system **600** in which a spring clip **680** detachably attaches the upper heat sink **620** to the thermal interface member **630** and to the lower heat sink **610**. Increasing the pressure and contact between the upper heat sink **620** and the thermal interface member **630** increases the transfer of thermal energy from the lower heat sink **610** to the upper heat sink **620**. In embodiments, the spring clip **680** may engage or pass through one or more complimentary receivers (e.g., one or more apertures) physically coupled to the thermal interface member **630** and/or the lower heat sink **610**.

[0112] FIG. 7A is a perspective view of an illustrative distributed thermal control system **700** that includes a chilled distribution block **710** coupled to a plurality of geographically distributed heat producing components **730**A-**730***n* (collectively, "heat producing components **730**") by a plurality of thermal conduits **720**A-**720***n* (collectively, "thermal conduits **720**"), in accordance with at least one embodiment described herein. FIG. **7**B is a schematic diagram that includes the distributed thermal control system **700** depicted in FIG. 7A, in accordance with at least one embodiment described herein. In embodiments, the distribution block **710** may be chilled using any number or combination of gaseous, liquid, and/or phase change materials.

[0113] Referring first to FIG. 7A, in at least some embodiments, the chilled distribution block **710** may include a liquid cooled block. (e.g., a water, glycol, or similar thermal transfer fluid cooled block) As depicted in FIG. **7**A, in some embodiments, the chilled distribution block **710** may be positioned proximate one or more cold plates or similar control devices. In embodiments, each of a plurality of heat producing components **730** may be thermally coupled to the chilled distribution block **710** via one or more thermal conduits **720**. In some embodiments, the one or more thermal conduits **720** may include one or more heat pipes or similar thermally conductive structures. In operation, a flow of coolant media through the chilled distribution block **710** maintains the block at a defined temperature or within a defined temperature range.

[0114] The one or more heat producing components **730** may include but are not limited to: voltage regulator circuitry, processor circuitry, microprocessor circuitry, or combinations thereof. In embodiments, the number of thermal conduits **720** thermally coupled to a particular heat producing component **730** may be based, at least in part, on the thermal load (e.g., 1 Watt per square centimeter (W/cm^2) or less; 2 W/cm^2 or less; 5 W/cm^2 or less; 10 W/cm^2 or less; 15 W/cm^2 or less; 20 W/cm^2 or less; 25 W/cm^2 or less; 30 W/cm^2 or less) presented by the respective heat producing component **730**, the desired temperature range (e.g., 5° C. to 100° C.; 10° C. to 90° C.; 15° C. to 80° C.; 20° C. to 75° C.; 25° C. to 65° C.; or 30° C. to 50° C.) for the respective heat producing component **730**, the distance between the chilled distribution block **710** and the respective component, or combinations thereof.

[0115] Referring next to FIG. **7**B, the chilled distribution block **710** is maintained at a defined temperature using a flow **760** of cooling media maintained at the defined temperature. Heat generated by heat producing components **730**A-**730**C is conveyed, via thermal conduits **720**A-**720**C to the chilled distribution block **710**. The temperature of the cooling media flowing through the chilled distribution block **710** increases due to the heat received from the heat producing components **730**A-**730**C. For example, as depicted in FIG. **7**B, the cooling media may be provided **760** to the chilled distribution block **710** at a temperature of 40° C. and may exit **762** the chilled distribution block **710** at a temperature of 45° C. The 45° C. cooling media may be provided to a first cold plate **740** thermally coupled to a heat producing component, such as a voltage regulator, and may exit **764** the first cold plate **740** at an elevated temperature. For example, as depicted in FIG. **7**B, the cooling media may exit **764** the first cold plate **740** at a temperature of 53° C. The 53° C. cooling media may be provided to a second cold plate **750** thermally coupled to a second heat producing component, such as a second voltage regulator, and may exit **766** the second cold plate **750** at an elevated temperature. For example, as depicted in FIG. **7**B, the cooling media may exit **766** the second cold plate **750** at a temperature of 62° C.

[0116] In embodiments, the cooling media may be provided **760** to the chilled distribution block **710** at any temperature. For example, the cooling media may be provided **760** to the chilled distribution block **710** at a temperature of about: 5° C. or less; 10° C. or less; 15° C. or less; 20° C. or less; 25° C. or less; 30° C. or less; 35° C. or less; 40° C. or less; 45° C. or less; or 50° C. or less. In embodiments, the cooling media may exit **764** the first cold plate **740** at any temperature. For example, the cooling media may exit **764** the first cold plate **740** at a temperature of about: 10° C. or greater; 20° C. or greater; 30° C. or greater; 40° C. or greater; 50° C. or greater; 60° C. or greater; 70° C. or greater; or 80° C. or greater.

[0117] FIG. **8**A is an elevation view of an illustrative die loading apparatus **800** for use with multiple semiconductor dies, the loading apparatus **800** including a pedestal member **810**, one or more pin arrays **820**A-**820***n* (two shown, collectively "pin arrays **820**") coupled to the pedestal member **810**, and one or more pusher members **830**, in accordance with at least one embodiment described herein. FIG. **8**B is a perspective view of an illustrative system that includes a plurality of semiconductor dies **840**A-**840***n* (two shown, collectively, "silicon dies **840**") that are seated to a socket disposed on a substrate **850** using a die loading apparatus **800** such as depicted in FIG. **8**A and in which, after installation, the pin arrays **820** create a fluid channel between the upper surface of the semiconductor dies **840** and the lower surface of the pedestal member **810**, in accordance with at least one embodiment described herein. FIG. **8**C is an elevation view of an illustrative single die loading apparatus **800** that includes a pedestal member **810**, a single pin array **820** coupled to the pedestal member **810**, and one or more pusher members **830**, in accordance with at least one embodiment described herein. FIG. **8**D is a perspective view of an illustrative system that includes a single semiconductor die **840** that is seated using a single loading apparatus **800** such as depicted in FIG. **8**C and in which the pin array **820** creates a fluid channel between the upper surface of the semiconductor die **840** and the lower surface of the pedestal member **810**, in accordance with at least one embodiment described herein.

[0118] In immersion cooling systems, the cooling medium directly contacts the heat producing elements in the system, in other words, the heat producing elements are immersed in the cooling medium. Semiconductor dies are typically pressed into complimentary sockets that are conductively and physically coupled to a substrate. A cool plate or cover is then disposed over or about at least a portion of the semiconductor die to hold the semiconductor die in place within the socket. However, covering the semiconductor die in an immersion cooled system adversely impacts the thermal performance of the system. Peripheral clamping of the semiconductor die causes stresses in the semiconductor die that can damage the die or, on larger multi-chip modules (MCMs), can cause "bowing" of the die to the point that some pins do not make electrical contact with the socket. The die loading apparatus **800** includes a pin array **820** that beneficially applies pressure across all or a portion of a semiconductor die or MCM while providing a fluid channel adjacent to the upper surface of the semiconductor die or MCM.

[0119] Referring first to FIGS. **8**A and **8**B, the die loading apparatus **800** includes a plurality of pin arrays **820**. Each of the pin arrays **820** applies pressure to one or more semiconductor dies **840** to properly seat each of the semiconductor dies **840** in a respective socket. The pin arrays **820** beneficially permit cooling medium flow across the upper surface of the semiconductor die **840** and also maintain pressure on the semiconductor dies **840**. In some embodiments, the semiconductor dies **840** may be mounted on a common substrate to form a multi-chip module (MCM). The pin array **820** may be fabricated using a rigid, dielectric or electrically non-conductive, material. The pedestal member **810** and the pusher member **830** may be fabricated using one or more rigid, dielectric, electrically non-conductive, or electrically conductive materials. In some embodiments, the pedestal member **810** and/or the pusher member **830** may include one or more attachment features to permit the attachment of the die loading apparatus to the substrate **850**. The pins forming the pin array **820** may have the same or different lengths. For example, the pin length of some of the pins may differ to accommodate a semiconductor die having a non-planar upper surface or an irregular contour. In embodiments, the pin length for each pin array **820** may differ to accommodate semiconductor dies **840** having different thicknesses. By varying the pin length based on semiconductor die thicknesses and/or to accommodate semiconductor dies **840** having irregular contours, the die loading apparatus **800** beneficially maintains a defined pressure across each of the semiconductor dies **840**.

[0120] Referring next to FIGS. **8**C and **8**D, the die loading apparatus **800** includes a single pin array **820**. The pin array **820** beneficially permits cooling medium flow across all or a portion of the upper surface of the semiconductor die **840** and also maintains a defined seating pressure on the semiconductor die **840**. The pins forming the pin array **820** may have the same or different lengths. For example, the pin length of some of the pins forming the pin array **820** may differ to accommodate a semiconductor die having a non-planar upper surface or an irregular contour. In embodiments, the pin length for each pin array **820** may differ to accommodate semiconductor dies **840** having different thicknesses. By varying the pin length based on semiconductor die thicknesses and/or to accommodate a semiconductor die **840** having irregular contours, the die loading apparatus **800** beneficially maintains a defined seating or insertion pressure across the semiconductor die **840**.

[0121] FIG. **9**A is a perspective view of a system **900** that includes a thermal solution **910** secured to a substrate **920** using a plurality of detent fasteners **930**A-**930***n* (four shown, collectively, "detent fasteners **930**") rotatably positionable between an UNLATCHED position in which the detent fastener does not engage a surface feature coupled to the substrate **920** and a LATCHED position in which the detent fastener engages a surface feature coupled to the substrate **920**, in accordance with at least one embodiment described herein. FIG. **9**B is a cross-sectional view of an illustrative system **900** in which the detent fastener **930** is disposed in the LATCHED position in which the rotating member **936** coupled to the detent fastener **930** engages a surface feature **940** coupled to the substrate **920**, in accordance with at least one embodiment described herein. FIG. **9**C includes a plan view and a cross-sectional view of an illustrative system **900** in which the detent fastener **930** is disposed in the LATCHED position in which the rotating member **936** coupled to the detent fastener **930** engages a surface feature **940** coupled to the substrate **920**, in accordance with at least one embodiment described herein. FIG. **9**D is a cross-sectional view of an illustrative system **900** in which the detent fastener **930** is disposed in the UNLATCHED position in which the rotating member **936** coupled to the detent fastener **930** does not engage the surface feature **940** coupled to the substrate **920**, in accordance with at least one embodiment described herein.

[0122] Turning first to FIG. **9**A, each of the detent fasteners **930** includes a fastener housing **932** disposed about at least a portion of a fastener member **934**, and a rotating member **936** pivotably coupled to the fastener housing **932**. The fastener member **934** may include a head portion **934**A and a body portion **934**B that extends from the head portion **934**A. In such embodiments, the fastener housing **932** may be disposed about at least a portion of the body portion **934**B of the fastener member **934**. The fastener housing **932** may have one or more apertures formed therethrough and at least a portion of the body portion **934**B the fastener member **934** may be slidably displaceable through the aperture formed in the fastener housing **932**. The rotatable member **936** may include an upper portion **936**A that in the UNLATCHED position is disposed proximate the head portion **936**A of the fastener member **934** and in the LATCHED position is disposed remote from the head portion of the fastener member **934**.

[0123] The rotating member **936** rotates from a first "UNLATCHED" position in which the rotating member **936** blocks access to the head of the fastener member **934** to a second "LATCHED" position in which the rotating member **936** does not block the head of the fastener member **934** and engages one or more surface features coupled to the substrate **920** to pre-load the thermal solution **910** and one or more semiconductor devices (not visible in FIG. **9**A) disposed beneath the thermal solution **910**. Thus, the detent fastener **930** provides a dual benefit: first, by preloading the thermal solution **910**, the detent fastener **930** limits the unequal forces or tilt imposed on the thermal solution **910** and semiconductor device, protecting the semiconductor device; second, the detent fastener **930** operates in a virtually foolproof manner by blocking access to the fastener member **934** when UNLATCHED (i.e., not engaged to the substrate surface feature) and permitting access to the fastener member **934** when LATCHED (i.e., engaged with the substrate surface feature).

[0124] In embodiments, the detent fastener **930** provides an eccentric or "cam" action that displaces the thermal solution **910** (and the attached semiconductor device) downward into a mating device such as socket coupled to the substrate **920**. In embodiments, the dimensions and/or geometry of the rotating member **930** may be altered or adjusted to compensate for different thermal solution thicknesses, different semiconductor device standoff distances, different substrate surface feature designs or combinations thereof.

[0125] Turning next to FIG. **9**B, the rotating member **936** coupled to the detent fastener **930** is rotated to the LATCHED position in which a portion of the rotating member **936** engages a surface feature **940** coupled to the substrate **920**. As depicted in FIG. **9**B, when the rotating member **936** is rotated to the LATCHED position, the upper portion of the rotating member **936** does not obstruct access to the head of the fastener member **934**, thereby permitting the tightening of the fastener member **934** to the substrate **920**.

[0126] Turning next to FIG. **9**C, the rotating member **936** coupled to the detent fastener **930** is again rotated to the LATCHED position in which a portion of the rotating member **936** engages a surface feature **940** coupled to the substrate **920**. As depicted in the FIG. **9**C plan view, when the rotating member **936** is rotated to the LATCHED position, access to the head of the fastener member **934** is unimpeded, permitting the manual or autonomous tightening of the fastener member **934** to the substrate **920**.

[0127] Turning to FIG. **9**D, the rotating member **936** coupled to the detent fastener **930** is rotated to the UNLATCHED position in which the rotating member **936** does not engage a surface feature **940** coupled to the substrate **920**. As depicted in the FIG. **9**D plan view, when the rotating member **936** is rotated to the UNLATCHED position, access to the head of the fastener member **934** is blocked, thereby providing a visual indicator of the UNLATCHED condition of the respective detent fastener **930**.

[0128] FIG. **10**A is a perspective view of a thermal solution **1000** that includes a flow-through coolant chamber **1004**, which allows coolant to flow through the coolant chamber, incorporating an internal distribution header **1016**A, an internal collection header **1016**B, a plurality of extended thermal members **1012**A-**1012***n* (collectively, "thermal members **1012**"), and a plurality of turbulence elements **1014**A-**1014***n* (collectively, "turbulence elements **1014**") disposed about at least a portion of the thermal members **1012** and, in which, the thermal solution thermally couples to one or more heat-producing electronic devices **1002**, in accordance with at least one embodiment described herein. As depicted in FIG. **10**A, a microcontroller **1008** measures the temperature of the heat producing device **1002** and, using feedback control, adjusts the output of a variable flow device **1006** to provide a flow of coolant through the coolant chamber **1004** based, at least in part on the thermal output of the heat producing device **1002**. IN other words, each of the turbulence elements or combinations thereof can be activated by the controller based on an optimal flow determined by the controller. In embodiments, control circuitry **1008** may receive one or more inputs that enable the control circuitry **1008** to predict the future thermal output of the heat producing device, thereby enabling feed forward control of the variable flow device **1006**.

[0129] The coolant chamber **1004** includes a base member **1010** having a plurality of thermal members **1012** physically and thermally coupled thereto. Turbulence elements **1014** are coupled to each of at least some of the plurality of thermal members **1012**. In embodiments, the turbulence elements **1014** may be rotatably coupled to each of at least some of the plurality of thermal members **1012**. In operation, as coolant flows through the coolant chamber **1004**, the turbulence elements **1014** promote the generation of a turbulent flow regime (i.e., Reynolds number greater than 4,000) across the base member **1010** and around the thermal members **1012**, increasing the heat transfer coefficient of the thermal solution **1000** and improving the heat transfer between the heat-producing device **1002** and the coolant flowing through the coolant chamber **1004**.

[0130] Generally, heat transfer within the thermal solution **1000** is given by the following equation:

$$q=UA\Delta T \qquad (1)$$

[0131] Where:

[0132] q=Thermal energy transferred (e.g., BTU)

[0133] U=Overall heat transfer coefficient (e.g., BTU/ft^2-° F.)

[0134] A=Effective heat transfer area (e.g., ft^2)

[0135] ΔT=Logarithmic mean temperature difference (e.g., ° F.)

[0136] Thus, by placing the coolant flowing through the coolant chamber **1004** in the turbulent flow regime, the overall heat transfer coefficient (U) is effectively increased, particularly when compared to the overall heat transfer coefficient achievable using a laminar or transitional flow regime. The presence of turbulence elements **1014** disposed about the thermal members **1012** in the coolant chamber **1004** beneficially and advantageously improves the performance of the thermal solution.

[0137] The coolant may include one or more liquid coolants or one or more gaseous coolant. The variable output flow device **1006** may therefore include one or more pumps or similar devices when a liquid coolant is used and one or more positive displacement blowers or similar device s when a gaseous coolant is used. The control circuitry **1008** varies or adjusts the mass flow rate of coolant through the coolant chamber **1004** to maintain the temperature of the heat-producing electronic device **1002** a temperature setpoint or within a defined temperature range. In embodiments, the control circuitry **1008** may receive one or more signals that include information indicative of the thermal output of the heat-producing electronic device **1002** (e.g., temperature data) and may employ a feedback control regime to control or otherwise adjust the temperature of the heat-producing electronic device **1002** at a defined value or within a defined range. In embodiments, the control circuitry **1008** may receive one or more signals that include information indicative of an expected further thermal output of the heat-producing electronic device **1002** (processor load data, GPU load data, etc.) and may employ an adaptive or feedforward control regime to control or otherwise adjust the temperature of the heat-producing electronic device **1002** at a defined value or within a defined range. In embodiments, the control circuitry **1008** alters or adjusts the coolant discharge mass flow rate provided by the variable output flow device **1006** to the coolant chamber **1004** using feedback control, feedforward control, or any combination thereof. Generally, the ability for the coolant to remove thermal energy from a system is given by the following equation:

$$q=\dot{m}C_p\Delta T \tag{2}$$

[0138] Where:

[0139] q=Thermal energy transferred (e.g., BTU)

[0140] $\dot{m}$=Coolant mass flow rate (e.g., lb/min)

[0141] C_p=Heat capacity of coolant (e.g., BTU/lb-° F.)

[0142] ΔT=Temperature change of coolant (e.g., ° F.)

[0143] Thus, by varying the coolant flow rate through the coolant chamber **1004**, the control circuitry **1008** is able to increase or decrease the thermal energy removed from the coolant chamber **1004**.

[0144] One or more coolant inlets **1020** receive the flow of coolant to the coolant chamber **1004**. An internal distribution header **1016**A distributes the coolant flow across the width of the coolant chamber **1004**, thereby increasing the effective available heat transfer area of the thermal solution **1000**, further improving the thermal performance of the thermal solution **1000**. An internal collection header **1016**B disposed within the chamber **1018** collects the coolant flowing across the base member and directs the cooling to one or more coolant outlets **1022**. The coolant chamber **1004** includes a housing **1018** affixable to the base member **1010**. One or more sealing devices, such as a gasket or "O"-ring provides a fluid tight seal between the base member **1010** and the housing **1018**.

[0145] The base member **1010** and the plurality of thermal members **1012** may be fabricated using one or more thermally conductive materials, such as copper, a copper containing alloy, aluminum, an aluminum containing alloy, or combinations thereof. In embodiments, at least a portion of the thermal members **1012** may include a generally cylindrical member to receive a respective turbulence element **1014**. In embodiments, at least a portion of the thermal members **1012** may include an extended heat transfer surface (e.g., a fin or similar structure).

[0146] In embodiments, each of the plurality of turbulence elements **1014**A-**1014***n* may include an aperture having a first diameter and each of the thermal members **1012** includes a shaft portion having a second diameter slightly smaller than the first diameter such that one or more turbulence elements may be disposed about the shaft portion of the thermal member **1012**. In such embodiments, the one or more turbulence elements **1014** may rotate about the shaft portion of the thermal member **1012**. In other embodiments, some or all of the turbulence elements **1014**A-**1014***n* may include one or more fins, vanes, or similar static elements to cause a turbulent coolant flow across the surface of the base member **1010**.

[0147] The turbulence elements **1014**A-**1014***n* may be fabricated using one or more materials, such as one or more metallic materials and/or one or more polymeric materials. In at least some embodiments, the turbulence elements **1014** may be fabricated using one or more self-lubricating materials. In at least some embodiments, the turbulence elements **1014** may include polycarbonate turbulence elements **1014**. In some embodiments, the turbulence elements **1014**A-**1014***n* may include impeller-type turbulence elements that include one or more blades, fins, or pitched elements coupled to a hub having an aperture formed therethrough.

[0148] The distribution header **1016**A includes an inlet fluidly coupled to the one or more coolant inlets **1020** and one or more fluid outlets to disperse the flow of coolant across the surface of the base member **1010** and about the thermal members **1012**. The collection header **1016**B includes a plurality of fluid inlets to receive the flow of coolant from across the base member **1010** and thermal members **1012** and one or more outlets fluidly coupled to the one or more coolant outlets **1022**.

[0149] FIG. **10**B is a flow diagram of an illustrative method **1000**B of cooling a heat producing device **1002** using a thermal solution **1000** such as described in detail in FIG. **10**A, in accordance with at least one embodiment described herein. As depicted in FIG. **10**B, the heat-producing device **1002** generates a thermal output. In embodiments, the thermal output of the heat-producing device **1002** may be based upon and/or proportionate to a computational load or demand placed upon the heat-producing device **1002**. One or more thermal sensors **1024**, such as one or more thermocouples, resistive thermal devices, or thermistors may be used to measure or otherwise sense one or more parameters indicative of the heat generated or otherwise emitted by the heat-producing device **1002**. In embodiment, the one or more thermal sensors **1024** may generate an output signal **1026** that includes a digital representation of the temperature of the heat-producing device **1002**. In other embodiments, the one or more thermal sensors **1024** may generate an analog output signal **1026** representative of the temperature of the heat-producing device **1002**. In such embodiments, one or more analog to digital (A/D) converters may convert the analog output signal may be converted to a signal containing a digital representation of the temperature of the heat-producing device **1002**.

[0150] The control circuitry **1008** receives, as an input, the one or more output signals **1026** generated by the one or more sensors **1024**. The control circuitry **1008** applies one or more control algorithms and, using the one or more output signals **1026** generated by the one or more sensors **1024**, generates a control output signal that is used to control the flow of coolant provided by the variable flow device **1006** through the coolant chamber **1004**. The flow of coolant provided by the variable flow device **1006** may be controlled **1028** to maintain the temperature of the heat-producing device **1002** at a desired temperature or within a desired temperature range. The variable flow device **1006** discharges coolant to the distribution header **1016**A disposed in the thermal solution **1000**. The coolant exits the distribution header **1030** via one or more convergent/divergent nozzles **1030** that fluidly couple the distribution header **1030** to the internal space of the coolant chamber **1004**. The turbulence elements **1014** disposed about and/or coupled to at least a portion of the thermal members **1012** cause the coolant to flow through the coolant chamber **1004** in a turbulent flow regime, thereby beneficially improving the heat transfer between the heat-producing device **1002** and the coolant.

[0151] FIG. **10**C is a flow diagram of an illustrative method **1000**C of cooling a heat-producing device **1002** with a thermally coupled thermal solution **1000** such as described in FIG. **10**A, in accordance with at least one embodiment described herein. As depicted in FIG. **10**C, at **1034**, a heat-producing device **1002** generates heat when in operation. At **1036**, the thermal solution **1000** removes at least a portion of the thermal energy/heat emitted, generated, or otherwise produced by the heat-producing device **1002**. At **1038**, the control circuitry **1008** receives one or more signals that include data and/or information indicative of the temperature of the heat-producing device **1002**. In embodiments, the control circuitry **1008** receives information and/or data representative of a projected or forecasted duty (e.g., work load) placed upon the heat-producing device **1002**.

[0152] At **1040**, using the measured temperature and the forecasted or projected duty placed upon the heat-producing device **1002**, the control circuitry **1008** applies one or more control algorithms to generate one or more output signals used to control the flow of coolant provided by the variable flow device **1006** to the coolant chamber **1004**. In embodiments, the control circuitry **1008** may alter or adjust the temperature of the coolant flowing to the coolant chamber **1004**, for example by controlling one or more coolers or chillers capable of reducing the temperature of the coolant.

[0153] At **1042** the control circuitry **1008** determines whether the temperature of the heat-producing device **1002** is at a defined temperature or within a defined temperature range. If the temperature is at the defined temperature or within the defined temperature range, the control circuitry **1008** continues monitoring the temperature of the heat-producing device at **1038**. If the temperature is not at the defined temperature or within the defined temperature range, the control circuitry **1008** alters and/or adjusts the at least one of: the flow of coolant provided to the cooling chamber **1004** by the variable flow device **1006** and/or the temperature of the coolant at **1040**.

[0154] FIG. **10**D is a perspective view of an illustrative turbulence element **1014** and an illustrative thermal solution **1000**D, in accordance with at least one embodiment described herein. As depicted in FIG. **10**D, the turbulence element **1014** may include a rotatable element, such as an impeller having any number of fins, airfoils, blades or similar static or dynamic elements sufficient to impart turbulence that are affixed to a hub and capable of causing or otherwise creating turbulence in a liquid or gaseous coolant flowing past the turbulence element **1014**. Also as depicted in FIG. **10**D, the hub of each of the turbulence elements **1014** may include an aperture or similar void space to accommodate the passage of at least a portion of the shaft of the thermal member **1012** extending from the base member **1010**.

[0155] FIG. **10**E is a perspective view of an illustrative distribution header **1016**A and/or collection header **1016**B (collectively, "headers **1016**"), in accordance with at least one embodiment described herein. As depicted in FIG. **10**E, each of the headers **1016** includes a vessel or housing that encloses a plenum portion **1044**. In embodiments, the distribution header **1016**A and the collection header **1016**B are structurally identical and, thus, coolant flow through the thermal solution **1000** is reversible (i.e., the coolant inlet **1020** may serve as the coolant outlet **1022** and vice versa). Each of the headers **1016** includes a plurality of nozzles **1046**A-**1046***n* (collectively, "nozzles **1046**") that fluidly couple the plenum **1044** to the interior space of the coolant chamber **1004**. In embodiments, the nozzles **1046** may include one or more convergent/divergent fluid nozzles having an intermediate tapered portion that is smaller in diameter than the inlet and outlet portions of the respective nozzle **1046**. In some embodiments, the nozzles **1046**A-**1046***n* may be the same size and/or fluid capacity. In other embodiments, one or more of the nozzles **1046**A-**1046***n* may be of different sizes or fluid capacities. For example, in some embodiments, fluid nozzles **1046** positioned in the middle of the plenum **1044** may have a smaller fluid capacity than the fluid nozzles positioned proximate the "ends" of the plenum **1044**. Such a nozzle arrangement beneficially assists in evening the flow of coolant across the width of the base member **1010**.

[0156] In embodiments, the thermal solution **1000** may be selected based upon the expected maximum thermal load presented by the heat-producing device **1002**. The fluid nozzles **1046** may then be selected to achieve a desired liquid or gaseous coolant flow rate through the thermal solution **1000** to maintain the heat-producing device **1002** at a desired and/or stable temperature. FIG. **10**F is a hypothetical model depicting a comparison of coolant flow **1054** through a thermal solution **1050** without distribution and collection headers **1016** and coolant flow **1054** through a thermal solution **1052** equipped with distribution and collection headers **1016**, in accordance with at least one embodiment described herein. Coolant flow **1054** through a thermal solution **1052** without distribution and collection headers **1016** preferentially flows through the portion of the coolant chamber **1004** proximate the fluid inlet **1020** to the coolant chamber **1004**, limiting the effectiveness or at least a portion of the base member **1010** and thermal members **1012**A-**1012***n*, compromising the efficiency of the thermal solution **1050**. In contrast, turbulence elements **1014** are selected or controlled to redefine the flow through the coolant chamber such that coolant flow **1054** through a thermal solution **1052** with distribution and collection headers **1016** results in a generally more even or uniform distribution of coolant across the base member **1010** and thermal members **1012**A-**1012***n*, improving the efficiency of the thermal solution **1052**.

[0157] FIG. **10**G is a plan view of an illustrative thermal solution **1000**G that includes a base member **1010**, a plurality of thermal members **1012**A-**1012***n* physically and thermally coupled to the base member **1010**, turbulence elements **1014**A-**1014***n* disposed about at least a portion of the thermal members **1012**A-**1012***n*, in accordance with at least one embodiment described herein. As depicted in FIG. **10**G, coolant enters the fluid inlet connection **1020** and flows into the coolant distribution header **1016**A. Coolant exits from the plenum **1044** of the distribution header **1016**A via each of the plurality of nozzles **1046**. Coolant flows across the base member **1010** and about the thermal members **1012** physically and thermally coupled to the base member **1010**. Turbulence elements **1014** on some or all of the thermal members **1012** cause the coolant to flow through the coolant chamber **1004** in a turbulent flow regime, beneficially improving the heat transfer between the heat-producing device **1002** and the coolant flowing through the coolant chamber **1004**. Coolant flows into plenum **1044** the collection header **1016**B via each of the plurality of nozzles **1046** and exits the plenum **1044** of the collection header **1016**B via the fluid outlet **1022**.

[0158] FIG. **10**H is a plan view of an illustrative thermal solution **1000**H that illustrates the thermal distribution of a heat-producing device disposed proximate the base member **1010** of the thermal solution **1000**H and also depicts the relative sizes and/or locations of a plurality of convergent/divergent nozzles **1070**A-**1070***n* disposed in the distribution header **1016**A and the collection header **1016**B, in accordance with at least one embodiment described herein. As depicted in FIG. **10**G, the convergent/divergent nozzles may be configured such that the one or more convergent/divergent nozzles **1070** disposed in the center of the distribution header **1016**A and the one or more convergent/divergent nozzles **1070** disposed in the center portion of the collection header **1016**B may be sized to pass a lesser volume of coolant than those convergent/divergent nozzles positioned toward the periphery of the distribution header **1016**A and the collection header **1016**B.

[0159] Also as depicted in FIG. **10**H, at least a portion of the side surface and the upper surface of each of the distribution header **1016**A and the collection header **1016**B are disposed proximate the inner surface of the housing **1018** when the housing is affixed to the base member **1010**. Thus, the coolant flowing into the housing **1018** flows into a distribution plenum portion **1072**A formed by the inner surfaces of the housing **1018** and the distribution header **1016**A. Coolant exits the distribution plenum portion via the convergent/divergent nozzles **1070**A-**1070***n* disposed in the distribution header **1016**A. Similarly, coolant exits the thermal solution **1000**I by first flowing across, about, and around the thermal members **1012**A-**1012***n* and turbulence elements **1014**A-**1014***n* and enters a collection plenum portion **1072**B formed by the inner surfaces of the housing **1018** and the collection header **1016**B via the convergent/divergent nozzles **1070**A-**1070***n* disposed in the collection header **1016**B.

[0160] FIG. **10**I is a perspective view of another illustrative thermal solution **1000**I that include a plurality of turbulence elements **1014**A-**1014***n* disposed on at least a portion of the thermal members **1012**A-**1012***n*, in accordance with at least one embodiment described herein. Here the turbulence elements are selected different from previous figures according to another optimal configuration that creates the desired coolant flow through the coolant chamber. As depicted in FIG. **10**I, coolant flows into the distribution plenum portion **1072**A, flows through the convergent/divergent nozzles **1070**A-**1070***n* disposed in the distribution header **1016**A and into the portion of the housing **1018** disposed about the thermal members **1012**A-**1012***n* and turbulence elements **1014**A-**1014***n*. Coolant exits the portion of the housing **1018** disposed about the thermal members **1012**A-**1012***n* and turbulence elements **1014**A-**1014***n* by flowing through the plurality of nozzles **1070**A-**1070***n* disposed in the collection header **1016**B and into the collection plenum portion **1072**B.

[0161] As used in this application and in the claims, a list of items joined by the term "and/or" can mean any combination of the listed items. For example, the phrase "A, B and/or C" can mean A; B; C; A and B; A and C; B and C; or A, B and C. As used in this application and in the claims, a list of items joined by the term "at least one of" can mean any combination of the listed terms. For example, the phrases "at least one of A, B or C" can mean A; B; C; A and B; A and C; B and C; or A, B and C.

[0162] As used herein processor-based devices, such as data servers, may include a network interface that can use embodiments or be used by embodiments. For example, data received from a network that is encoded, network interface can use a decoder that speculatively decodes one or more groups of tokens. Network interface can include transceiver, processors, transmit queue, receive queue, memory, and bus interface, and DMA engine. Transceiver can be capable of receiving and transmitting packets in conformance with the applicable protocols such as Ethernet as described in IEEE 802.3, although other protocols may be used. Transceiver can receive and transmit packets from and to a network via a network medium (not depicted). Transceiver can include physical layer (PHY) circuitry and media access control (MAC) circuitry. PHY circuitry can include encoding and decoding circuitry (not shown) to encode and decode data packets according to applicable physical layer specifications or standards. MAC circuitry can be configured to assemble data to be transmitted into packets, that include destination and source addresses along with network control information and error detection hash values. MAC circuitry can be configured to process MAC headers of received packets by verifying data integrity, removing preambles and padding, and providing packet content for processing by higher layers.

[0163] Processors can be any a combination of a: processor, core, graphics processing unit (GPU), field programmable gate array (FPGA), application specific integrated circuit (ASIC), or other programmable hardware device that allow programming of network interface. For example, processors can provide for allocation or deallocation of intermediate queues. For example, a "smart network interface" can provide packet processing capabilities in the network interface using processors.

[0164] Packet allocator can provide distribution of received packets for processing by multiple CPUs or cores using timeslot allocation described herein or RSS. When packet allocator uses RSS, packet allocator can calculate a hash or make another determination based on contents of a received packet to determine which CPU or core is to process a packet.

[0165] Interrupt coalesce can perform interrupt moderation whereby network interface interrupt coalesce waits for multiple packets to arrive, or for a time-out to expire, before generating an interrupt to host system to process received packet(s). Receive Segment Coalescing (RSC) can be performed by network interface whereby portions of incoming packets are combined into segments of a packet. Network interface provides this coalesced packet to an application.

[0166] Direct memory access (DMA) engine can copy a packet header, packet payload, and/or descriptor directly from host memory to the network interface or vice versa, instead of copying the packet to an intermediate buffer at the host and then using another copy operation from the intermediate buffer to the destination buffer.

[0167] Memory can be any type of volatile or non-volatile memory device and can store any queue or instructions used to program network interface. Transmit queue can include data or references to data for transmission by network interface. Receive queue can include data or references to data that was received by network interface from a network. Descriptor queues can include descriptors that reference data or packets in transmit queue or receive queue. Bus interface can provide an interface with host device (not depicted). For example, bus interface can be compatible with peripheral connect Peripheral Component Interconnect (PCI), PCI Express, PCI-x, Serial ATA (SATA), and/or Universal Serial Bus (USB) compatible interface (although other interconnection standards may be used).

[0168] Decoding engine can apply in-order or sequential decoding of data received by network interface as well as speculative decoding of data received by network interface where an applied discard window is selected based on a chosen offset between a token position decoded by in-order or sequential decoding and a token position decoded by speculative decoding. The chosen offset can be selected to fill a speculative decoded buffer but not overfill the buffer.

[0169] Processor-based systems, such as servers, can use embodiments described herein to provide data to or from the system to another device through a mesh or fabric. System includes processor, which provides processing, operation management, and execution of instructions for system. Processor can include any type of microprocessor, central processing unit (CPU), graphics processing unit (GPU), processing core, or other processing hardware to provide processing for system, or a combination of processors. Processor controls the overall operation of system, and can be or include, one or more programmable general-purpose or special-purpose microprocessors, digital signal processors (DSPs), programmable controllers, application specific integrated circuits (ASICs), programmable logic devices (PLDs), or the like, or a combination of such devices.

[0170] In one example, system includes interface coupled to processor, which can represent a higher speed interface or a high throughput interface for system components that needs higher bandwidth connections, such as memory subsystem or graphics interface components, or accelerators. Interface represents an interface circuit, which can be a standalone component or integrated onto a processor die. Where present, graphics interface interfaces to graphics components for providing a visual display to a user of system. In one example, graphics interface can drive a high definition (HD) display that provides an output to a user. High definition can refer to a display having a pixel density of approximately 100 PPI (pixels per inch) or greater and can include formats such as full HD (e.g., 1080p), retina displays, 4K (ultra-high definition or UHD), or others. In one example, the display can include a touchscreen display. In one example, graphics interface generates a display based on data stored in memory **1030** or based on operations executed by processor or both. In one example, graphics interface generates a display based on data stored in memory or based on operations executed by processor or both.

[0171] Accelerators can be a fixed function offload engine that can be accessed or used by a processor. For example, an accelerator among accelerators can provide sequential and speculative decoding operations in a manner described herein, compression (DC) capability, cryptography services such as public key encryption (PKE), cipher, hash/authentication capabilities, decryption, or other capabilities or services. In some embodiments, in addition or alternatively, an accelerator among accelerators provides field select controller capabilities as described herein. In some cases, accelerators can be integrated into a CPU socket (e.g., a connector to a motherboard or circuit board that includes a CPU and provides an electrical interface with the CPU). For example, accelerators can include a single or multi-core processor, graphics processing unit, logical execution unit single or multi-level cache, functional units usable to independently execute programs or threads, application specific integrated circuits (ASICs), neural network processors (NNPs), programmable control logic, and programmable processing elements such as field programmable gate arrays (FPGAs). Accelerators can provide multiple neural networks, CPUs, processor cores, general purpose graphics processing units, or graphics processing units can be made available for use by artificial intelligence (AI) or machine learning (ML) models. For example, the AI model can use or include any or a combination of: a reinforcement learning scheme, Q-learning scheme, deep-Q learning, or Asynchronous Advantage Actor-Critic (A3C), combinatorial neural network, recurrent combinatorial neural network, or other AI or ML model. Multiple neural networks, processor cores, or graphics processing units can be made available for use by AI or ML models.

[0172] Memory subsystem represents the main memory of system and provides storage for code to be executed by processor, or data values to be used in executing a routine. Memory subsystem can include one or more memory devices such as read-only memory (ROM), flash memory, one or more varieties of random access memory (RAM) such as DRAM, or other memory devices, or a combination of such devices. Memory stores and hosts, among other things, operating system (OS) to provide a software platform for execution of instructions in system. Additionally, applications can execute on the software platform of OS from memory. Applications represent programs that have their own operational logic to perform execution of one or more functions. Processes represent agents or routines that provide auxiliary functions to OS or one or more applications or a combination. OS, applications, and processes provide software logic to provide functions for system. In one example, memory subsystem includes memory controller, which is a memory controller to generate and issue commands to memory. It will be understood that memory controller could be a physical part of processor or a physical part of interface. For example, memory controller can be an integrated memory controller, integrated onto a circuit with processor.

[0173] While not specifically illustrated, it will be understood that system can include one or more buses or bus systems between devices, such as a memory bus, a graphics bus, interface buses, or others. Buses or other signal lines can communicatively or electrically couple components together, or both communicatively and electrically couple the components. Buses can include physical communication lines, point-to-point connections, bridges, adapters, controllers, or other circuitry or a combination. Buses can include, for example, one or more of a system bus, a Peripheral Component Interconnect (PCI) bus, a Hyper Transport or industry standard architecture (ISA) bus, a small computer system interface (SCSI) bus, a universal serial bus (USB), or an Institute of Electrical and Electronics Engineers (IEEE) standard 1394 bus (Firewire).

[0174] In one example, system includes interface, which can be coupled to interface. In one example, interface represents an interface circuit, which can include standalone components and integrated circuitry. In one example, multiple user interface components or peripheral components, or both, couple to interface. Network interface provides system the ability to communicate with remote devices (e.g., servers or other computing devices) over one or more networks. Network interface can include an Ethernet adapter, wireless interconnection components, cellular network interconnection components, USB (universal serial bus), or other wired or wireless standards-based or proprietary interfaces. Network interface can transmit data to a device that is in the same data center or rack or a remote device, which can include sending data stored in memory. Network interface can receive data from a remote device, which can include storing received data into memory. Various embodiments can be used in connection with network interface, processor, and memory subsystem.

[0175] In one example, system includes one or more input/output (I/O) interface(s). I/O interface can include one or more interface components through which a user interacts with system (e.g., audio, alphanumeric, tactile/touch, or other interfacing). Peripheral interface can include any hardware interface not specifically mentioned above. Peripherals refer generally to devices that connect dependently to system. A dependent connection is one where system provides the software platform or hardware platform or both on which operation executes, and with which a user interacts.

[0176] In one example, system includes storage subsystem to store data in a nonvolatile manner In one example, in certain system implementations, at least certain components of storage can overlap with components of memory subsystem. Storage subsystem includes storage device(s), which can be or include any conventional medium for storing large amounts of data in a nonvolatile manner, such as one or more magnetic, solid state, or optical based disks, or a combination. Storage holds code or instructions and data in a persistent state (i.e., the value is retained despite interruption of power to the processor-based system). Storage can be generically considered to be a "memory," although memory is typically the executing or operating memory to provide instructions to processor. Whereas storage is nonvolatile, memory can include volatile memory (i.e., the value or state of the data is indeterminate if power is interrupted to the processor-based system). In one example, storage subsystem includes controller to interface with storage. In one example controller is a physical part of interface or processor or can include circuits or logic in both processor and interface.

[0177] A volatile memory is memory whose state (and therefore the data stored in it) is indeterminate if power is interrupted to the device. Dynamic volatile memory can involve refreshing the data stored in the device to maintain state. One example of dynamic volatile memory incudes DRAM (Dynamic Random Access Memory), or some variant such as Synchronous DRAM (SDRAM). A memory subsystem as described herein may be compatible with a number of memory technologies, such as DDR3 (Double Data Rate version 3, original release by JEDEC (Joint Electronic Device Engineering Council) on Jun. 27, 2007). DDR4 (DDR version 4, initial specification published in September 2012 by JEDEC), DDR4E (DDR version 4), LPDDR3 (Low Power DDR version3, JESD209-3B, August 2013 by JEDEC), LPDDR4) LPDDR version 4, JESD209-4, originally published by JEDEC in August 2014), WIO2 (Wide Input/output version 2, JESD229-2 originally published by JEDEC in August 2014, HBM (High Bandwidth Memory, JESD325, originally published by JEDEC in October 2013, LPDDR5 (currently in discussion by JEDEC), HBM2 (HBM version 2), currently in discussion by JEDEC, or others or combinations of memory technologies, and technologies based on derivatives or extensions of such specifications.

[0178] A non-volatile memory (NVM) device is a memory whose state is determinate even if power is interrupted to the device. In one embodiment, the NVM device can comprise a block addressable memory device, such as NAND technologies, or more specifically, multi-threshold level NAND flash memory (for example, Single-Level Cell ("SLC"), Multi-Level Cell ("MLC"), Quad-Level Cell ("QLC"), Tri-Level Cell ("TLC"), or some other NAND). A NVM device can also comprise a byte-addressable write-in-place three dimensional cross point memory device, or other byte addressable write-in-place NVM device (also referred to as persistent memory), such as single or multi-level Phase Change Memory (PCM) or phase change memory with a switch (PCMS), NVM devices that use chalcogenide phase change material (for example, chalcogenide glass), resistive memory including metal oxide base, oxygen vacancy base and Conductive Bridge Random Access Memory (CB-RAM), nanowire memory, ferroelectric random access memory (FeRAM, FRAM), magneto resistive random access memory (MRAM) that incorporates memristor technology, spin transfer torque (STT)-MRAM, a spintronic magnetic junction memory based device, a magnetic tunneling junction (MTJ) based device, a DW (Domain Wall) and SOT (Spin Orbit Transfer) based device, a thyristor based memory device, or a combination of any of the above, or other memory.

[0179] A power source (not depicted) provides power to the components of the processor-based system. More specifically, power source typically interfaces to one or multiple power supplies in processor-based system to provide power to the components of processor-based system. In one example, the power supply includes an AC to DC (alternating current to direct current) adapter to plug into a wall outlet. Such AC power can be renewable energy (e.g., solar power) power source. In one example, power source includes a DC power source, such as an external AC to DC converter. In one example, power source or power supply includes wireless charging hardware to charge via proximity to a charging field. In one example, power source can include an internal battery, alternating current supply, motion-based power supply, solar power supply, or fuel cell source.

[0180] In an example, processor-based system can be implemented using interconnected compute sleds of processors, memories, storages, network interfaces, and other components. High speed interconnects can be used such as PCIe, Ethernet, or optical interconnects (or a combination thereof).

[0181] Embodiments herein may be implemented in various types of computing and networking equipment, such as switches, routers, racks, and blade servers such as those employed in a data center and/or server farm environment. The servers used in data centers and server farms comprise arrayed server configurations such as rack-based servers or blade servers. These servers are interconnected in communication via various network provisions, such as partitioning sets of servers into Local Area Networks (LANs) with appropriate switching and routing facilities between the LANs to form a private Intranet. For example, cloud hosting facilities may typically employ large data centers with a multitude of servers. A blade comprises a separate computing platform that is configured to perform server-type functions, that is, a "server on a card." Accordingly, a blade includes components common to conventional servers, including a main printed circuit board (main board) providing internal wiring (i.g., buses) for coupling appropriate integrated circuits (ICs) and other components mounted to the board.

[0182] A processor-based environment includes multiple computing racks, some including a Top of Rack (ToR) switch, a pod manager, and a plurality of pooled system drawers. Various embodiments can be used in a switch. Generally, the pooled system drawers may include pooled compute drawers and pooled storage drawers. Optionally, the pooled system drawers may also include pooled memory drawers and pooled Input/Output (I/O) drawers. In the illustrated embodiment the pooled system drawers include an Intel® XEON® pooled computer drawer, and Intel® ATOM™ pooled compute drawer, a pooled storage drawer, a pooled memory drawer, and a pooled I/O drawer. Some of the pooled system drawers is connected to ToR switch via a high-speed link, such as a 40 Gigabit/second (Gb/s) or 100 Gb/s Ethernet link or a 100+Gb/s Silicon Photonics (SiPh) optical link. In one embodiment high-speed link comprises an 800 Gb/s SiPh optical link.

[0183] Multiple of the computing racks may be interconnected via their ToR switches (e.g., to a pod-level switch or data center switch), as illustrated by connections to a network. In some embodiments, groups of computing racks are managed as separate pods via pod manager(s). In one embodiment, a single pod manager is used to manage racks in the pod. Alternatively, distributed pod managers may be used for pod management operations.

[0184] Environment further includes a management interface that is used to manage various aspects of the environment. This includes managing rack configuration, with corresponding parameters stored as rack configuration data. As used in any embodiment herein, the terms "system" or "module" may refer to, for example, software, firmware and/or circuitry configured to perform any of the aforementioned operations. Software may be embodied as a software package, code, instructions, instruction sets and/or data recorded on non-transitory computer readable storage mediums. Firmware may be embodied as code, instructions or instruction sets and/or data that are hard-coded (e.g., nonvolatile) in memory devices.

[0185] As used in any embodiment herein, the term "circuitry" may comprise, for example, singly or in any combination, hardwired circuitry, programmable circuitry such as computer processors comprising one or more individual instruction processing cores, state machine circuitry, and/or firmware that stores instructions executed by programmable circuitry or future computing paradigms including, for example, massive parallelism, analog or quantum computing, hardware embodiments of accelerators such as neural net processors and non-silicon implementations of the above. The circuitry may, collectively or individually, be embodied as circuitry that forms part of a larger system, for example, an integrated circuit (IC), system on-chip (SoC), desktop computers, laptop computers, tablet computers, servers, smartphones, etc.

[0186] Any of the operations described herein may be implemented in a system that includes one or more mediums (e.g., non-transitory storage mediums) having stored therein, individually or in combination, instructions that when executed by one or more processors perform the methods. Here, the processor may include, for example, a server CPU, a mobile device CPU, and/or other programmable circuitry. Also, it is intended that operations described herein may be distributed across a plurality of physical devices, such as processing structures at more than one different physical location. The storage medium may include any type of tangible medium, for example, any type of disk including hard disks, floppy disks, optical disks, compact disk read-only memories (CD-ROMs), compact disk rewritables (CD-RWs), and magneto-optical disks, semiconductor devices such as read-only memories (ROMs), random access memories (RAMs) such as dynamic and static RAMs, erasable programmable read-only memories (EPROMs), electrically erasable programmable read-only memories (EEPROMs), flash memories, Solid State Disks (SSDs), embedded multimedia cards (eMMCs), secure digital input/output (SDIO) cards, magnetic or optical cards, or any type of media suitable for storing electronic instructions. Other embodiments may be implemented as software executed by a programmable control device.

[0187] Thus, the present disclosure is directed to systems and methods of improving the thermal performance of processor-based devices. Such thermal performance improvement may include limiting the degree of tilt experienced by a semiconductor device as a thermal solution coupled to the semiconductor device is tightened to the substrate. Such thermal performance improvements may include increasing the available heat transfer area associated with a particular heat producing semiconductor device. Such thermal performance improvements may include thermally coupling one or more cool blocks thermally coupled to one or more remote heat-producing devices to a central cool block that may be cooled using a cooling medium or coupled to a central heat-producing semiconductor device.

[0188] The following examples pertain to further embodiments. The following examples of the present disclosure may comprise subject material such as at least one device, a method, at least one machine-readable medium for storing instructions that when executed cause a machine to perform acts based on the method, means for performing acts based on the method and/or a system for cooling one or more heat-producing components in a processor-based device.

[0189] According to example 1, there is provided an electronic device cooling system. The cooling system may include: a cold plate thermally and physically couplable to a first heat-producing semiconductor device; a thermal retention block member thermally and physically couplable to the cold plate; a remote device cooler block thermally and physically couplable to a second heat-producing device, the second heat-producing device disposed remote from the first heat-producing semiconductor device; and one or more thermal channels, each of the one or more thermal channels having a first end and a second end, the first end of each of the one or more thermal channels thermally coupled to the remote device cooler block and the second end of each of the one or more thermal channels thermally coupled to the thermal retention block member.

[0190] Example 2 may include elements of example 1 where the cold plate may include a liquid cooled cold plate having at least one fluid inlet and at least one fluid outlet.

[0191] Example 3 may include elements of any of examples 1 or 2 and the electronic device cooling system may further include: comprising one or more cold plate bracket members to physically couple the cold plate to a substrate that includes the first heat-producing semiconductor device.

[0192] Example 4 may include elements of any of examples 1 through 3 where the one or more cold plate bracket members may include at least one of: one or more aluminum cold plate bracket members; one or stainless steel cold plate bracket members.

[0193] Example 5 may include elements of any of examples 1 through 4 where the cold plate may include a copper cold plate having a plurality of microchannels to provide fluid flow across an upper surface of the copper cold plate.

[0194] Example 6 may include elements of any of examples 1 through 5 where the thermal retention block member is disposed proximate the upper surface of the cold plate; and where the first heat-producing semiconductor device is disposed proximate a lower surface of the cold plate.

[0195] Example 7 may include elements of any of examples 1 through 6 where the thermal retention block member forms at least a portion of one or more of the plurality of microchannels.

[0196] Example 8 may include elements of any of examples 1 through 7 where the one or more thermal channels may include one or more sealed heat pipes.

[0197] Example 9 may include elements of any of examples 1 through 8 where the cold plate is integrally formed with the thermal retention block member.

[0198] Example 10 may include elements of any of examples 1 through 9 and the electronic device cooling system may further include: a second remote device cooler block thermally and physically couplable to a third heat-producing device, the third heat-producing device disposed remote from the first heat-producing semiconductor device and the second heat-producing device; and one or more second thermal channels, each of the one or more second thermal channels having a first end and a second end, the first end of each of the one or more second thermal channels thermally coupled to the second remote device cooler block and the second end of each of the one or more thermal channels thermally coupled to the thermal retention block member.

[0199] According to example 11, there is provided a semiconductor device carrier apparatus. The apparatus may include: a frame member having an upper surface couplable to a thermal solution and a lower surface couplable to a heat-producing semiconductor device; where the frame member includes a plurality of apertures, each of the plurality of apertures to accommodate the passage of at least one fastener to couple the frame member to a substrate that includes the heat-producing semiconductor device; a plurality of short stopper members disposed on the lower surface of the frame member and about the periphery of the frame member; where each of the plurality of short stopper members includes a first material having a first durometer value; and a plurality of long stopper members disposed on the lower surface of the frame member and about the periphery of the frame member; wherein each of the plurality of long stopper members includes a second material having a second durometer value, the second durometer value less than the first durometer value.

[0200] Example 12 may include elements of example 11 where the frame member comprises a frame member having an upper surface couplable to a thermal solution that includes an extended surface heat sink.

[0201] Example 13 may include elements of any of examples 11 or 12 where the frame member further includes a plurality of thermal solution attachment features.

[0202] According to example 14, there is provided a thermal solution spring cell. The spring cell may include: a fastener head; a fastener body coupled to the fastener head that includes: an upper portion coupled to the fastener head, the upper portion including a cylindrical member having a first diameter; a lower portion coupled to the upper portion, the lower portion including: \a cylindrical portion having a second diameter greater than the first diameter, to form a shoulder between the upper portion and the lower portion; and a groove to receive a clip member, the groove formed at least partially about the periphery of the lower cylindrical portion, the groove disposed proximate an end of the lower portion of the fastener body distal from the upper portion of the fastener body; a compressible element disposed proximate at least a portion of the upper portion of the fastener body; and a retaining ring to at least partially compress the compressible element about the upper portion of the fastener body and physically engage the shoulder between the upper portion of the fastener body and the lower portion of the fastener body.

[0203] Example 15 may include elements of example 14 and the spring cell may further include: a spacer element disposed about at least a portion of the lower portion of the fastener body; and a clip member disposed at least partially within the groove to retain the spacer element between the retaining ring and the clip member.

[0204] Example 16 may include elements of any of examples 14 or 15 where the clip member may include at least one of: a E-Ring or a C-Clip.

[0205] Example 17 may include elements of any of examples 14 through 16 where the compressible element comprises a helical coil spring disposed about a periphery of at least a portion of the upper portion of the fastener body.

[0206] According to example 18, there is provided a central processing unit (CPU) backplate apparatus. The apparatus may include: a backplate to couple to a first surface of a printed circuit board opposite a CPU disposed on a second surface of the printed circuit board, the first surface transversely opposed across a thickness of the printed circuit board from the second surface; an extended heat transfer surface physically and thermally coupled to a first surface of the backplate, the first surface of the backplate transversely opposed across a thickness of the backplate from a second surface of the backplate, the second surface of the backplate proximate the first surface of the printed circuit board.

[0207] Example 19 may include elements of example 18 where the backplate comprises at least one of: a copper backplate, a copper containing alloy backplate, an aluminum backplate, or an aluminum containing backplate.

[0208] Example 20 may include elements of any of examples 18 or 19 where the extended heat transfer surface may include at least one of: a copper extended heat transfer surface, a copper containing alloy extended heat transfer surface, an aluminum extended heat transfer surface, or an aluminum alloy extended heat transfer surface.

[0209] Example 21 may include elements of any of examples 18 through 20 where the second surface of the backplate includes a recess to accommodate a voltage regulator disposed on the first surface of the printed circuit board.

[0210] According to example 22, there is provided a semiconductor device extended surface heat transfer apparatus. The heat transfer apparatus may include: a first extended surface heat transfer device that includes a baseplate having an upper surface and a lower surface and a plurality of fins physically and thermally coupled to the upper surface of the baseplate, the first extended surface heat transfer device having a first longitudinal axis; a thermally conductive rotatable mount having a first end and a second end, wherein the first end of the thermally conductive rotatable mount attaches to the upper surface of the baseplate of the first extended surface heat transfer device; and a second extended surface heat transfer device that includes a baseplate having an upper surface and a lower surface and a plurality of fins physically and thermally coupled to the upper surface of the baseplate, the second extended surface heat transfer device having a second longitudinal axis; wherein the second end of the thermally conductive rotatable mount attaches to the lower surface of the baseplate of the second extended surface heat transfer device; and wherein the thermally conductive rotatable mount permits the second longitudinal axis of the second extended surface heat transfer device to rotate through an angle of at least 90 degrees with respect to the first longitudinal axis of the first extended surface heat transfer device.

[0211] Example 23 may include elements of example 22 and the heat transfer apparatus may additionally include: a fixed pin set physically coupled to the upper surface of the baseplate of the first extended surface heat transfer device, the fixed pin set reversible positionable between a first position and a second position: where, in the first position, the second extended surface heat transfer device is fixed with respect to the first extended surface heat transfer device; and where, in the second position the second extended surface heat transfer device is rotatable with respect to the first extended surface heat transfer device.

[0212] Example 24 may include elements of any of examples 22 or 23 where the thermally conductive rotatable mount may include: a thermally conductive roller member rotatable with respect to the baseplate of the first extended surface heat transfer device and affixed to the baseplate of the second extended surface heat transfer device; a biasing element disposed about at least a portion of the thermally conductive roller member; wherein the biasing element biases the thermally conductive roller member toward the baseplate of the first extended surface heat transfer device; and a support sleeve disposed about at least a portion of the biasing element, the support sleeve affixed to the baseplate of the first extended surface heat transfer device; wherein the thermally conductive roller member is displaceable with respect to the support sleeve.

[0213] Example 25 may include elements of any of examples 22 through 24 where the fixed pin set may include: a pin member that includes a ridge disposed about the periphery of the pin member; a biasing element disposed about the pin member; and a support member disposed about the biasing element such that the biasing element is trapped between the ridge disposed about the periphery of the pin member and the support member; wherein a vertical displacement of the pin member compresses the biasing element.

[0214] According to example 26, there is provided a two-part, detachable heat sink system. The system may include: a first extended surface heat transfer device having a first heat transfer area, an upper surface, and a lower surface, the lower surface disposed proximate a heat-producing device coupled to a substrate; a thermal interface member thermally coupled to the upper surface of the first extended surface heat transfer device; a second extended surface heat transfer device having a second heat transfer area, an upper surface, and a lower surface, the lower surface, the second extended surface heat transfer device disposed proximate and thermally coupled to the thermal interface member; and one or more fasteners to detachably attach the second extended surface heat transfer device to the thermal interface member and to the first extended surface heat transfer device.

[0215] Example 27 may include elements of example 26 where the second heat transfer area is greater than or equal to the first heat transfer area.

[0216] Example 28 may include elements of any of examples 26 or 27 where the one or more fasteners comprise a plurality of spring and shoulder threaded fasteners.

[0217] Example 29 may include elements of any of examples 26 through 28 where the one or more fasteners comprise one or more clamping systems, each of the one or more clamping systems may include: a clamp member having a first end and an opposed second end; a first attachment fixture disposed proximate the first end of the clamp member, the first attachment fixture to couple to the first extended surface heat transfer device; and a second attachment fixture disposed proximate the second end of the clamp member, the first attachment fixture to couple to the first extended surface heat transfer device.

[0218] Example 30 may include elements of any of examples 26 through 29 where the one or more fasteners comprise at least one spring clip.

[0219] According to example 31, there is provided a thermal transfer system. The thermal transfer system may include: a distribution block including at least one cooling medium inlet to receive a cooling medium and at least one cooling medium outlet; a cold block physically and thermally couplable to a first heat-producing, board-mounted device, the cold block including at least one cooling medium inlet fluidly coupled to the at least one cooling medium outlet of the distribution block to receive the cooling medium from the distribution block; at least one remote cold block physically and thermally couplable to at least one heat producing board mounted device; and at least one thermal conduit having a first end and a second end, the first end thermally couplable to the distribution block and the second end thermally couplable to the remote cold block.

[0220] Example 32 may include elements of example 31 where the distribution block may include a distribution block physically and thermally couplable to a second heat-producing, board-mounted device.

[0221] Example 33 may include elements of any of examples 31 or 32 where the at least one thermal conduit may include at least one heat pipe.

[0222] Example 34 may include elements of any of examples 31 through 33 where the cold block may include a cold block disposed between the first heat-producing, board-mounted device and the distribution block.

[0223] According to example 35, there is provided a semiconductor die insertion system. The system may include: a pedestal member having a thickness, an upper surface, and a lower surface; at least one pin array that includes a plurality of pin members extending from the lower surface of the pedestal member, the at least one pin array disposed across at least a portion of the lower surface of the pedestal member; wherein each of the plurality of pin members extend a first distance from the lower surface of the pedestal member; and a pusher member having a upper surface and a lower surface, the pusher member including at least one extension member that projects a second distance from the lower surface of the pusher member; wherein the second distance is greater than the sum of the pedestal member thickness and the first distance.

[0224] Example 36 may include elements of example 35 where the extension member projects from at least a portion of a periphery of the pusher member.

[0225] Example 37 may include elements of any of examples 35 or 36 where the at least one pin array may include a plurality of pin arrays.

[0226] According to example 38, there is provided a thermal solution fastener. The fastener may include: a fastener member having a head portion and a body portion; a fastener housing disposed about at least a portion of the body portion of the fastener member, the fastener slidably displaceable through an aperture formed in the fastener housing; and a rotatable member rotatably coupled to the fastener housing, the rotatable member including: an upper portion that in a first position is disposed proximate the head portion of the fastener member and in a second position is disposed remote from the head portion of the fastener member; and a lower portion that in the first position disengages from a surface feature coupled to an upper surface of a substrate and in the second position engages the surface feature coupled to the upper surface of the substrate.

[0227] Example 39 may include elements of example 38 where the fastener housing further includes a plurality of pockets to receive a hinge portion of the rotatable member.

[0228] According to example 40, there is provided a thermal solution. The thermal solution may include: an enclosed chamber that includes: a thermally conductive lower surface to dispose proximate at least a portion of a surface of a heat-producing electronic component; at least one coolant inlet to receive a coolant flow; and at least one coolant outlet to discharge the received coolant flow; and a plurality of turbulence elements to cause a coolant flowing through the enclosed chamber to flow in a turbulent flow regime across at least a portion of the thermally conductive lower surface.

[0229] Example 41 may include elements of example 40 where the thermally conductive lower surface further includes: a plurality of thermal members thermally coupled to the thermally conductive lower surface, wherein the plurality of turbulence elements physically couple to at least a portion of the plurality of thermal members.

[0230] Example 42 may include elements of any of examples 40 or 41 where the plurality of turbulence elements include a plurality of thermally conductive turbulence elements.

[0231] Example 43 may include elements of any of examples 40 through 42 and the thermal solution may additionally include: a distribution header fluidly coupled to the at least one coolant inlet, the distribution header including at least one convergent/divergent nozzle.

[0232] Example 44 may include elements of any of examples 40 through 43 and the thermal solution may additionally include: a distribution header fluidly coupled to the at least one coolant inlet, the distribution header including: at least one convergent/divergent nozzle.

[0233] According to example 45, there is provided a thermal solution system. The system may include: at least one sensor to measure a thermal output of at least one heat-producing electronic component; a variable flow output fluid mover to discharge a coolant; an enclosed chamber that includes: a thermally conductive lower surface to dispose proximate at least a portion of a surface of a heat-producing electronic component; at least one coolant inlet to receive a coolant flow; and at least one coolant outlet to discharge the received coolant flow; and a plurality of turbulence elements to cause a coolant flowing through the enclosed chamber to flow in a turbulent flow regime across at least a portion of the thermally conductive lower surface; and control circuitry communicatively coupled to the at least one sensor and the variable flow output fluid mover, the control circuitry to: adjust the coolant flow provided by the variable flow output fluid mover based on the thermal output of the at least one heat-producing electronic component.

[0234] Example 46 may include elements of example 45 and the control circuitry may further: receive data representative of a future expected computational load on the at least one heat-producing electronic component; and adjust the coolant flow provided by the variable flow output fluid mover based on the future expected computational load on the at least one heat-producing electronic component.

[0235] Example 47 may include elements of any of examples 45 or 46 where the thermally conductive lower surface further includes: a plurality of thermal members thermally coupled to the thermally conductive lower surface, wherein the plurality of turbulence elements physically couple to at least a portion of the plurality of thermal members.

[0236] Example 48 may include elements of any of examples 45 through 47 where the thermally conductive lower surface further includes: a plurality of thermally conductive turbulence elements.

[0237] Example 49 may include elements of any of examples 45 through 48 and the system may further include: a distribution header fluidly coupled to the at least one coolant inlet, the distribution header including: at least one convergent/divergent nozzle.

[0238] Example 50 may include elements of any of examples 45 through 49 and the system may further include: a distribution header fluidly coupled to the at least one coolant inlet, the distribution header including: at least one convergent/divergent nozzle.

[0239] According to example 51, there is provided a method for cooling a heat producing electronic device. The method may include: receiving, from at least one sensor by control circuitry, data representative of a thermal output of at least one heat-producing electronic component; distributing via one or more nozzles a coolant flow through an enclosed chamber thermally coupled to the heat-producing electronic device; adjusting, by control circuitry, a coolant flow rate through the enclosed chamber; and causing the coolant flow through the enclosed chamber to flow in a turbulent flow regime.

[0240] Example 52 may include elements of example 51 and the method may further include: receiving, by the control circuitry, data representative of a future expected computational load on the at least one heat-producing electronic component; and adjusting, by the control circuitry, the coolant flow provided by the variable flow output fluid mover based on the future expected computational load on the at least one heat-producing electronic component.

[0241] Example 53 may include elements of any of examples 51 or 52 where distributing via one or more nozzles a coolant flow through an enclosed chamber thermally coupled to the heat-producing electronic device further includes: distributing via one or more convergent/divergent nozzles the coolant flow through the enclosed chamber.

[0242] Example 54 may include elements of any of examples 51 through 53 where causing the coolant flow through the enclosed chamber to flow in a turbulent flow regime further includes: causing the coolant flow through the enclosed chamber to flow in a turbulent flow regime using a plurality of turbulence elements physically coupled to at least a portion of a plurality of thermal members disposed in the enclosed chamber.

[0243] Example 55 may include elements of any of examples 51 through 54 where causing the coolant flow through the enclosed chamber to flow in a turbulent flow regime using a plurality of turbulence elements physically coupled to at least a portion of a plurality of thermal members further includes: causing the coolant flow through the enclosed chamber to flow in a turbulent flow regime using a plurality of turbulence elements rotatably, physically coupled to at least a portion of a plurality of thermal members.

[0244] According to example 56, there is provided a controller. The controller may include: an input/output interface; and control circuitry to: receive, from at least one sensor, data representative of a thermal output of at least one heat-producing electronic component; receive, via the I/O interface, data representative of a future expected computational load on the at least one heat-producing electronic component; and adjust, using a variable output fluid mover, a turbulent coolant flow rate through an enclosed chamber thermally coupled to a heat-producing electronic device based at least in part the received data representative of a thermal output of at least one heat-producing electronic component and the received data representative of a future expected computational load on the at least one heat-producing electronic component.

[0245] The terms and expressions which have been employed herein are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described (or portions thereof), and it is recognized that various modifications are possible within the scope of the claims. Accordingly, the claims are intended to cover all such equivalents. Various features, aspects, and embodiments have been described herein. The features, aspects, and embodiments are susceptible to combination with one another as well as to variation and modification, as will be understood by those having skill in the art. The present disclosure should, therefore, be considered to encompass such combinations, variations, and modifications.

[0246] As described herein, various embodiments may be implemented using hardware elements, software elements, or any combination thereof. Examples of hardware elements may include processors, microprocessors, circuits, circuit elements (e.g., transistors, resistors, capacitors, inductors, and so forth), integrated circuits, application specific integrated circuits (ASIC), programmable logic devices (PLD), digital signal processors (DSP), field programmable gate array (FPGA), logic gates, registers, semiconductor device, chips, microchips, chip sets, and so forth.

[0247] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

What is claimed:

1. A two-part, separable, heat sink system, comprising:

a first extended surface heat transfer device having an upper surface and a lower surface, the lower surface of the first extended surface heat transfer device thermally couplable to a thermally emissive device coupled to a substrate;

a second extended surface heat transfer device having an upper surface and a lower surface;

a thermal interface member to thermally couple the first extended surface heat transfer device to the second extended surface heat transfer device, the thermal interface member disposed proximate the upper surface of the first extended surface heat transfer device and proximate the lower surface of the second extended surface heat transfer device; and at least one attachment feature, the at least one attachment feature to detachably physically couple the thermal interface member between the first extended surface heat transfer device and the second extended surface heat transfer device.

2. The two-part heat sink system of claim **1**, wherein the first extended surface heat transfer device comprises a first plurality of parallel fins to provide a first heat transfer area; and wherein the second extended surface heat transfer device comprises a second plurality of parallel fins to provide a second heat transfer area.

3. The two-part heat sink system of claim **2**, wherein the first heat transfer area is less than the second heat transfer area.

4. The two-part heat sink system of claim **2**, wherein the first extended surface heat transfer device physically couples to the second extended surface heat transfer device such that the first plurality of fins are disposed parallel to the second plurality of fins.

5. The two-part heat sink system of claim **2**, wherein the first extended surface heat transfer device physically couples to the second extended surface heat transfer device such that the first plurality of fins are disposed perpendicular to the second plurality of fins.

6. The two-part heat sink system of claim **1**, wherein the at least one attachment feature comprises: at least one spring and shoulder threaded fastener to physically couple the first extended surface heat transfer device to the second extended surface heat transfer device such that the thermal interface member is disposed between the first extended surface heat transfer device and the second extended surface heat transfer device.

7. The two-part heat sink system of claim **1**, wherein the at least one attachment feature comprises: at least one spring clip to physically couple the first extended surface heat transfer device to the second extended surface heat transfer device such that the thermal interface member is disposed between the first extended surface heat transfer device and the second extended surface heat transfer device.

8. The two-part heat sink system of claim **1**, wherein the at least one attachment feature comprises: a clamp member having a central member, a first end, and a second end disposed at an end of the central member opposite the first end; a first coupling fixture disposed proximate the first end of the clamp member, the first coupling fixture to physically couple to a first location on the first extended surface heat transfer device; and a second coupling fixture disposed proximate the first end of the clamp member, the first coupling fixture to physically couple to a first location on the first extended surface heat transfer device; wherein the central member extends transversely across at least a portion of the second extended surface heat transfer device.

9. The two-part heat sink system of claim **8**, wherein the first coupling fixture includes a threaded fastener; and wherein the second coupling fixture includes a threaded fastener.

10. The two-part heat sink system of claim **1**, wherein the thermal interface member comprises a member having a member having a thermal conductivity greater than 200 Watts/meter-Kelvin (W/m-K).

11. An electronic device, comprising:

a substrate;

processor circuitry coupled to the substrate;

a two-part, separable, heat sink system thermally couplable, comprising:

a first extended surface heat transfer device having an upper surface and a lower surface, the lower surface of the first extended surface heat transfer device thermally couplable to the processor circuitry;

a second extended surface heat transfer device having an upper surface and a lower surface;

a thermal interface member to thermally couple the first extended surface heat transfer device to the second extended surface heat transfer device, the thermal interface member disposed proximate the upper surface of the first extended surface heat transfer device and proximate the lower surface of the second extended surface heat transfer device; and

at least one attachment feature, the at least one attachment feature to detachably physically couple the thermal interface member between the first extended surface heat transfer device and the second extended surface heat transfer device.

12. The device of claim **11**, wherein the first extended surface heat transfer device comprises a first plurality of parallel fins to provide a first heat transfer area; and wherein the second extended surface heat transfer device comprises a second plurality of parallel fins to provide a second heat transfer area.

13. The device of claim **12**, wherein the first heat transfer area is less than the second heat transfer area.

14. The device of claim **12**, wherein the first extended surface heat transfer device physically couples to the second extended surface heat transfer device such that the first plurality of fins are disposed parallel to the second plurality of fins.

15. The device of claim **12**, wherein the first extended surface heat transfer device physically couples to the second extended surface heat transfer device such that the first plurality of fins are disposed perpendicular to the second plurality of fins.

16. The device of claim **11**, wherein the at least one attachment feature comprises: at least one spring and shoulder threaded fastener to physically couple the first extended surface heat transfer device to the second extended surface heat transfer device such that the thermal interface member is disposed between the first extended surface heat transfer device and the second extended surface heat transfer device.

17. The device of claim **11**, wherein the at least one attachment feature comprises: at least one spring clip to physically couple the first extended surface heat transfer device to the second extended surface heat transfer device such that the thermal interface member is disposed between the first extended surface heat transfer device and the second extended surface heat transfer device.

18. The device of claim **11**, wherein the at least one attachment feature comprises: a clamp member having a central member, a first end, and a second end disposed at an end of the central member opposite the first end; a first coupling fixture disposed proximate the first end of the clamp member, the first coupling fixture to physically couple to a first location on the first extended surface heat transfer device; and a second coupling fixture disposed proximate the first end of the clamp member, the first coupling fixture to physically couple to a first location on the first extended surface heat transfer device; wherein the central member extends transversely across at least a portion of the second extended surface heat transfer device.

19. The device of claim **18**, wherein the first coupling fixture includes a threaded fastener; and wherein the second coupling fixture includes a threaded fastener.

20. The device of claim **11**, wherein the thermal interface member comprises a member having a member having a thermal conductivity greater than 200 Watts/meter-Kelvin (W/m-K).

21. A semiconductor package cooling method, comprising:

thermally coupling a two-part, separable, heat sink system, to a thermally emissive device coupled to a substrate, wherein the two-part, separable, heat sink system includes: a first extended surface heat transfer device having an upper surface and a lower surface, the lower surface of the first extended surface heat transfer device thermally couplable to a thermally emissive device coupled to a substrate;

a second extended surface heat transfer device having an upper surface and a lower surface;

a thermal interface member to thermally couple the first extended surface heat transfer device to the second extended surface heat transfer device, the thermal interface member disposed proximate the upper surface of the first extended surface heat transfer device and proximate the lower surface of the second extended surface heat transfer device; and at least one attachment feature, the at least one attachment feature to detachably physically couple the thermal interface member between the first extended surface heat transfer device and the second extended surface heat transfer device.

22. The two-part heat sink system of claim **1**, comprising a controller comprising:

an input/output (I/O) interface; and

control circuitry to:

receive, from at least one sensor, data representative of a thermal output of at least one heat-producing electronic component;

receive, via the I/O interface, data representative of a future expected computational load on the at least one heat-producing electronic component; and

adjust, using a variable output fluid mover, a turbulent coolant flow rate through an enclosed chamber thermally coupled to a heat-producing electronic device based at least in part the received data representative of a thermal output of at least one heat-producing electronic component and the received data representative of a future expected computational load on the at least one heat-producing electronic component.

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