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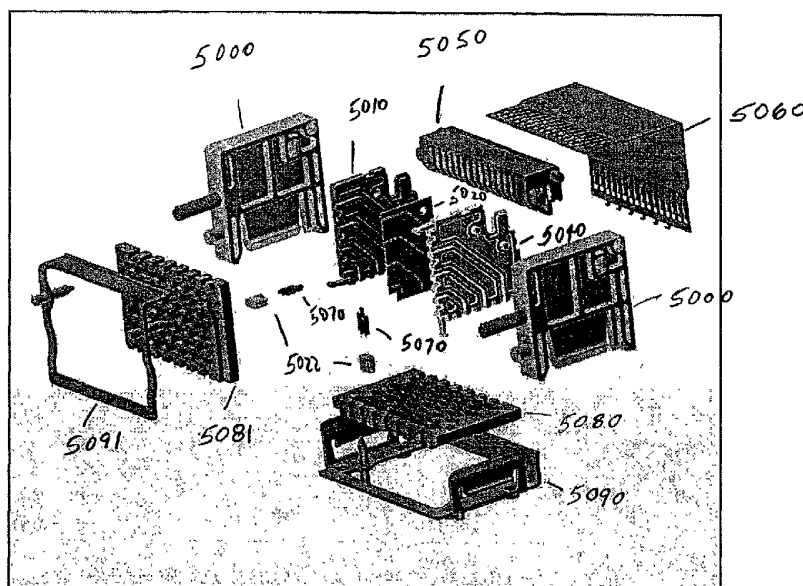
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(54) Title: INTERCONNECTION SYSTEM



(57) Abstract: An interconnection system includes spacers arranged adjacent each other in a row, the spacers having printed circuit boards disposed therebetween. Each printed circuit board has at least one pair of electrical conductors respectively disposed on opposite faces thereof. All of the printed circuit boards have one end exposed on a first plane and a second end exposed on a second plane. Electrically conductive contacts are disposed within cells in a pair of interposers so as to have one end making electrical contact with one of the printed circuit boards and another end extending through its respective cell in its respective interposer.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERCONNECTION SYSTEM

Background of the Invention

Field of the Invention

The present invention relates generally to electrical interconnection systems, and more particularly, to a high speed, high-density interconnection system for differential and single-ended transmission applications.

Description of the Related Art

Backplane systems are comprised of a complex printed circuit board that is referred to as the backplane or motherboard, and several smaller printed circuit boards that are referred to as daughtercards that plug into the backplane. Each of the daughtercards may include a chip that is referred to as a driver/receiver. The driver/receiver sends and receives signals from driver/receivers on other daughtercards. A signal path is formed between the driver/receiver on a first daughtercard and a driver/receiver on a second daughtercard. The signal path includes an electrical connector that connects the first daughtercard to the backplane, the backplane, a second electrical connector that connects the second daughtercard to the backplane, and the second daughtercard having the driver/receiver that receives the carried signal. Various driver/receivers being used today can transmit signals at data rates between 5-10 Gb/sec and greater. The limiting factor (data transfer rate) in the signal path is the electrical connectors that connect each daughtercard to the backplane. A need thus exists in the art for a high-speed electrical connector capable of handling the required high-speed transfer of data.

Further, the receivers are capable of receiving signals having only 5% of the original signal strength sent by the driver. This reduction in signal strength increases the importance of minimizing cross-talk between signal paths to avoid signal degradation or errors being introduced into digital data streams. With high speed, high-density electrical connectors, it is even more important to eliminate or reduce cross-talk. Thus,

a need exists in the art for a high-speed electrical connector capable of handling high-speed signals that reduces cross-talk between signal paths.

There are various types of electrical connectors. One type is a through hole connector which could either be a compliant pin or through hole solder. Backplane systems have typically used connectors that consist of multiple contacts having pins that are inserted into the through hole contained in the printed circuit boards to be connected. The pins can be compliant fit or can be soldered in place. These require a relatively large diameter hole in the printed circuit board for receiving the pins of the connector. The larger hole results in a greater probability of defects from plating and a larger capacitance that reduces the signal speed that can be accommodated by these connectors. For example, plated through holes may not be properly plated and thus pins being inserted from the electrical connector can cause opens, shorts, etc. A plated through hole causes a capacitive effect which reduces the data rate which can be transferred through the pin and hole. Further, many contact type connectors are made from stamped parts that have varying geometries that increase signal reflection and reduce signal speed. Thus, it is advantageous to reduce the diameter of plated through holes using compression mount-type connectors that rely on a spring making contact with a pad on a board.

Many of these problems can be solved using a compression mount type electrical connector. This type of connector overcomes many of the deficiencies of the through hole contact type but compression mount connectors need bulky and expensive hardware to fasten the compression mount connector to the printed circuit board. Intimate contact needs to be maintained between compression mount contacts and the PC board surface without using additional fasteners such as jackscrews.

Additionally, regardless of the type of electrical connector, the electrical connector has to be capable of being mated/unmated at least 250 and perhaps in excess of 5000 times. If the contacts wear, then contact resistance will increase. Contact wear can occur through metal-to-metal contact either through a point or line. For example, a

certain area may continually get wiped as the connector is mated/unmated and the contact tends to wear through the metal sliding action can also cause wear. Also, some compression mount type connectors use dendrite contacts on flexible circuits. One difficulty with dendrite contacts is that these contacts tend to wear and are only good for a half a dozen mating cycles and the dendrites start to flatten out and the multiple points of contacts are lost thereby reducing reliability. Thus, a need exists for a compression mount-type connector that eliminates or reduces contact wear.

Another problem with prior art electrical connectors is that impedance changes over the length of the signal path reduce the potential signal speed. A need exists for an electrical connector in which impedance can be controlled at a specific value and where the specific value remains relatively constant over the length of the signal path.

In summary, electrical connectors used to electrically connect circuit boards such as backpanels to daughtercards suffer from several deficiencies including poor shielding resulting in electrical noise, changes in impedance and the inability to connect and disconnect many times without damage to the electrical connector. These deficiencies limit the data rate that can be transferred through the connector. Thus, a need exists in the art for a high-density electrical connector that overcomes the aforementioned problems to a large extent.

The interconnect arrangement according to one of the afore-cited related applications provides a twinax shielded coax structure that has constant impedance from daughtercard interface to the backplane interface. The coaxial structure provides for constant impedance of 65 ohms single ended impedance, 50 ohms odd mode impedance and 100 ohms differential impedance.

A single ended interconnect path utilizes one conductor to transfer data. A differential interconnect path utilizes two conductors to transmit the same data. The benefit of a differential interconnect path relative to a single ended interconnect path is that

transmission speed increases and noise immunity and electro-magnetic interference (EMI) concerns are reduced.

Utilizing the twinax design according to one of the afore-cited related applications, the connector design described herein will provide an excellent technique for transmitting differential data utilizing copper conductors. The same is true for the single ended version. The single ended design utilizes a coaxial conductor to transmit data. This makes it possible to transmit analog (RF) or digital data with signal degradation comparable to that of a coaxial cable.

Refer first to Figures 1A and 1B where an interconnect system for a high speed, high density interconnect path is illustrated. Figure 1A shows the electrical connector with the over-mold omitted for simplicity of explanation. The connector 18 is used to electrically connect daughtercard 20 to a backpanel 22. The connector 18 includes, as depicted in Figure 1B, a daughtercard interposer 30, a backpanel interposer 32, an over-mold 34 which over-molds semi-rigid twinax or coax cables. The over-mold 34 is preferably injection molded, for example, from PBT (polybutylene terephthalate). As depicted in Figures 1A and 1B, only two twinax cables 40, 42 are shown for ease of illustration, although it is anticipated that 80 pairs or more of twinax may be used in the electrical connector. This embodiment uses twinax cable that is bent into a desired shape. A more rigid construction that is molded in a single piece may also be used. For the cables 40 and 42, the center conductor is copper, the dielectric material may be Teflon™ and the outside jacket may be a braid. Preferably, the differential impedance between center conductors is approximately 100 ohms. Using standard formulas, the impedance can easily be adjusted by varying the distance between center conductors and the dielectric constant for example. In Figure 1A, the over-mold 34 is omitted for clarity. As depicted in Figures 1A and 1B, spring contact arrangements 50, 52, 60, 62 are positioned within the interposers 30 and 32, respectively, and surround ends of the twinax cables 40 and 42 in order to shield the twinax cables and control the impedance of the connector.

Spring contacts and the uses thereof are explained in U.S. Patent No. 4,998,306, issued January 29, 1991, entitled "LOW-LOSS ELECTRICAL INTERCONNECTS", U.S. Patent No. 5,886,590, issued March 23, 1999, entitled "MICROSTRIP TO COAX VERTICAL LAUNCHER USING FUZZ BUTTON AND SOLDERLESS INTERCONNECTS", U.S. Patent No. 6,039,580, issued March 21, 2000, entitled "RF CONNECTOR HAVING A COMPLIANT CONTACT", U.S. Patent No. 4,924,918, issued May 15, 1990, entitled "MACHINE FOR MANUFACTURING BUTTON CONNECTOR AND METHOD THEREFOR", and U.S. Patent No. 5,007,843, issued April 16, 1991, entitled "HIGH-DENSITY CONTACT AREA ELECTRICAL CONNECTORS", all of which are hereby incorporated by reference in their entirety into the present specification. The conductive element provides high reliability, multiple points of contact and is randomly compressed into a shape that provides multiple electrical contact points to a mating surface.

As illustrated in Figures 1A and 1B, the connector 18 would be assembled by connecting interposer 30 and the backpanel interposer 32. As depicted in Figure 1B, the connector 18 is assembled as follows. First, the twinax cables 40, 42 are formed. All of the spring contacts are installed into interposers 30 and 32. The twinax cables 40 and 42 are then installed into the interposers 30 and 32. The assembly is then insert molded to form the over-mold 34 that makes the entire electrical connector 18 rigid. The over-mold 34 is preferably PBT. The electrical connector 18 could then be connected to the daughtercard 20 using fasteners such as screws, rivets, compression posts, and the like.

The spring connectors 50, 52, 60, and 62 can be made from a single gold plated fine wire that is compressed into a very small shape. The resulting object is a wire mass having spring performance and demonstrates superior electrical signal conduction from high current DC to microwave frequencies. The typical size of such a spring contact is 0.01 inch in diameter by 0.060 in length. The signal carrying spring contacts preferably have the same outer diameter as the signal carrying center cable. The ground contact

spring contacts do not have to be the same diameter or length as the signal carrying spring contacts. The spring contacts 50, 52, 60, and 62 are employed in the illustrative embodiments, preferably each formed from a strand of metal wire, each strand being wadded together to form a desired cylindrically shaped "button" of material having a density of between 20% and 30%. As depicted in Figures 1A and 1B, each wadded-wire connected spring contact fits snugly in openings of the daughtercard interposer 30 and the backpanel interposer 32. Each wadded-wire spring contact 50, 52, 60, and 62 makes electrical contact at multiple points when compressed against the contact area. Connectors of this type have significant advantages over other types of connectors and provide connections of high integrity and reliability.

The spring contacts can be fabricated using nickel wire, or wire made from alloys such as beryllium and copper, silver and copper, or phosphorous and bronze. The compression of the wadded wire of the spring contacts is substantially elastic so that, when the compressive force of the twinax cables is removed, the spring contacts return to their original shape. The wire is randomly compressed into a cylindrical shape and the wire has some spring constant associated with it to provide resiliency when pressure is applied. Advantageously, this allows the electrical connector 18 to be connected and disconnected as many times as is needed. In the embodiments described above, the wadded-wire connector elements 50, 52, 60, and 62 can comprise components manufactured by Technical Wire Products, Inc. of Piscataway, New Jersey, under the trademark Fuzz Button™.

Referring now to Figure 2, the twinax cables 40 and 42 are inserted into the backpanel interposer 32. Figure 2 differs from Figure 1 in that two twinax cables 40 and 42 are depicted instead of one. It is important to note that central conductors 120 and 122 are not shielded from each other. However, it is important to shield twinax pairs from each other as depicted in Figure 2.

As depicted in Figure 2, the backpanel interposer 32 has two opposed U-shaped openings 100 and 102 each respectively having an outer U-shaped peripheral wall 110

and 112, an inner U-shaped peripheral wall 117 and 118 and a straight wall 114 and 116, respectively. Walls 114 and 116 face each other as depicted in Figure 2. Inserted into the U-shaped openings are a plurality of spring contacts 200, 202, 204, and 206, respectively, each being in a half U-shape as depicted in Figure 2. For example, spring contacts 200 and 202 each have a half U-shape and when placed together form a U partially surrounding the twinax cable 40. It should be understood that other shielding methods could be used to replace the spring contacts.

The twinax cable 40 has two central conductors 120 and 122 surrounded by Teflon™ sheathing 124, for example. Preferably, signal carrying spring contacts 300-306 (see Figure 3) have the same outer diameters as the two central conductors 120, 122. The Teflon™ sheathing 124 may be covered by an electrically conductive copper layer or by a rigid or semi-rigid outer case 128 made of copper and aluminum or a tin filled braiding. Case 128 may be formed using a plating process. As depicted in Figure 2, the rigid outer case 128 is stripped away to a length E, thereby exposing the Teflon™ sheathing 124. The Teflon™ sheathing 124 is stripped away from the central conductor to a length F. This stripping is done symmetrically on both ends of twinax cables 40 and 42. The spring contacts 200, 202, 204, and 206 are in electrical contact with the layer 128 so as to form a shield.

Refer now to Figure 3 that depicts a bottom view of Figure 2. Mounted within the interposer 32 are spring contacts stacked one upon another in a half U-configuration through the thickness of interposer 32 for surrounding and shielding the central twinax leads 120 and 122, respectively, of twinax cables 40 and 42. Also depicted are a plurality of vertically extending cylindrical spring contacts 210, 212, and 214 that are positioned between walls 114 and 116. The spring contacts 210 and 214 extend through the thickness of interposer 32 and are used to shield twinax cables 40 and 42 from each other. As depicted in Figure 3, it should be understood that there is a full 360° shielding for twinax cables 40 and 42 for the stripped away portions of coax cables 40 and 42 that extend through the interposer 32. As depicted in Figure 3, there are four

spring contacts 300, 302, 304, and 306 in contact with the exposed portions of central conductors 120 and 122 of twinax cables 40 and 42.

Figure 4 is an illustration similar to Figures 2 and 3 in which the daughtercard interposer 32 has been omitted for clarity. As is evident in Figure 4, there are four stacks of half U-shaped spring contacts 200, 222, 224, 226, 228; 202, 232, 234, 236, 238; and 204, 242, 244, 246, 248, 206, 252, 254, 256, and 258 (not shown). These four stacks together with the vertically extending spring contacts form a full 360° shield around twinax cables 40 and 42.

Figure 5 is similar to Figure 4 except that spring contacts 200, 222, 224, 226 and 228 have been omitted to show spring contacts 306, and 304 respectively in contact with central conductors 122 and 120.

As depicted in Figure 6, it can be seen that spring contacts 300 and 302 and also 304 and 306 (not shown) contact the exposed portions of the central signal carriers 120 and 122. These spring contacts 300-306 are the signal carrying spring contacts. It is important that the signal carrying spring contacts are substantially the same diameter as the twinax central conductors 120 and 122 to maintain constant impedance.

Refer now to Figure 7 where a bottom perspective view of the electrical connector 18 is depicted. As depicted in Figure 7, a central portion 701 is formed between the straight wall 114 and the bottom of the outer U-shaped wall 110. The central portion 701 includes through holes 700 and 702 that receive vertically extending spring contacts 300 and 302. A wall 704 is formed centrally in the U-shaped area to form a first half U-shaped opening 710 and a second U-shaped opening 712 which respectively receive spring contacts 206, 252, 254, 256, and 258 and 204, 242, 244, 246, and 248.

As depicted in Figure 8, a plurality of electrically non-conductive patterns 402 and 404 are on the daughtercard 20 and the backpanel 22, respectively. The pattern 402 has an electrically conductive area 410 having roughly a figure eight configuration. The patterns can be formed using known photolithographic techniques. A first non-

conductive area 412 and a second non-conductive area 414 are spaced apart from each and within an outer periphery 420 of the pattern 402. The first non-conductive area 412 has two areas 430 and 432 that include conductive pads 440 and 442. The second non-conductive area 414 has two areas 434 and 436 that include conductive pads 444 and 446. Openings 430, 432, 434, and 436 receive the center conductors 120 and 122 of twinax cables 40 and 42 that extend from the interposer 30 such that spring contacts 300, 302, 304, and 306 are respectively brought into contact with the conductive pads 440, 442, 444, and 446. Referring back to Figure 4, spring contacts 228, 238, 248 and 258 will be in electrical contact with the electrically conductive area 410. In this manner, the spring contacts provide a shielding path to ground. The electrically conductive area 410 is connected to ground plane on the daughtercard and on the backplane. The inner surfaces of openings 430, 432, 434, and 436 are electrically conductive and are connected to signal paths so that spring contacts 306, 304, 302, and 300 are in electrical contact therewith when the interposer 30 is used to connect the daughtercard 20 and the backpanel 22. Spring contacts are mounted in the interposer 32. Advantageously, the spring contacts 300, 302, 304, and 306 will be compressed when the daughtercard and backpanel are mated which provides a normal force on the signal line and on the cable. The spring contacts 300, 302, 304, and 306 and 228, 238, 248, and 258 will be compressed to the board 20 maintaining normal forces with respect to the daughtercard pattern 402. The pattern 404 on the backpanel 22 is the same as the pattern 402 and need not be described in detail herein. The pattern 404 includes an electrically conductive portion 458 and a first non-conductive area 460 and a second non-conductive area 462. Advantageously, the electrical connector 18 can be connected and reconnected multiple times without degrading the signal contacts 300, 302.

Refer now to Figure 9 where a backpanel 700 is depicted connected to a daughtercard 710. Such an arrangement is also usable in mid-plane connectors such as mid-plane connector 600 depicted in Figure 9 that is connected to a daughtercard 610.

Refer now to Figure 10 illustrating an electrical connector 1000. At the outset it should be noted that the electrical conductors 1020, 1022, and 1024 have the same electrical characteristics as electrical conductors as 40 and 42 discussed above. As depicted in Figure 10, an electrical conductor 1024 has the shortest path and an electrical conductor 1020 has the longest path. Referring to Figure 11, for example, conductor 1020 has a downwardly extending straight portion 1020', an angled portion 1020" and a horizontally extending straight portion 1020"". The straight portions 1020' and 1020" facilitate installation of ends of the conductor 1020 into cable housing interposers 1030 and 1032, as explained below. For ease of explanation, only the housing for conductors 1020, 1022, and 1024 is explained here, although other sets of conductors are illustrated which have the same housings. Figures 11-13C illustrate additional details of the aforementioned arrangement.

Referring again to Figure 10, the electrical connector 5000 includes opposed guide blocks 1002 and 1004 mounted on opposite ends of the electrical connector 1000, as discussed in detail below. The guide blocks 1002 and 1004 and the cable housings 1006-1014 can either be formed of individual molded parts as depicted and assembled together or can be formed as an over-molded assembly as described previously with respect to Figure 1B. In between guide blocks 1002 and 1004 are a plurality of sets of electrical conductors. As used herein, conductors 1020, 1022, and 1024 form one vertical set of conductors. As illustrated in Figure 10, there are four horizontal sets of three vertically stacked electrical conductors forming a vertical and horizontal array of twinax cable conductors.

Each of the electrical conductors 1020, 1022, and 1024 are retained by cable housings 1006 and 1008 and the other electrical conductors are retained by the respective cable housings 1008-1014. As depicted in Figure 10, cable housing 1006 is specially adapted to mate with the guide block 1002 using horizontal pins 1006', 1006" and 1006"" which interlock with corresponding holes 1002', 1002" and 1002"" in the guide block 1002. Housings 1006 and 1008 each include recesses 1007, 1009, and 1011 and 1013, 1015,

and 1017, respectively. Each cable housing includes a boss and a hole, for example, in cable housing 1008, there is a boss 1023 and a hole 1025 for interlocking with the cable housing 1006.

As depicted in Figure 10, the electrical connector 1000 is a right angle (that is, 90 degree) electrical connector, although other configurations such as a straight connector can be arranged.

The electrical connector 1000 includes a central twinax or coax portion 1001 that includes all of the copper wire conductors 1020, 1022, and 1024 and all of the interlocked cable housings 1006-1012, and the guide blocks 1002 and 1004. As depicted in Figure 10, there is a front rectangular surface 1026 and a bottom rectangular surface 1028 to the assembled central assembly 1001. Opposite ends of the conductors 1020, 1022, and 1024 extend slightly beyond the surfaces 1026 and 1028, respectively, exposing the outer jacket 128 of each of the twinax conductors 1020 and 1024. The central conductors 120 and 122 extend slightly beyond the dielectric 124 and the outer jacket 128 of the twinax conductors 1020 and 1024.

A rectangular interposer 1030 has a front surface 1030' and a back surface 1030". The interposer 1030 (that is, surface 1030') mates with the front surface 1026 of the assembly 1001. A second rectangular interposer 1032, having a front surface 1032' and a back surface 1032", mates (that is, surface 1032') with the bottom surface 1028 of the assembly 1001. The copper wire conductors 120 and 122 engage with the interposers 1030 and 1032 as explained below.

Mylar retainers 1038 and 1040 respectively retain spring contacts 1034 and 1036. The Mylar retainers 1038 and 1040 could be made from any suitable material including heat shrinkable plastic. The spring contacts 1034 and 1036 are strategically placed and extend within interposer cable housing 1030 and 1032 and interposer slides 1042 and 1044, respectively. The front surface 1030' of the interposer 1030 is rigidly mounted to the front surface 1026 by either press fit studs, ultrasonic welding or epoxy. A pair of

opposed pins 1009 and 1009' extend from the surface 1026 and the guide blocks 1002 and 1004, respectively, into recessed holes that (not shown) extend inwardly from the surface 1030'. The pins 1009 and 1009' keep the interposer 1030 aligned with the cable housings 1006-1014. Pins (not shown) extend from the surface 1026 of the guide blocks 1002, 1004 to keep the interposer 1032 aligned with the cable housings 1006-1014. The spring contacts 1034 and 1036 include ground contact spring contacts and signal carrying spring contacts as explained below. Guide pins 1046 and 1048 are provided on the backpanel for mounting the electrical connector 5000 thereto. Guide pins 1046 and 1048 extend through holes 1050 and 1035 and 1048 and 1033, respectively, and mate with the latching mechanisms. As depicted in Figure 10, a cylindrical guide socket body 1003 extends from the guide block 1002 for receiving the guide pin 1048. Guide block 1004 has a similar guide socket body (not shown) for receiving guide pin 1046. The guide blocks 1002 and 1004 each have a threaded insert 1027 and 1029, respectively, positioned at right angles from the guide socket body 1003 and aligned with corresponding holes 1061 and 1063 in interposer 1030 and holes 1080 and 1082 in the interposer slide 1042. Threaded fasteners extend from the daughtercard to fasten the electrical connector 5000 to be threaded into the threaded inserts 1027 and 1029.

Turning now to Figure 11, it can be more clearly seen that the Mylar sheet 1038 includes a plurality of stamped holes. The stamped holes are in a specific pattern for retaining and placing the spring contacts in holes in the interposers 1030 and 1032 and the interposer slides 1042 and 1044. The holes used to retain the signal carrying spring contacts must be held to tight tolerances to hold the spring contacts securely yet not so tight to overly compress the spring contacts and significantly change the outer diameter thereof.

Stamped holes 1070, 1072, 1074 and 1076 are in vertical alignment for receiving retaining tines 1090, 1092, 1094, and 1096 in the interposer 1030. The holes 1404 and 1406 and the retaining tines 1090-1096 maintain the interposer slide 1042 in alignment

with the interposer 1030. The retaining tines 1090-1096 are of sufficient length to permit the interposer slide 1042 to be biased into the extended position by springs 1091 and 1093 mounted in holes 1095 and 1097 in the surface 1030" of the interposer 1030. The retaining tines 1090-1096 will be flush or below surface 1092 in the retracted position. The spring contacts 1034 maintain the alignment of the Mylar sheet 1038 relative to the interposer 1030 and the interposer slide 1042. The interposer 1030 includes a top set of holes 1110 for receiving the leads of conductor 5020, middle holes 1112 for receiving the center leads of conductor 1022 and a bottom set of holes 1114 for receiving the leads of the conductor 1024. Each interposer has multiple ground holes, for example, four ground holes, into which the spring contacts are placed to make contact with the outer conductive layer 128 of each of the conductors 1020, 1022, and 1024. For example, as depicted in Figure 11 with respect to conductor 1020, the interposer 1030 has holes 1120, 1122, 1124, and 1126. The Mylar sheet has corresponding holes 1130, 1132, 1134, and 1136. Each interposer 1030 and 1032 includes a plurality of recesses shaped to match the exterior of each of the conductors 5020, 5022, and 1024. As depicted in Figures 11 and 12, the electrical conductors have a straight center section and rounded outer sections. The spring contacts placed in holes 1130, 1132, 1134, and 1136 will be in contact with the outer jacket 128 of the conductor and will provide a ground path and electrical shield between adjacent twinax cables. The recess 1150 extends inwardly from front surface 1032' of the interposer 1032. For example, the recess 1150 may comprise opposed curved walls 1160 and 1162 connected by straight sections 1170 and 1172. The straight sections 1170 and 1172 are depicted as extending horizontally. The recess 1150 is shaped to receive the outer jacket 128 of the twinax cable.

Turning now to Figure 12, the interposer 1032 is depicted in large data. It should be understood that interposers 1030 and 1032 are identical except for the opposed holes used for the guide pins 1046 and 1048 that extend respectively through interposer 1032 into guide blocks 1002 and 1004. The holes 1048 and 1050 are offset relative to a longitudinal centerline of the interposer slide 1044, as are holes 1033 and 1035 that are

aligned therewith. By contrast, the holes 1066 and 1068 in the interposer 1030 are on the centerline as are the holes in the interposer slide 1048.

Each central conductor 120 and 122 has multiple spring contacts associated with it. For example, as depicted in Figure 12, there are two holes 1260 and 1262 aligned with the central conductors 120 and 122. There are also two central spring contacts (not shown) which make contact with the central leads of the conductors 120 and 122 and which have one end in the holes 1260 and 1262. A front surface of the insulator 124 can bottom out in the recess 1150. With respect to the recess 1150, there are four spring contacts 1250, 1252, 1254, and 1256 installed in holes 1280-1284. Holes 1280-1284 are blind holes and intersect with the periphery of the recess 1150. One ground contact, preferably a spring contact (not shown), is installed in each of the holes 1250-1256 and these spring contacts used as ground contacts with the electrically conductive outer jacket 128 of the central conductor. Four ground contacts provide excellent shielding. Additional holes and spring contacts can be added to enhance cross-talk reduction.

The hole 1250 is centrally located between signal carrying spring contacts 1260 and 1262. Hole 1254 is offset relative to the center of recess 1150 closer to hole 1260, whereas in the adjoining recess 1152, hole 1270 is offset in the opposite direction. Thus, adjacent vertically aligned recesses have offset holes for spring contacts. By offsetting the holes, a greater percentage of the circumference is shielded.

Referring now to Figures 13A, B and C and referring to the interposer slide 1042, it should be seen that there are four vertically aligned holes 1370, 1372, 1374, and 1376 for respectively receiving tines 1090, 1092, 1094, and 1096. Preferably, the interposer will be spring loaded in a direction away from interposer 1030. This protects the spring contacts from becoming damaged or dislodged during shipping and assembly. It should be understood that the explanation is provided only for the left most set of holes and that the hole pattern repeats. The uppermost conductor 1020 has a set of corresponding holes in the interposer 1042. Hole 1330 for receiving a ground spring

contact aligns with hole 1130 in the Mylar sheet and hole 1120 in interposer 1030. Hole 1332 aligns with hole 1132 in the Mylar sheet and hole 1122 in the interposer. Hole 1334 aligns with hole 1134 in the Mylar sheet and hole 1124 in the interposer 1030. Hole 1336 aligns with hole 1136 in the Mylar sheet and hole 1126 in interposer 1030. Similarly, holes 1380 align with holes 5080 in the Mylar sheet 1038 and holes 1110 in the interposer 1030. As depicted in Figure 13A, the interposer 1032 is illustrated in an extended position in which the fuzz buttons are below the surface 1042" or at maximum 0.020 above the surface 1042" and are thereby protected during shipment of the electrical conductor 1000. As depicted in Figure 13A, there is a gap between the surface 1032" of the interposer 1032 and the surface 1042 of the interposer slide. The spring contacts are held between the interposer 1030 and the interposer slide 1048 are in contact with the daughtercard 20. By contrast, the interposer 1032 and the interposer slide 1044 are in contact with the backpanel 22.

The backpanel printed circuit board with guide has a plurality of conductive pads 1390. The pads have two signal carrying conductors 1392 and 1394 to be brought into contact with the signal carrying spring contacts and an outer ground section 1396 (see Figure 14). The pads 1390 advantageously do not have to be through plated holes. The pads 1390 can be surface mount or can have blind vias. By avoiding through plated holes, capacitive effects associated with the holes are reduced and speed can be increased.

It is important to provide shielding for the length of the exposed central conductor and for the length of the signal carrying spring contacts to prevent cross-talk between adjacent twinax cables. The aforementioned connector advantageously achieves this shielding using four spring contacts connected to ground. These spring contacts provide less than 360° shielding but testing has revealed that the level of shielding achieved is sufficient to provide data rates up to 10 Gb/sec and greater.

Further, the Mylar sheet 1038 retains the signal carrying spring contacts by compressing the spring contact around the circumference without reducing the outer diameter significantly. Thus, the diameter of the spring contact is not changed

significantly when compressed into the PC board. Also advantageously, the force exerted by the spring contacts in a direction away from the PC board is relatively small, thus allowing the use of a simple latching mechanism. By changing the shape, number and rigidity of the conducting elements, the contact resistance, contact force and compressibility can be selected within a wide range to meet the needs of the particular application. The overall cumulative contact force of spring contacts 1039 and 1036 against contact surfaces 1390 is low due to the resilient construction and compressibility of the springs.

While the interconnection systems described above have numerous advantages as compared with Prior Art interconnection systems, many drawbacks were found in practical applications of such interconnection systems. Namely, a substantial number of precision components were needed to fabricate such interconnection systems, thereby increasing production costs and reducing production yields. Furthermore, assembling such interconnection systems with unprotected spring contacts proved to be extremely difficult in view of the fragility of the spring contacts, thereby also increasing production costs and reducing production yields.

In view of the above, a detailed study of the interconnection systems described above was undertaken in order to determine how their drawbacks could be eliminated. It was determined that by using "top hats" in conjunction with the spring contacts, the resultant improved interconnection system could be substantially simplified and the number of components needed substantially reduced as compared to the interconnection systems described above, thereby decreasing production costs and increasing production yields. Furthermore, assembling such improved interconnection systems using top hats in conjunction with the spring contacts simplified assembling such improved interconnection systems, thereby also decreasing production causes and increasing production yields.

A top hat is a solid metal cylinder that makes contact with the spring contacts and pad on PCB. One end of the cylinder has a shoulder that extends in a plane that is

substantially perpendicular to an axis of the cylinder. Such top hats are manufactured in sizes allowing for insertion of spring contacts. For example, Technical Wire Products, Inc. of Piscataway, New Jersey manufacture top hats for use with their Fuzz Buttons™. The closed end of the top hat cylinder may be flat, hemispherical, conical, or include serrations or points to facilitate making good electrical contact with its mating contact.

Figure 14 is an exploded view of an example embodiment of an electrical connector according to the principles of one of the above-identified applications. In comparing the connector 2000 of Figure 14 with the connector 1000 of Figure 10, one immediately notices that there are significantly fewer elements to the connector 2000 of Figure 14. This reduction of elements reduces manufacturing costs while simplifying the assembly of the connector.

Referring to Figure 14, elements 2001 essentially correspond to elements 1001 of Figure 10 but with one exception. Namely, the twinax cable sections 2020, 2022, and 2024 have their center conductors in the same plane as that of their respective outer conductors. That is, it has been found that it is unnecessary to extend the center conductors beyond the plane of their respective outer conductors. This simplifies the fabrication of the twinax cable sections 2020, 2022, and 2024 and reduces their cost while making them stronger in that the exposed center conductors of the twinax cable sections 1020, 1022, and 1024 of Figure 10 were vulnerable to being bent or damaged.

Referring back to Figure 14, elements 2036 and 2034 are not merely the spring contacts 1036 and 1034 of Figure 10 but rather comprise spring contacts and their corresponding top hats, the details of which will be discussed below. Interposers 2042 and 2044 include guide apertures 2048, 2050, 2080, and 2082 that are used to position their respective interposers using guide pins 2048 and 2046 in the case of interposer 2044. The guide pins for interposer 2042 are not shown. As will be discussed later, elements 2036 and 2034 may also comprise one-piece semi-rigid spring contacts.

Figure 15 is a view of a partially assembled connector. End pieces 2100 are located on the ends of spacers 2110. In the connector illustrated in Figure 15, the spacers 2110 include a greater number of twinax cable sections than those of Figure 14. Since the spacers 2110 are identical, this allows the fabrication of connectors of varying size utilizing the same components. This also reduces manufacturing and production costs while simplifying the assembly of connectors of varying size. Furthermore, while a particular number of twinax cable sections are shown for each spacer, the present invention is not limited thereto. Connectors of varying size can easily be fabricated utilizing a small number of different identical elements. Multiple guide pin apertures 2150 are shown for each end piece 2100. As will be discussed below, only two of the three apertures 2150 are used in the fabrication of the connector.

Figure 16 is another view of the spacers 2110 and their relationship with the corresponding twinax cable sections. While not clearly illustrated in this drawing, the spacers 2110 may include small pins and mating apertures so as to allow them to be aligned and to snap together. Other alignment and fastening techniques may also be used.

As illustrated in Figure 17, after the elements illustrated in Figures 15 and 16 are assembled, they may be permanently joined by over-molding or encapsulation to produce a unified subassembly capable of withstanding mechanical and thermal shock as well as being essentially impervious to moisture.

Figure 18 is a view of a portion of one interposer 2300 of the connector of Figure 14. The interposer 2300 includes a pair of apertures 2305 that mate with corresponding guides 2210 illustrated in Figure 17. The interposer 2300 includes four apertures located so as to correspond to apertures 2220 of the connector illustrated in Figure 17. This allows a pair of the interposers 2300 to be affixed to the connector illustrated in Figure 17 utilizing screws or pins, for example, which are inserted through the apertures of interposers 2300 into apertures 2220 of the connector illustrated in Figure 17.

The pattern of the apertures 2310, 2320, 2330, and 2340 for each twinax cable section is illustrated in Figure 18. Apertures 2320 and 2340 will respectively contain top hats that will contain spring contacts therein that will connect to the center conductors of a respective twinax cable section while apertures 2310 and 2330 will respectively contain top hats that will contain spring contacts therein that will connect to the shield conductor of a respective twinax cable section. The number of top hats that will contain spring contacts therein that will connect to the shield conductor of a respective twinax cable section is not limited to two as in this example embodiment.

Referring to Figure 19, four top hats 2410, 2420, 2430, and 2440, three shown, have been inserted into respective apertures 2310, 2320, 2330, and 2340 in the interposer 2300. In a similar fashion top hats will be inserted into the remaining respective apertures in the interposer 2300. The apertures are made sufficiently large to allow vertical movement with respect to the interposer 2300 as will be discussed below.

As illustrated Figure 20, spring contacts 2510, 2520, 2530, and 2540 are respectively inserted against respective top hats 2410, 2420, 2430, and 2440. These spring contacts are sufficiently resilient to be retained by the top hats yet can still move with respect to the top hats. Since a substantial portion of the spring contacts 2510, 2520, 2530, and 2540 are disposed within their respective cores in interposer 2300, they are less likely to be damaged in comparison to the exposed spring contacts 1034 and 1036 of the connector of Figure 10.

Figure 21 illustrates a single twinax cable section 2600 arranged with its corresponding top hats 2410, 2420, 2430, and 2440 and spring contacts 2510, 2520, 2530, and 2540. As can be seen, spring contacts 2520 and 2540 connect to the inner conductors of the single twinax cable section 2600 while spring contacts 2530 and 2510 connect to the outer shield conductor of the single twinax cable section 2600.

Figure 21A is a partial close-up view that illustrates the relationship between the single twinax cable section 2600 and its respective spring contacts 2520, 2530, and 2540 and

its respective top hats 2420, 2430, and 2440. Note that Figure 21A, top hats 2420, 2430, and 2440 are shown as having pointed ends.

Figure 22 illustrates an interposer 2300 with all of its respective twinax cable sections and spring contacts and top hats in place, arranged next to a printed circuit board 2600. Figure 23 illustrates the arrangement of Figure 22 with the over-molding or encapsulation shown but no interposer while Figure 24 illustrates the arrangement of Figure 23 with the interposers 2300 in place and with the connector being affixed to a printed circuit board 2600.

Initially, spacers, such as spacers 2110 of Figure 15, and twinax cable sections, such as sections 2020, 2022, and 2024 of Figure 14, are snapped together until a connector portion of the appropriate size has been assembled.

As illustrated in Figure 15, end pieces 2100 are then affixed to each end of the spacer assembly and the resultant assembly joined together, normally by over-molding or encapsulation utilizing a suitable encapsulant. After assembly, the resultant structure would appear as illustrated in Figure 17.

The next assembly step is to take two interposers, such as the interposer 2300 illustrated in Figure 18, and insert top hats of the appropriate size in each of the appropriate apertures in the two interposers, such as top hats 2410, 2420, 2430, and 2440 and interposer 2300 illustrated in Figure 19. Then, as illustrated in Figure 20, spring contacts are placed in each top hat in each interposer. Since the top hats have shoulders that are larger than the apertures in the interposers, and since the resiliency of the spring contacts prevent them from falling out of the top hats, the resultant structure illustrated in Figure 20 is relatively stable and may be moved without fear of losing components, particularly if the interposer is kept horizontal. The spring contacts may be inserted into their respective top hats prior to the top hats being inserted into their respective apertures.

One resultant interposer structure, as illustrated in Figure 20, is then mated with each end of the structure, as illustrated in Figure 17, utilizing the guides 2210 and corresponding apertures 2305 for alignment purposes. The resiliency of the spring contacts facilitate their making good electrical contact with the inner conductors and outer shield of each of the twinax cable sections. Furthermore, the resiliency of the spring contacts facilitate the top hats extending outward beyond the apertures of their respective interposers to enable them to make good electrical contact with the printed circuit boards which they are to be mated to.

The interposers are then affixed to the structure, as illustrated in Figure 24, utilizing appropriate fixing means, such as screws, rivets, pins, or adhesives. The resultant structure is then affixed to its mating printed circuit boards as illustrated in Figure 24 utilizing guide pins and apertures 2150 for alignment purposes.

While the above-noted interconnection arrangement was significantly better than earlier designs with regard to both electrical and mechanical characteristics, several drawbacks were found during the fabrication and testing of the above-noted interconnection arrangement.

Namely, the above-noted interconnection arrangement required large numbers of high precision parts, resulting in high fabrication and assembly costs. In addition, twinax cable was needed in the fabrication of the above-noted interconnection arrangement. While offering excellent electrical characteristics, twinax cable is expensive and difficult to work with.

Furthermore, the use of contact springs for both electrical connections and to provide a resilient force oftentimes prevented the design of the contact springs to be optimized for both electrical and mechanical requirements. For example, it was found that the spring travel could not be greater than 0.025 inches. In the case of large interconnection arrangements, a spring travel of 0.040 inches was needed to ensure that the interconnection arrangement would properly interface with its mating surface. In

addition, it was found that a relatively high mating force resulted in view of the large number of springs in the interconnection arrangement, the relatively high mating force being too high in some cases.

Summary of the Invention

The interconnection system in accordance with the present invention was designed to overcome the drawbacks of the above-noted interconnection arrangement. The interconnection system in accordance with the present invention has considerably fewer parts than the above-noted interconnection arrangement, has half the number of springs per connection of the above-noted interconnection arrangement and uses these springs only to provide a resilient force, and does not use twinax cable.

It is an object of the present invention to provide an electrical interconnection system capable of carrying signals at data rates of 10 Gb/sec or more.

Still another object of the present invention is to provide an electrical interconnection system having a differential pair having constant impedance over the signal path and capable of carrying signals at data rates of 10 Gb/sec or more.

Another object of the present invention is to provide an electrical interconnection system in which cross-talk between signal paths of adjacent conductors within the electrical interconnection system is reduced and/or eliminated.

Yet another object of the present invention is to provide a compression type electrical interconnection system using a spring configuration.

These and other objects of the present invention may be achieved by providing an interconnection system comprising: a plurality of printed circuit boards each having at least one pair of electrical conductors respectively disposed on opposite faces of each of said plurality of printed circuit boards; a plurality of spacers arranged to be disposed adjacent to each other in a row having two ends, each spacer arranged to allow one of said plurality of printed circuit boards to be disposed between it and another of said

plurality of spacers; each face of each of said plurality of spacers including a groove for each of said electrical conductors of an adjacent printed circuit board, said groove arranged to provide an airspace between its spacer and said conductor of said adjacent printed circuit board, each of said electrical conductors having first and second ends, said printed circuit boards and said plurality of spacers being arranged to leave exposed, on a first plane, all of said first ends of said plurality of electrical conductors and to leave exposed, on a second plane, all of said second ends of said plurality of electrical conductors; a pair of end pieces respectively arranged to be disposed adjacent said ends of said row of plurality of spacers; first and second interposers respectively arranged to be disposed adjacent said first and second planes, each interposer having an aperture arranged to receive a cell for each conductor pair of said plurality printed circuit boards; and a plurality of electrically conductive contacts, each electrically conductive contact having first and second ends and being arranged to be respectively disposed in one of said cells of said first and second interposers, wherein said first end of each of said plurality of electrically conductive contacts respectively electrically contacts one of said conductor pairs of said plurality of printed circuit boards and wherein said second end of each of said plurality of electrically conductive contacts extends through its respective cell in its respective interposer beyond a plane of said interposer.

In the system noted above:

each of said electrically conductive contacts can comprise a leaf spring contact, one end of said spring contact comprising said first end of said respective electrically conductive contact and a second end of said spring comprising said second end of said electrically conductive contact;

said one end of each of said spring contacts can be arranged to provide a resilient force to urge it towards its respective electrical conductor to electrically connect it thereto;

each cell can comprise at least two springs arranged to provide a resilient force to urge said cell toward its respective interposer;

each cell can comprise cylindrical apertures arranged to receive said at least two springs;

each cell can comprise at least two tabs arranged to mate with corresponding slots in its respective aperture of its respective interposer;

said at least one pair of electrical conductors of adjacent printed circuit boards can be staggered to increase distances between said electrical conductors of said adjacent printed circuit boards;

each printed circuit board can comprise at least one aperture and each spacer comprises at least one boss on either side thereof, said at least one aperture of said printed circuit board arranged to mate with said at least one boss of said spacer;

can further comprise a backbone including slots arranged to receive said plurality of spacers;

can further comprise an end plate arranged to contain one of said interposers and to mate to said end caps; and

can further comprise a shield plate arranged to cover two sides of the interconnection system.

These and other objects of the present invention may be achieved by providing a method of manufacturing an interconnection system, the method comprising:

disposing a plurality of printed circuit boards each having at least one pair of electrical conductors respectively disposed on opposite faces of each of said plurality of printed circuit boards;

disposing a plurality of spacers adjacent to each other in a row having two ends, each spacer arranged to allow one of said plurality of printed circuit boards to be disposed between it and another of said plurality of spacers; each face of each of said plurality of spacers including a groove for each of said electrical conductors of an adjacent printed circuit board, said groove arranged to provide an airspace between its spacer and said conductor of said adjacent printed circuit board, each of said electrical conductors having first and second ends, said printed circuit boards and said plurality of spacers being arranged to leave exposed, on a first plane, all of said first ends of said plurality of electrical conductors and to leave exposed, on a second plane, all of said second ends of said plurality of electrical conductors;

disposing a pair of end pieces respectively adjacent said ends of said row of plurality of spacers;

disposing first and second interposers respectively adjacent said first and second planes, each interposer having an aperture arranged to receive a cell for each conductor pair of said plurality printed circuit boards; and

disposing a plurality of electrically conductive contacts, each electrically conductive contact having first and second ends and respectively disposed in one of said cells of said first and second interposers, wherein said first end of each of said plurality of electrically conductive contacts respectively electrically contacts one of said conductor pairs of said plurality of printed circuit boards and wherein said second end of each of said plurality of electrically conductive contacts extends through its respective cell in its respective interposer beyond a plane of said interposer.

The method above can further comprise:

providing a leaf spring contact for each of said electrically conductive contacts, one end of said spring contact comprising said first end of said respective electrically conductive contact and a second end of said spring comprising said second end of said electrically conductive contact;

arranging said one end of each of said spring contacts to provide a resilient force to urge it towards its respective electrical conductor to electrically connect it thereto;

providing at least two springs for each cell to provide a resilient force to urge said cell toward its respective interposer;

providing cylindrical apertures in each cell to receive said at least two springs;

providing at least two tabs for each cell, said at least two tabs arranged to mate with corresponding slots in its respective aperture of its respective interposer;

providing a backbone including slots to receive said plurality of spacers;

providing an end plate to contain one of said interposers and to mate to said end caps; and

providing a shield plate to cover two sides of the interconnection system.

Still other advantages of the present invention will become readily apparent to those skilled in the art from the following detailed description, wherein embodiments of the invention are shown and described, simply by way of illustration. As will be realized, the invention is capable of other and different embodiments, and its several details are capable of modifications in various respects, all without departing from spirit and scope of the present invention. Accordingly, the drawings and description thereof are to be regarded as illustrative in nature, and not as restrictive.

Brief Description of the Drawings

The present invention is illustrated by way of example, and not by limitation, in the figures of the accompanying drawings, wherein elements having the same reference numeral designations represent like elements throughout and wherein:

Figure 1A is a perspective view of an electrical connector according to one of the afore-cited related applications mounted to a daughtercard and a backplane with an over-mold omitted for clarity.

Figure 1B is the same view as Figure 1A with the over-mold depicted.

Figure 2 is a perspective view of the electrical connector according to one of the afore-cited related applications with the semi-rigid twinax connected to the back panel interposer only and with the backpanel and over-mold omitted for clarity.

Figure 3 is a bottom perspective view of Figure 2.

Figure 4 is the same view as Figure 2 with the back panel interposer omitted for clarity.

Figure 5 is the same view as Figure 4 with some of the spring contacts omitted for clarity.

Figure 6 is the same view as Figure 5 with additional spring contacts omitted for clarity.

Figure 7 is a bottom perspective view with the spring contacts omitted for clarity.

Figure 8 is a perspective view of the daughtercard and backpanel including PC board patterns.

Figure 9 illustrates a backpanel, mid-panel and daughtercard in an actual application.

Figure 10 is an exploded view of a second embodiment of an electrical connector according to one of the afore-cited related applications.

Figure 11 is an enlarged exploded view of the cable housing interposers.

Figure 12 is an enlarged view of a front side of the interposer cable housing shown in Figure 10.

Figure 13A is a perspective view of the electrical connector of one of the afore-cited related applications mounted to a daughtercard with the daughtercard interposer slide

being in a retracted position and the backpanel interposer slide being in an extended position.

Figure 13B is a cross-sectional view of spring contacts being retained by the Mylar sheet illustrating one end of the spring contacts within the interposer slide when the interposer slide is in an extended position.

Figure 13C is a cross-sectional view similar to Figure 13B illustrating the one end of the spring contacts extending beyond the interposer slide when the interposer slide is in a retracted position.

Figure 14 is an exploded view of an example embodiment of an electrical connector according to one of the afore-cited related applications.

Figure 15 is a view of a partially assembled connector according to one of the afore-cited related applications.

Figure 16 is a view of portions of the connector according to one of the afore-cited related applications.

Figure 17 is a view of the connector according to one of the afore-cited related applications prior to the attachment of the interposers.

Figure 18 is a view of one interposer of the connector of Figure 14.

Figure 19 is a view of the interposer of Figure 18 with one set of top hats inserted therein.

Figure 20 is a view of the interposer of Figure 19 with one set of spring contacts respectively against in the one set of top hats.

Figure 21 is a view of the interposer of Figure 20 with one end of a single twinax cable arranged with one set of spring contacts and top hats.

Figure 21A is a close-up view of a portion of the arrangement of Figure 21 with some elements being omitted for clarity.

Figure 22 is a view corresponding to that of Figure 21 but with all of the twinax cables being arranged with their respective spring contacts and top hats.

Figure 23 is a view of the connector of Figure 22 after encapsulation.

Figure 24 is a view of the connector of Figure 23 after attachment of the interposers.

Figure 25 is an exploded view of an interconnection system in accordance with an example embodiment of the present invention.

Figure 26 is a view of printed circuit board 5021 of Figure 25.

Figure 27 is a view of printed circuit boards 5020 and 5021 of Figure 25 along with one cell 1070.

Figure 28 is a view of spacer 5040.

Figure 29 is an exploded view of interposer 5080,

Figure 30 is a view of printed circuit board 5021 sandwiched between spacers 5010 and 5040.

Figure 31 is a view of a single cell including a pair of electrical contacts and a pair of springs.

Figure 32 is an exploded view of the cell of Figure 31.

Figure 33 is an exploded view of the cell of Figure 31 and an interposer.

Figure 34 is a view of the cell of Figure 31 disposed within an aperture of an interposer.

Figure 35 is a detailed view of an end cap.

Figure 36 is a detailed view of a backbone.

Figure 37 is a detailed view of an end plate.

Figure 38 is a detailed view of a shield plate.

Figure 39 is an exploded view of a backbone and an end cap.

Figure 40 is a view of a backbone and an end cap.

Figure 41 is a detailed view of a spacer and a backbone.

Figure 42 is a detailed view of spacers, printed circuit boards, and an interposer.

Figure 43 is an exploded view of an end plate and an end cap.

Figure 44 is a detailed view of an end plate and an end cap.

Figure 45 is an exploded view of a shield plate and an interposer.

Figure 46 is a detailed view of a shield plate and an interposer.

Figure 47 is a detailed view of an assembled interconnection system with an interposer omitted.

Figure 48 is a detailed view of an assembled interconnection system.

Figure 49 is a detailed view of an assembled interconnection system with both interposers shown.

Figure 49 is an exploded view of an assembled interconnection system with both interposers shown.

Detailed Description

Figure 25 is an exploded view of an interconnection system in accordance with an example embodiment of the present invention. Some elements have been omitted for the sake of clarity. As illustrated in Figure 25, double sided printed circuit boards 5020 and 5021 have electrical conductors printed thereon to replace the center conductors of

the twinax of the above-noted interconnection arrangement. The printed circuit boards 5020 and 5021 will be discussed in detail below.

Spacers 5010 and 5040 are disposed on either side of the printed circuit boards 5020 and 5021. The spacers 5010 and 5040 are fabricated with grooves corresponding to the electrical conductors of the printed circuit boards 5020 and 5021 and arranged to prevent the electrical conductors of the printed circuit boards 5020 and 5021 from touching the spacers 5010 and 5040. That is, the electrical conductors of the printed circuit boards 5020 and 5021 are insulated by an air dielectric from the spacers 5010 and 5040.

In addition, the spacers 5010 and 5040 are fabricated either of an electrically conductive material or with an electrically conductive layer to electromagnetically shield the electrical conductors of the printed circuit boards 5020 and 5021 in an analogous fashion to the outer shield of the twinax cable of the above-noted interconnection arrangement. The spacers 5010 and 5040 will be discussed in detail below.

A plurality of printed circuit boards 5020 and 5021 and their corresponding spacers 5010 and 5040 are arranged to snap into a backbone 5050. End caps 5000 are provided on either end and snap into both the backbone 5050 and the outermost spacers 5010 and 5040. Only one end cap 5000 has been illustrated in Figure 25 for the sake of clarity. The backbone 5050 and end caps 5000 will be discussed in detail below.

An interposer 5080 includes a plurality of apertures arranged to receive a plurality of corresponding cells 5022, each cell 5022 including a pair of springs 6020, 6021 and corresponding contacts 6030, 6031. The pair of springs 6020, 6021 provided a resilient force and the contacts 6030, 6031 are electrically connected to the conductors of the printed circuit boards 5020 and 5021 with a wiping action similar to that used in card edge connectors. The interposer 5080 and cells 5022 including the pair of springs 6020, 6021 and corresponding contacts 6030, 6031 will be discussed in detail below.

A mounting clip 5090 and shield 5060 snap together with the above-noted parts of the interconnection system to form a composite arrangement. The mounting clip 5090 and shield 5060 are electrically conductive so as to electromagnetically shield the parts contained therein. The mounting clip 5090 and shield 5060 will be discussed in detail below. An additional interposer 5081 and mounting clip 5091 (included in Figure 50) have been omitted from Figure 25 for the sake of clarity. The mounting clips 5090 and 5091 and the shield 5060 also provide a low impedance ground returned for the spacers 5010 and 5040, interposers 5080 and 5081, daughtercard, and back panel.

Figure 26 is a view of printed circuit board 5021 and Figure 27 is a view of printed circuit boards 5020 and 5021 along with one cell 1070. Four electrical conductors 6001, 6002, 6003, and 6004 are shown in Figure 26. There are corresponding to electrical conductors on the backside of the printed circuit board 5021. When the interconnection system of the present invention requires two wire balanced pairs, one of the electrical conductors 6001-6004 of the printed circuit board 5021 and its corresponding electrical conductor on the backside of printed circuit board 5021 are utilized to form the two wire balanced pair. Since the length of the two electrical conductors is identical, there is no skew between the two electrical conductors (skew being the difference in time that it takes for a signal to propagate the two electrical conductors).

Referring to Figure 27, note that the electrical conductors 6001-6004 on printed circuit board 5021 are staggered with respect to the electrical conductors 6101 and 6102 on the printed circuit 5020 (the other electrical conductors of printed circuit board 5020 being visible in Figure 27). This serves to reduce the cross-talk between the electrical conductors by mechanically separating them as much as possible.

Furthermore, cell 1070 includes contacts 6030 and 6031 that make electrical contact with corresponding electrical conductors on either side of printed circuit board 5021. Springs 6020 and 6021 are included in cell 1070 to provide a resilient force. Since contacts 6030 and 6031 are used only to provide electrical connections, the force exerted on the electrical conductors of the printed circuit board 5021 can be optimized

from an electrical standpoint. Furthermore, the wiping action provided by the contacts 6030 and 6031 ensure a good electrical connection between the contacts and the corresponding electrical conductors of the printed circuit boards 5020 and 5021. Similarly, since the springs 6020 and 6021 are only used to provide a resilient force, the force exerted by the springs 6020 and 6021 can be optimized from a mechanical standpoint.

Figure 28 is a view of spacer 5040. Figure 29 is an exploded view of interposer 5080, cell 1070 including electrical contacts 6030 and 6031 and springs 6020 and 6021, printed circuit board 5021, and spacers 5010 and 5040. Figure 30 is a view of printed circuit board 5021 sandwiched between spacers 5010 and 5040.

Referring to Figure 28, spacer 5040 includes channels 3010 that are designed to contain the electrical conductors of printed circuit board 5020 and to allow an air space between the spacer 5040 and the electrical conductors of the adjacent printed circuit boards. The surfaces of the spacer 5040 that are mechanically adjacent to the printed circuit boards 5020 and 5021 and the channels 3010 are electrically conductive to electromagnetically shield the electrical conductors of the printed circuit board 5020 and to provide an air dielectric between the electrical conductors of the printed circuit board 5020 and the channels 3010. The backside of the spacer 5040 includes similar channels that are designed to contain the electrical conductors of printed circuit board 5021. Both the backside of the spacer 5040 and the channels contained therein are electrically conductive to electromagnetically shield the electrical conductors of the printed circuit board 5021 and to provide an air dielectric between the electrical conductors of the printed circuit board 5021 and the channels thereof. The spacers 5040 can either be of a conductive material, such as a metal, or can be of a non-conductive material, such as a plastic, covered with a layer of a conductive material. Furthermore, the complex impedances of the electrical conductors and their associated channels can be adjusted by varying the dimensions thereof. Still furthermore, the channels can include a layer of a dielectric material, such as Teflon, to further adjust the

complex impedances of the electrical conductors and their associated channels as well as adjusting the breakdown voltage thereof.

Fingers 3020, 3030, and 3040 are provided on the spacer 5040 to mechanically interface with the other parts of the interconnection system. Fingers 3020 and 3030 include protrusions 3021 and 3031 and are sufficiently resilient to allow them to snap into corresponding recesses in the mating parts of the interconnection system. Similarly, fingers 3040 is arranged to fit into a corresponding slot in a mating part of the interconnection system.

Bosses 3050 are provided to fit in the apertures 2010 and 2012 of the printed circuit board 5021. Referring to Figures 29 and 30, it can be seen that printed circuit board 5021 is sandwiched between spacers 5010 and 5040. It is to be noted that the side of the spacer 5010 that is adjacent to the printed circuit board 5021 includes channels designed to contain the electrical conductors of printed circuit board 5021 and both the side of the spacer 5010 and its channels are electrically conductive in the same fashion as spacer 5040.

As will be illustrated and discussed later, the interconnection system in accordance with the present invention includes a laminated sandwich including a spacer 5010, a printed circuit board 5021, a spacer 5040, a printed circuit board 5020, a spacer 5010, a printed circuit board 5021, a spacer 5040, ..., etc.

Referring to Figure 29 again, the slots 3020 of the spacers 5010 and 5040 interface with corresponding notches 4010 of the interposer 5080. Furthermore, the cells 5070 are arranged to fit in apertures 4020 of the interposer 5080.

Both the printed circuit boards 5020 and 5021 can be fabricated by commonly available techniques utilizing any material suitable for the frequency of operation of the interconnection system. The electrical conductors thereof can also be fabricated by commonly available techniques utilizing materials and dimensions commensurate with the frequency of operation of the interconnection system.

The spacers 5010 and 5040 can be fabricated either of a conductive metal or of a non-conductive material, such as a plastic, having a coating of a conductive material. Commonly available techniques can be utilized to provide the coating of a conductive material on spacers fabricated of the non-conductive material.

The cells 5070 can be fabricated by commonly available techniques utilizing any non-conductive material suitable for the frequency of operation of the interconnection system. The interposer 5080 can be fabricated by commonly available techniques. The interposer 5080 electromagnetically shields the electrical conductors of the printed circuit boards by being fabricated either of a conductive material or of a non-conductive material coated with a conductive material. The springs 6020 and 6021 can be fabricated by commonly available techniques utilizing any material having suitable mechanical properties.

Similarly, the electrical contacts 6030 and 6031 can be fabricated by commonly available techniques utilizing any material having suitable electrical and mechanical characteristics. While they are illustrated as being of unitary construction, they can be fabricated of laminated materials such as gold plated phosphor bronze often used industry wide in card edge connectors.

Figure 31 is a view of a single cell 5070 including a pair of electrical contacts 6100 and a pair of springs 6120. Figure 32 is an exploded view of the cell 5070 of Figure 31. Figure 33 is an exploded view of the cell 5070 of Figure 31 and an interposer 5080 and Figure 34 is a view of the cell 5070 of Figure 31 disposed within an aperture 6200 of the interposer 5080 of Figure 33.

Referring to Figures 31-34, each cell 5070 is preferably fabricated of an electrically insulative material, such as a plastic. The electrical contacts 6100 of each cell 5070 can either be disposed within the cell during fabrication or subsequently fitted within the cell. The springs 6120 of each cell 5070 are disposed within cylindrical apertures 6130 but

do not need to be permanently affixed to the cell. While open cylindrical apertures 6130 are illustrated, it is understood that closed apertures can also be used.

The interposer 5080 includes a plurality of apertures 6200 arranged to receive the plurality of cells 5070. Each cell 5070 has a pair of tabs 6140 arranged to fit within corresponding slots 6210 disposed within the apertures 6200 of the interposer 5080. The tabs 6140 prevent the cells 5070 from falling through the apertures 6200. It is to be understood that the specific shape of the cells and corresponding apertures are merely for exemplary purposes. The present invention is not limited to these shapes.

Figure 35 is a view of an end cap 5000. The end cap 5000 includes apertures 6300 arranged to mate with bosses disposed on adjacent spacers as well as bosses disposed on the backbone 5050. The end cap 5000 further includes both a screw 6310 and a pin 6320 arranged to mechanically interface the interconnection system with a daughtercard, that can be a multilayered daughtercard having a large number of layers, for example, more than 30 layers, as well as a tongue 6330 arranged to mate with an end plate 5090. While the end cap 5000 is illustrated as being symmetrical, that is, can be used on either end of the interconnection system, separate left and right-handed end caps may also be used. The screw 6310 and pin 6320 of the end cap 5000 may be integrally formed with the end cap 5000 or may be attached thereto after fabrication of the end cap 5000. It has been found that it is often necessary to utilize a metal rather than a plastic screw 6310 in view of the mechanical stresses involved. It is understood that the present invention is not limited to the use of a screw 6310 and pin 6320 but rather other fastening means may also be used. As noted previously, both the end caps 5000 and spacers 5010,5040 can be fabricated of an insulative material, such as a plastic, covered with a conductive material to provide electromagnetic shielding or can be fabricated entirely of a conductive material, such as a metal.

Figure 36 is a detailed view of a backbone 5050. Figure 37 is a detailed view of an end plate 5090 and Figure 38 is a detailed view of a shield plate 5060.

Referring to Figures 36-38, the backbone 5050 includes bosses 6400 arranged to mate with the end caps 5000 as well as slots 6420 arranged to receive the spacers 5010, 5040 and printed circuit boards 5020, 5021 and tines 6430 arranged to mate with the spacers 5010, 5040. The end plate 5090 includes pins 6460 arranged to mate with a backplane, that can be a multilayer backplane, for example, a backplane having more than 30 layers, as well as slots 6470 arranged to receive the tongues and 6330 of the end caps 5000. The pins 6460 precisely locate and polarize the interconnection system assembly to the backplane. The shield plate 5060 includes hooks 6500 arranged to fit in slots 5081 in the interposer 5080.

Figure 39 is an exploded view of a backbone 5050 and an end cap 5000. Figure 40 is a view of a backbone 5050 and an end cap 5000 assembled together. Figure 41 is a view of a spacer 5010 and a backbone 5050 assembled together. Figure 42 is a view of spacers 5010, 5040, printed circuit boards 5020, 5021, and an interposer 5080 assembled together.

Referring to Figures 39-42, the bosses 6400 of the backbone 5050 are disposed within corresponding apertures 6300 in the end caps 5090 forming a rigid structure. The use of bosses 6400 and apertures 6300 is for exemplary purposes and the present invention is not limited thereto. That is, other fastening means can be used to mechanically connect the backbone 5050 to the end caps 5090. Furthermore, a combination of tines and tongues and mating slots are used to mechanically connect the backbone 5050 to the spacers 5010, 5040. The illustrated combination is for exemplary purposes and the present invention is not limited thereto. In a similar fashion, the tongues of the spacers are arranged to mate with corresponding slots in the interposer. The illustrated combination of tongues and slots is for exemplary purposes and the present invention is not limited thereto.

Figure 43 is an exploded view of an end plate 5090 and an end cap 5000. Figure 44 is a detailed view of an end plate 5090 and an end cap 5000. Figure 45 is an exploded view of a shield plate 5060 and an interposer 5080. Figure 46 is a detailed view of a

shield plate 5060 and an interposer 5080. Figure 47 is a detailed view of an assembled interconnection system with an interposer 5080 omitted. Figure 48 is a detailed view of an assembled interconnection system.

Referring to Figures 43-48, the tongue 6330 of each end cap 5000 is arranged to mate with a corresponding slot 6470 in the end plate 5090. As with the other illustrated fastening means, the present invention is not limited to the use of a tongue 6330 and corresponding slot 6470. The hooks 6500 on the shield plate 5060 are arranged to mate with corresponding slots 5081 in the interposer. As can be seen from Figures 47 and 48, the entire interconnection system assembly snaps together to form a rigid structure in which the electrical conductors 6001-6004 on the printed circuit boards 5020, 5021 are entirely electromagnetically shielded.

The tongue 6330 is the latching mechanism that engages with the slots 6470 of shield plate 5090. The latching mechanism best matches the Z-axis travel (that is, the travel in a direction perpendicular to the interposer 5080) incorporated in the differential cell 5070.

Figure 49 is a detailed view of an assembled interconnection system with both interposers 5080 and 5081 shown and Figure 49 is an exploded view of an assembled interconnection system with both interposers 5080 and 5081 shown.

Referring to Figures 49 and 50, an additional interposer 5081 with associated cells 5070 and an additional end plate 5091 complete the entire assembly. The additional end plate 5091 is attached to the overall assembly by any usual fastening means and can include pins or other fastening means to attach the assembled interconnection system to a daughtercard, for example.

The additional interposer 5081 and additional end plate 5091 can either be identical to the interposer 5080 and end plate 5090 or can be different, depending upon the application of the interconnection system assembly.

While the planes of the two interposers 5080 and 5081 have been illustrated as being perpendicular to each other, the present invention is not limited thereto. That is, for some applications, the planes of the two interposers 5080 and 5081 can be at a 45-degree angle, for example.

Tuning of the transmission path of the interconnection system assembly is achieved by balancing the inductive and capacitive elements of the transmission path at either extremes of the desired travel of the differential cell assembly.

Modeling of the broadside-coupled trace within the spacer channels 3010 is completed to optimize the transmission path with the preferred dielectric laminate and the air dielectric characteristics within the spacer channels 3010 to achieve a differential impedance of 100 Ohms, for example.

The contacts 6030, 6031 are comprised of a series of impedance steps that are controlled to achieve best impedance performance over the full travel of the cell 5070. When configuring the impedance steps, the capacitive stubbing of the unused portion due to the point of displacement or travel of the cell 5070 is considered. Further consideration of impedance control is facilitated at the contacts 6030, 6031 and the daughtercard interface.

A truly passive interconnect can be achieved with the inter-dependant control of the characteristic inductive and capacitive elements within the interconnection system assembly.

Claims

What is claimed is:

1. An interconnection system comprising:

a plurality of printed circuit boards each having at least one pair of electrical conductors respectively disposed on opposite faces of each of said plurality of printed circuit boards;

a plurality of spacers arranged to be disposed adjacent to each other in a row having two ends, each spacer arranged to allow one of said plurality of printed circuit boards to be disposed between it and another of said plurality of spacers; each face of each of said plurality of spacers including a groove for each of said electrical conductors of an adjacent printed circuit board, said groove arranged to provide an airspace between its spacer and said conductor of said adjacent printed circuit board, each of said electrical conductors having first and second ends, said printed circuit boards and said plurality of spacers being arranged to leave exposed, on a first plane, all of said first ends of said plurality of electrical conductors and to leave exposed, on a second plane, all of said second ends of said plurality of electrical conductors;

a pair of end pieces respectively arranged to be disposed adjacent said ends of said row of plurality of spacers;

a plurality of cells;

first and second interposers respectively arranged to be disposed adjacent said first and second planes, each interposer having an aperture arranged to receive one of said plurality of cells for each conductor pair of said plurality printed circuit boards; and

a plurality of electrically conductive contacts, each electrically conductive contact having first and second ends and being arranged to be respectively disposed in one of

said cells of said first and second interposers, wherein said first end of each of said plurality of electrically conductive contacts respectively electrically contacts one of said conductor pairs of said plurality of printed circuit boards and wherein said second end of each of said plurality of electrically conductive contacts extends through its respective cell in its respective interposer beyond a plane of said interposer.

2. The system of claim 1, wherein each of said electrically conductive contacts comprises a leaf spring contact, one end of said spring contact comprising said first end of said respective electrically conductive contact and a second end of said spring comprising said second end of said electrically conductive contact.

3. The system of claim 2, wherein said one end of each of said spring contacts is arranged to provide a resilient force to urge it towards its respective electrical conductor to electrically connect it thereto.

4. The system of claim 1, wherein each cell comprises at least two springs arranged to provide a resilient force to urge said cell toward its respective interposer.

5. The system of claim 4, wherein each cell comprises cylindrical apertures arranged to receive said at least two springs.

6. The system of claim 1, wherein each cell comprises at least two tabs arranged to mate with corresponding slots in its respective aperture of its respective interposer.

7. The system of claim 1, wherein said at least one pair of electrical conductors of adjacent printed circuit boards are staggered to increase distances between said electrical conductors of said adjacent printed circuit boards.

8. The system of claim 1, wherein each printed circuit board comprises at least one aperture and each spacer comprises at least one boss on either side thereof, said at least one aperture of said printed circuit board arranged to mate with said at least one boss of said spacer.

9. The system of claim 1, further comprising a backbone including slots arranged to receive said plurality of spacers.

10. The system of claim 1, further comprising an end plate arranged to contain one of said interposers and to mate to said end caps.

11. The system of claim 1, further comprising a shield plate arranged to cover two sides of the interconnection system.

12. A method of manufacturing an interconnection system, the method comprising:

disposing a plurality of printed circuit boards each having at least one pair of electrical conductors respectively disposed on opposite faces of each of said plurality of printed circuit boards;

disposing a plurality of spacers adjacent to each other in a row having two ends, each spacer arranged to allow one of said plurality of printed circuit boards to be disposed between it and another of said plurality of spacers; each face of each of said plurality of spacers including a groove for each of said electrical conductors of an adjacent printed circuit board, said groove arranged to provide an airspace between its spacer and said conductor of said adjacent printed circuit board, each of said electrical conductors having first and second ends, said printed circuit boards and said plurality of spacers being arranged to leave exposed, on a first plane, all of said first ends of said plurality of electrical conductors and to leave exposed, on a second plane, all of said second ends of said plurality of electrical conductors;

disposing a pair of end pieces respectively adjacent said ends of said row of plurality of spacers;

disposing first and second interposers respectively adjacent said first and second planes and disposing a plurality of cells in said first and second interposers, each interposer having an aperture arranged to receive one of said plurality of cells for each conductor pair of said plurality printed circuit boards; and

disposing a plurality of electrically conductive contacts, each electrically conductive contact having first and second ends and respectively disposed in one of said cells of said first and second interposers, wherein said first end of each of said plurality of electrically conductive contacts respectively electrically contacts one of said conductor pairs of said plurality of printed circuit boards and wherein said second end of each of said plurality of electrically conductive contacts extends through its respective cell in its respective interposer beyond a plane of said interposer.

13. The method of claim 12, further comprising providing a leaf spring contact for each of said electrically conductive contacts, one end of said spring contact comprising said first end of said respective electrically conductive contact and a second end of said spring comprising said second end of said electrically conductive contact.

14. The method of claim 13, further comprising arranging said one end of each of said spring contacts to provide a resilient force to urge it towards its respective electrical conductor to electrically connect it thereto.

15. The method of claim 12, further comprising providing at least two springs for each cell to provide a resilient force to urge said cell toward its respective interposer.

16. The method of claim 15, further comprising providing cylindrical apertures in each cell to receive said at least two springs.

17. The method of claim 12, further comprising providing at least two tabs for each cell, said at least two tabs arranged to mate with corresponding slots in its respective aperture of its respective interposer.

18. The method of claim 12, further comprising providing a backbone including slots to receive said plurality of spacers.

19. The method of claim 12, further comprising providing an end plate to contain one of said interposers and to mate to said end caps.

20. The method of claim 12, further comprising providing a shield plate to cover two sides of the interconnection system.

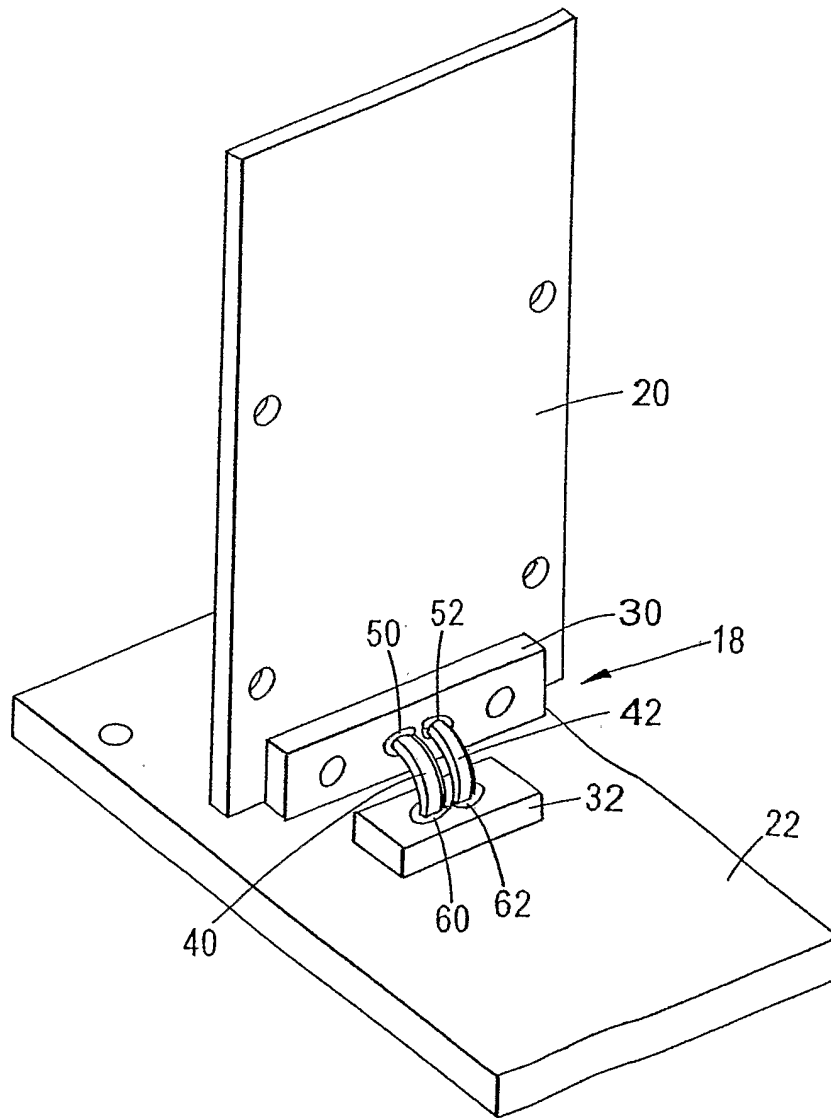


FIG. 1A

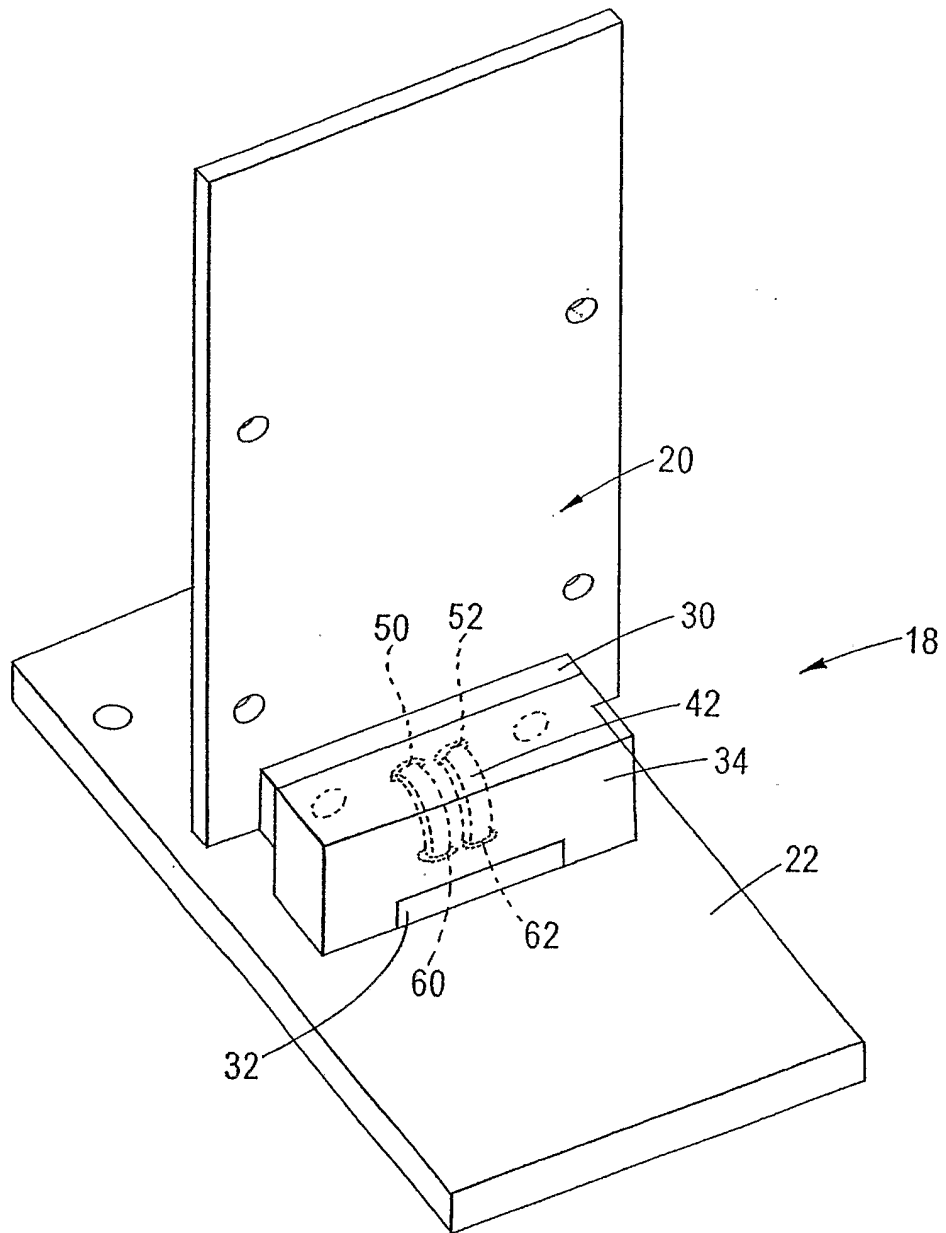


FIG. 1B

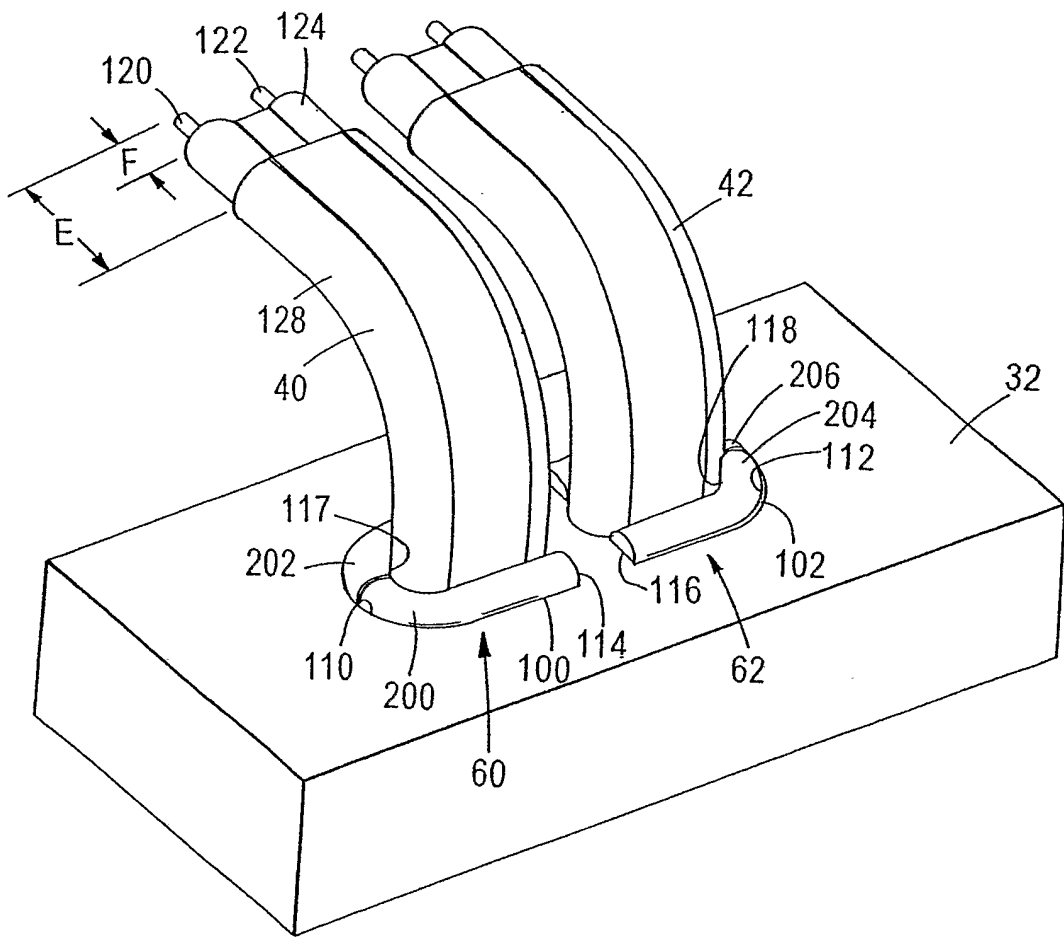


FIG. 2

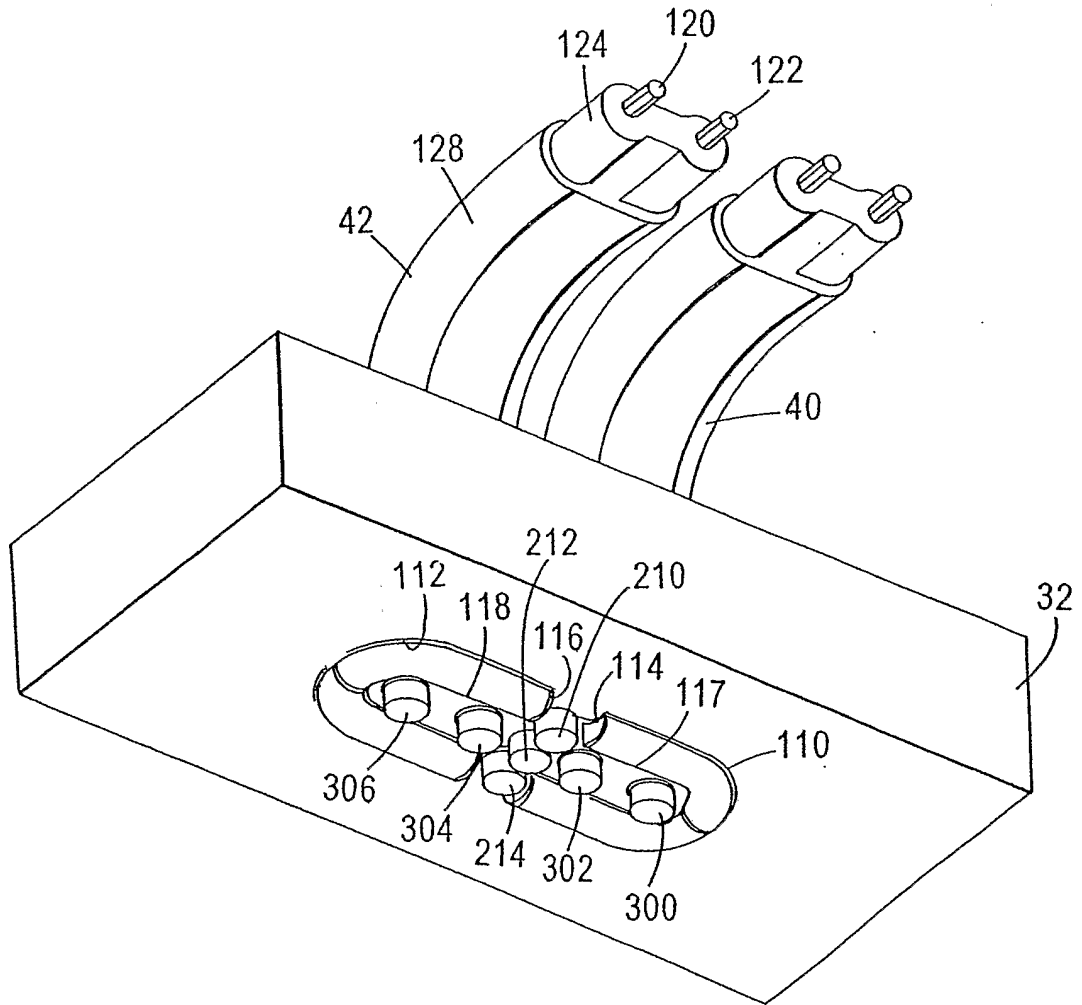


FIG. 3

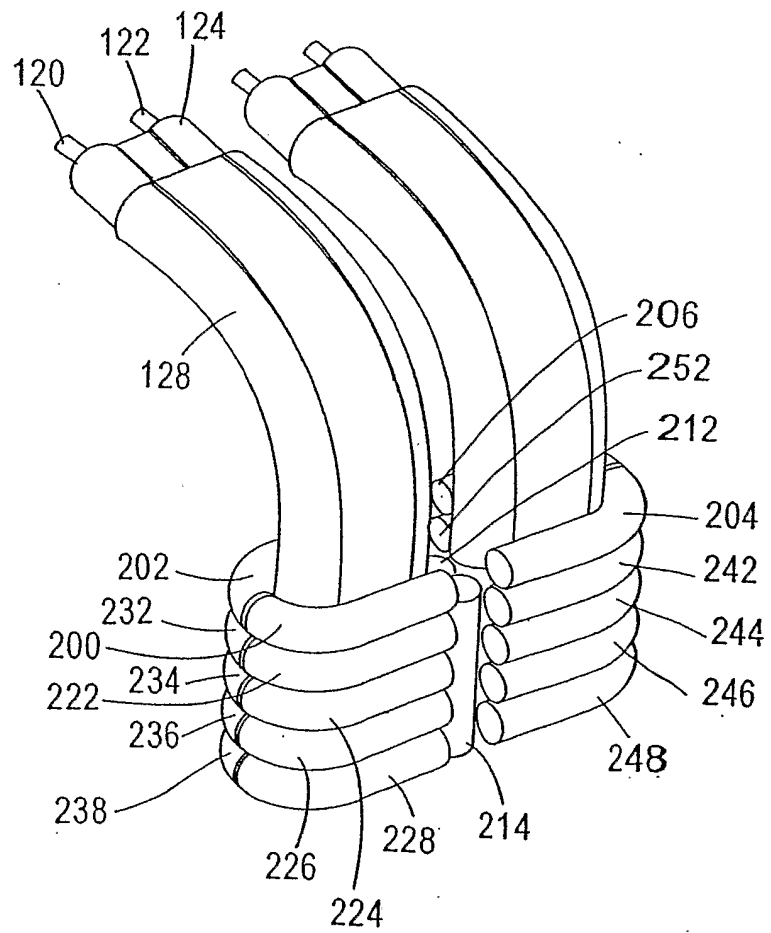


FIG. 4

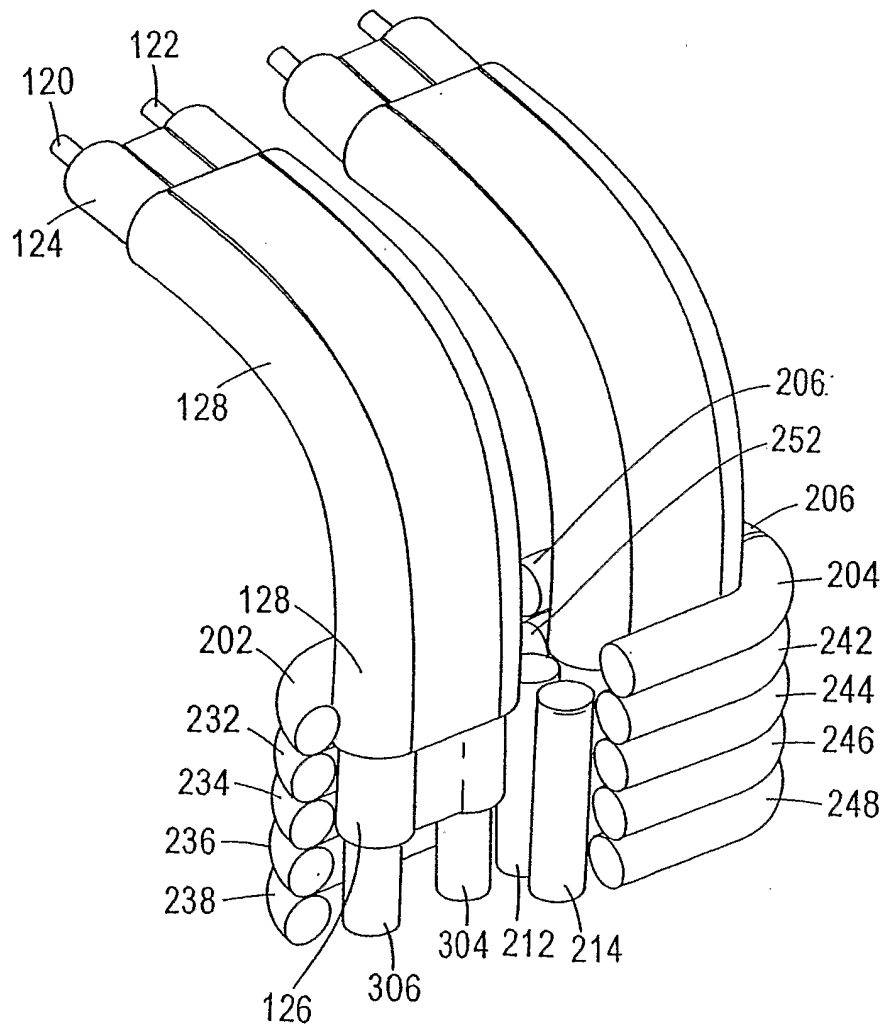


FIG. 5

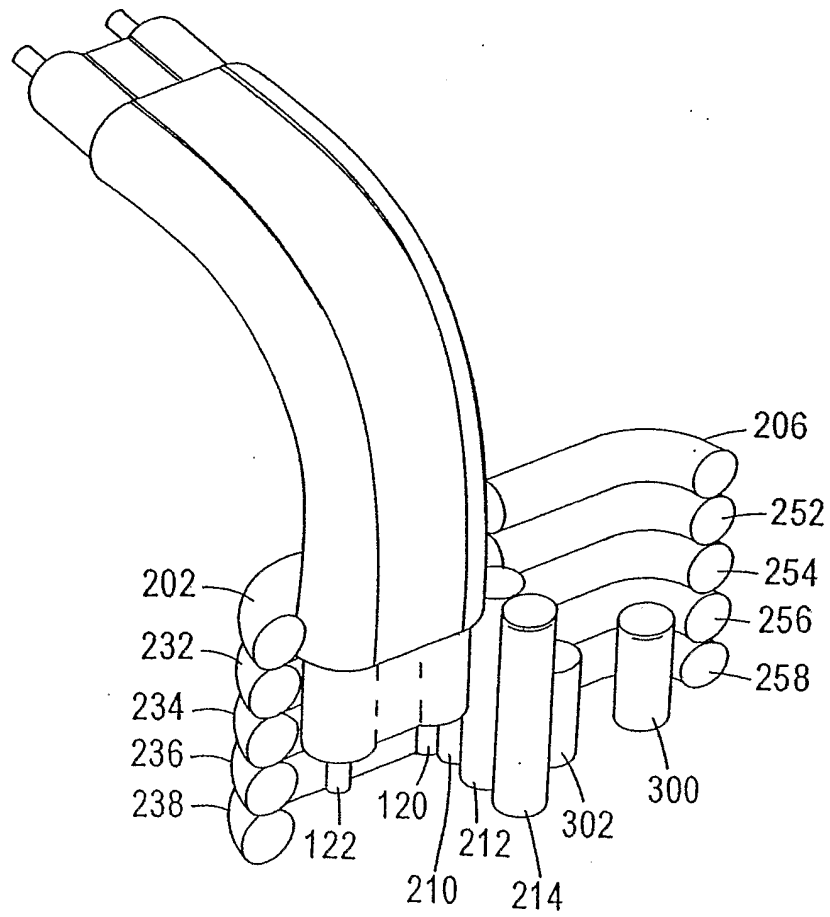


FIG. 6

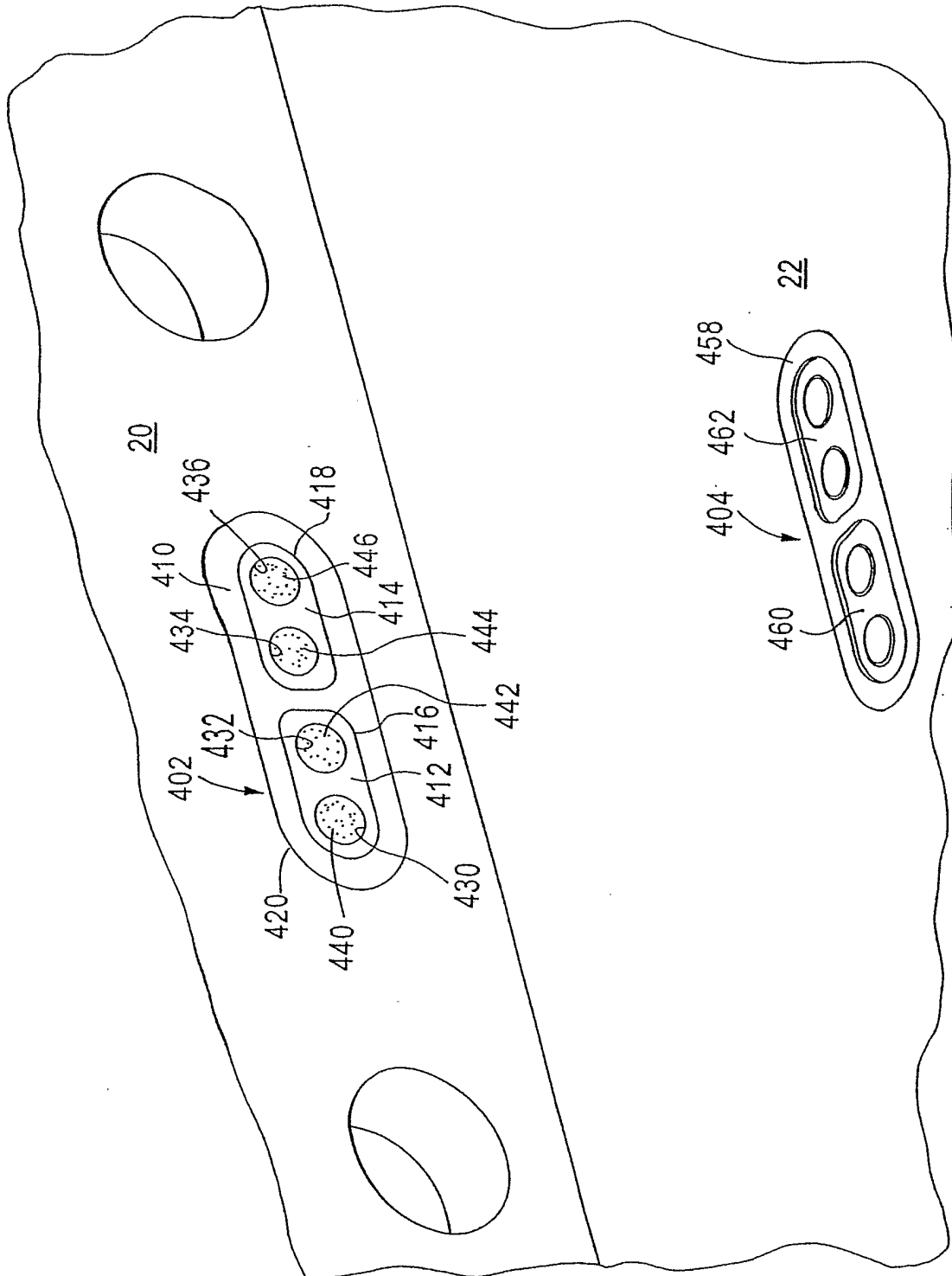
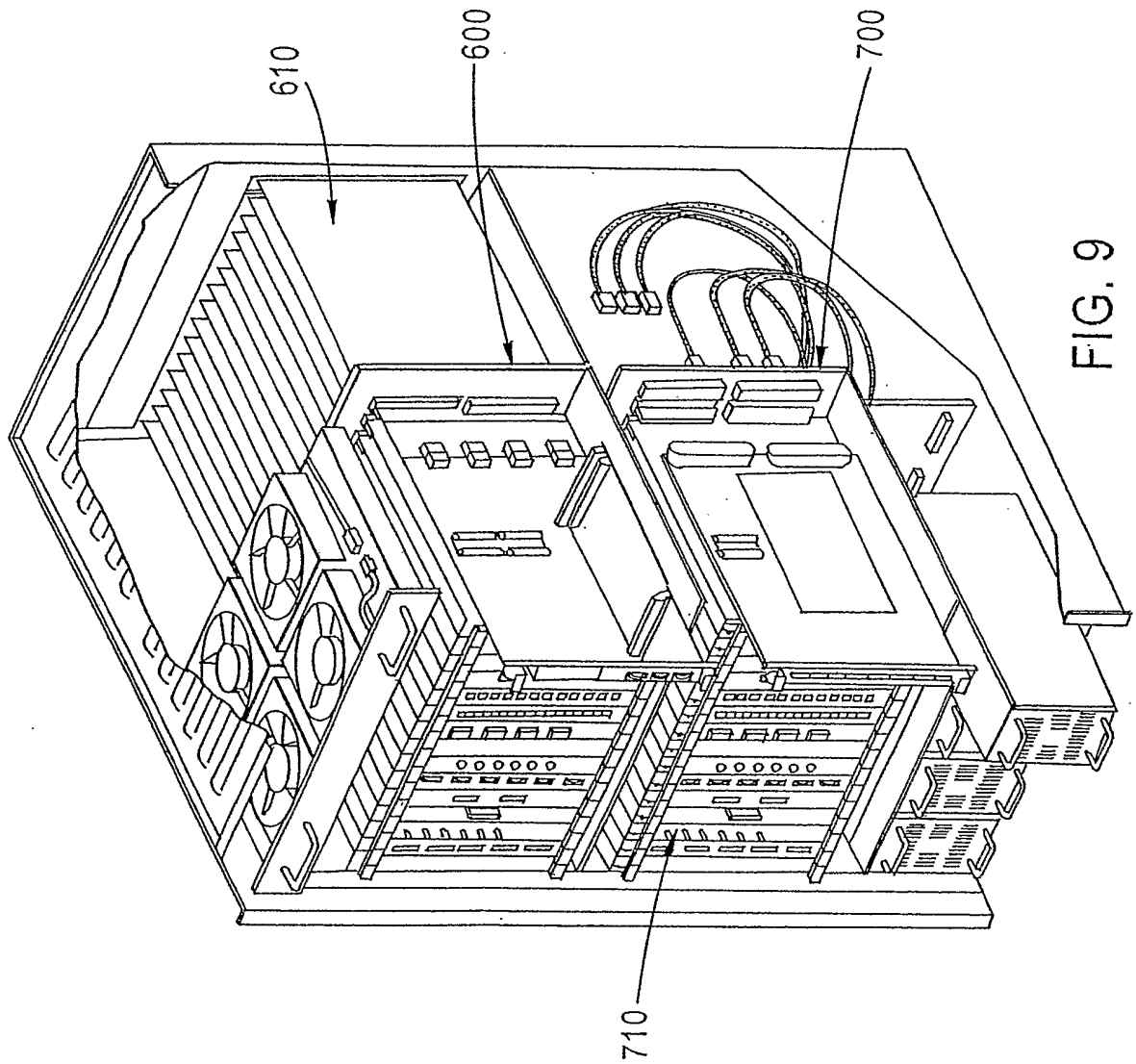


FIG. 8



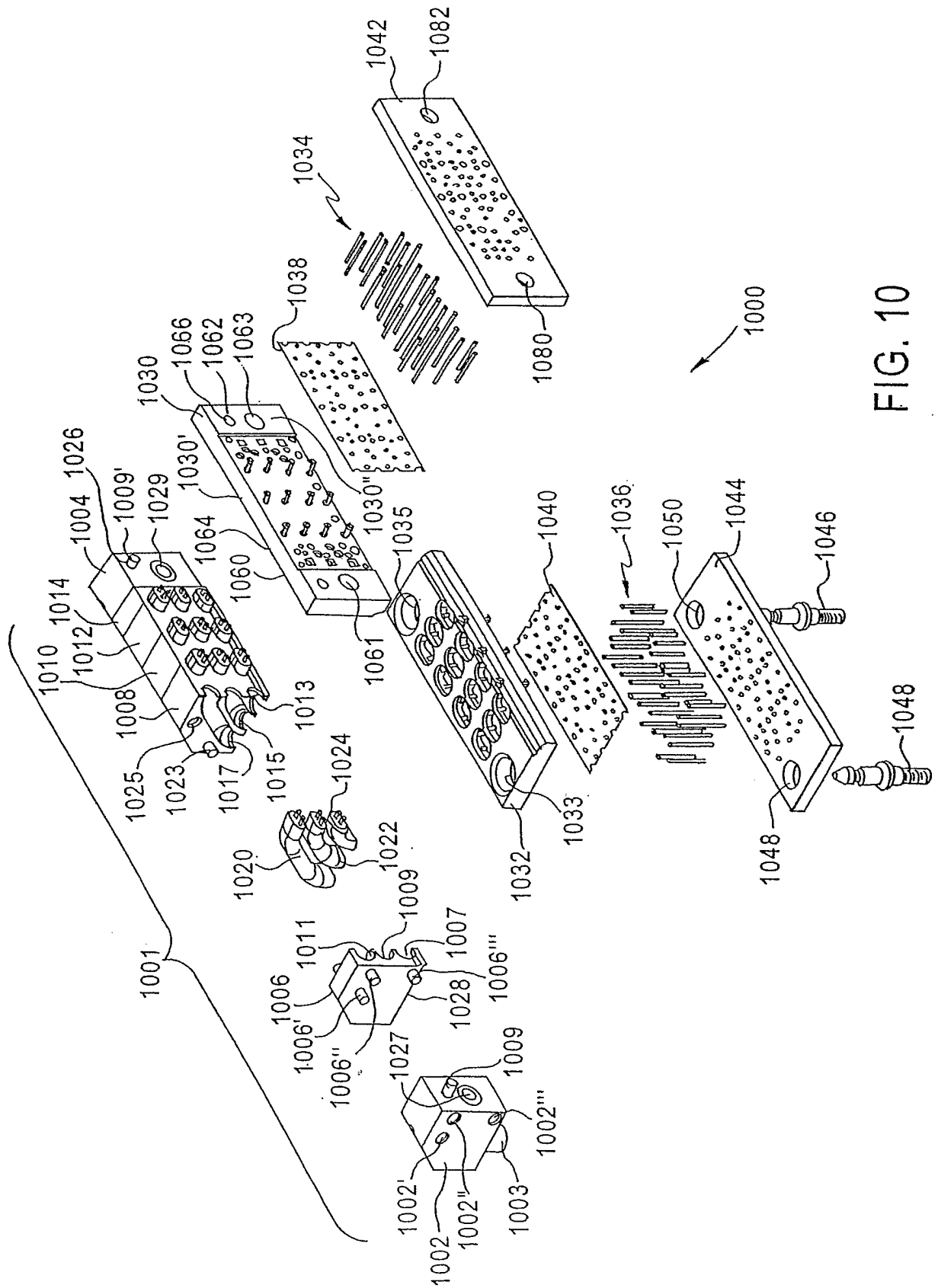


FIG. 10

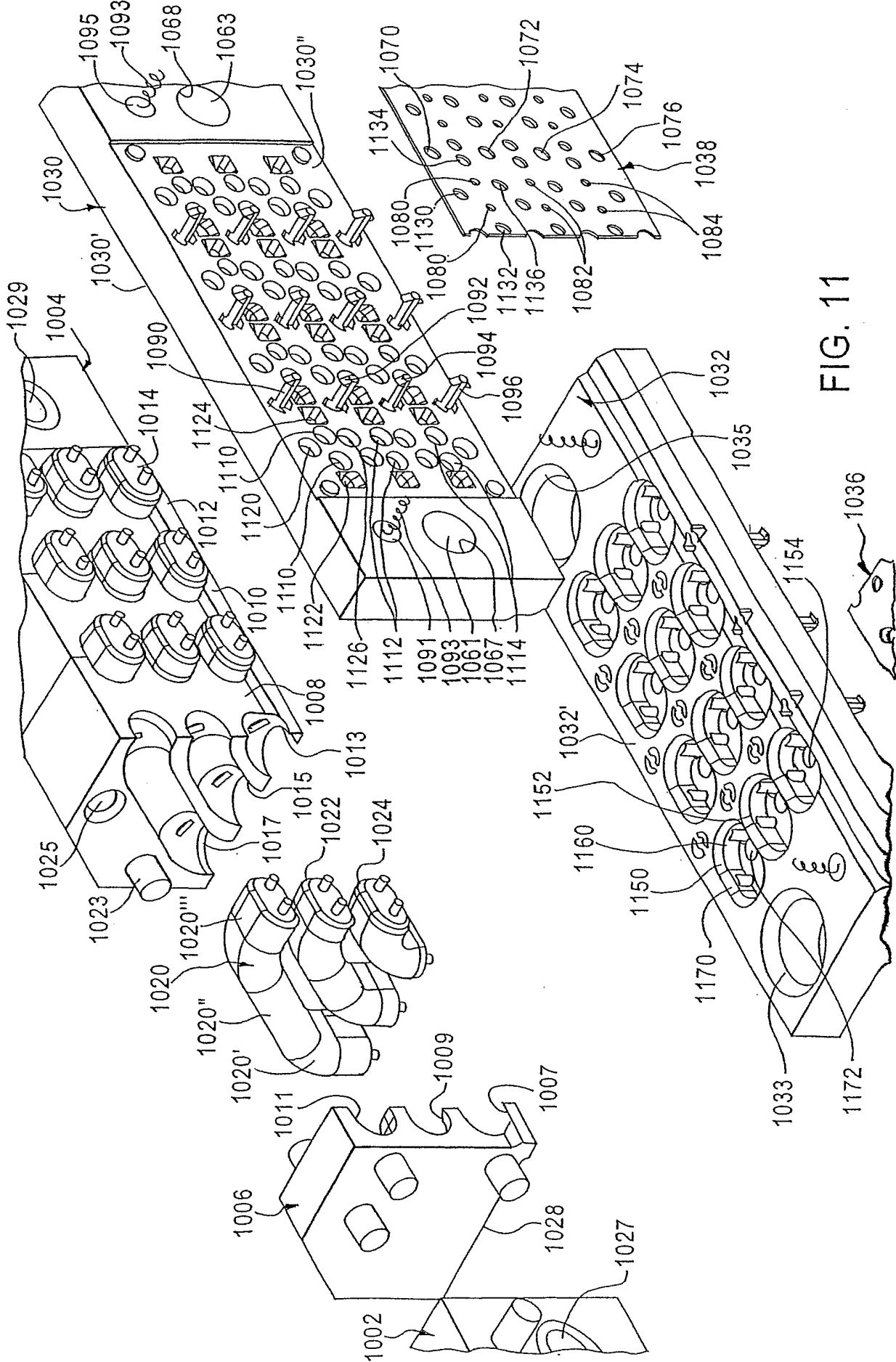


FIG. 11

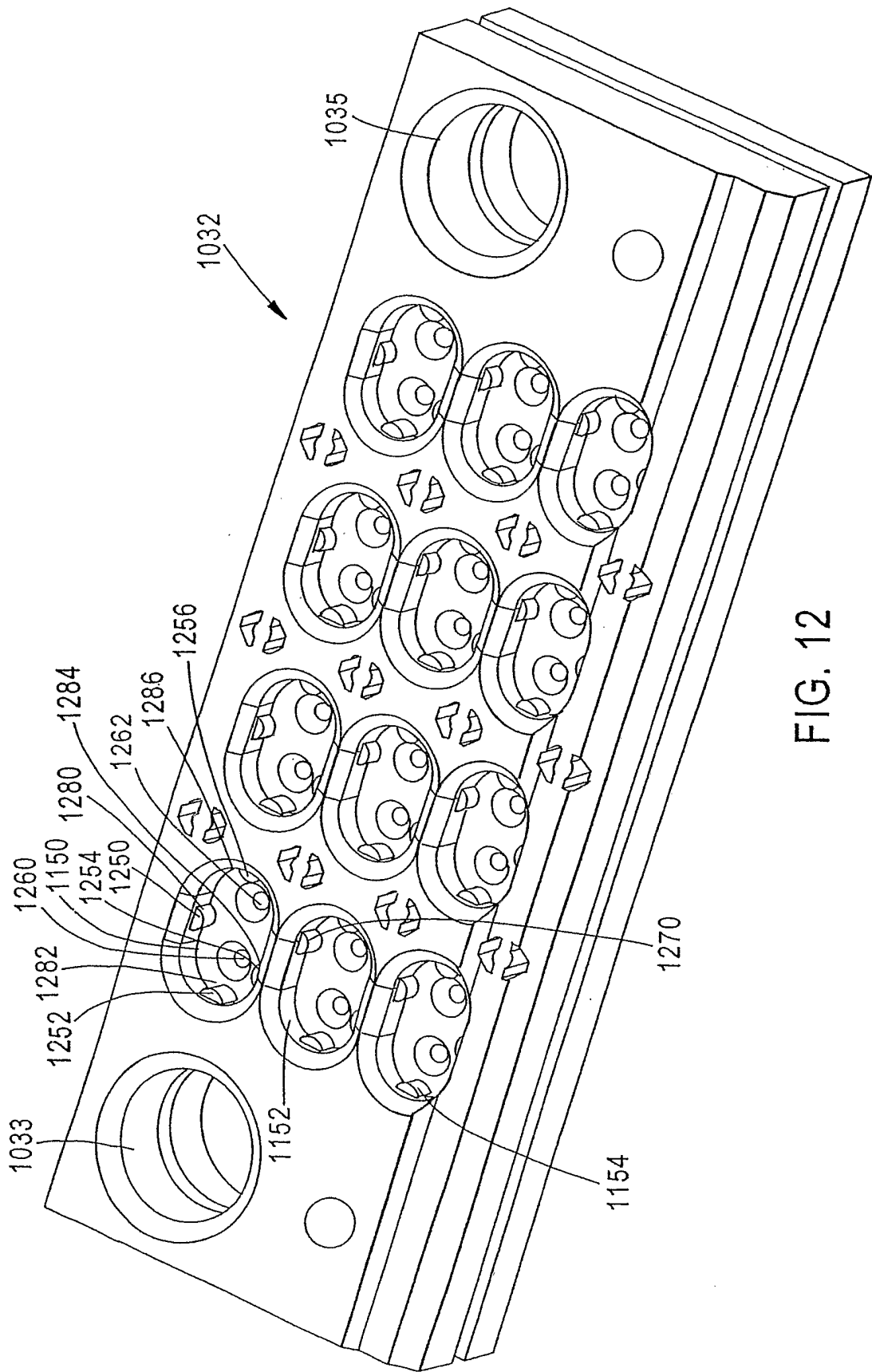


FIG. 12

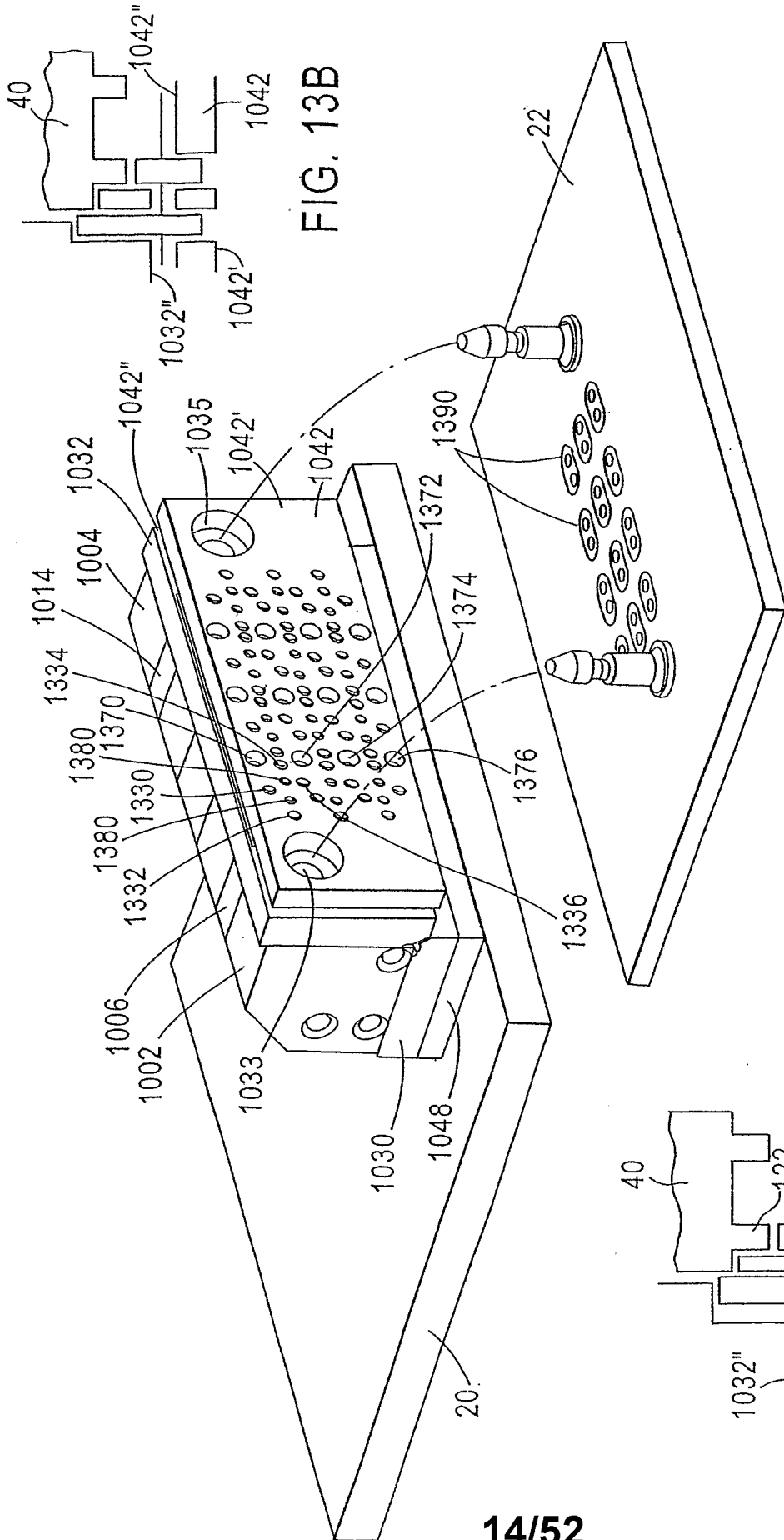
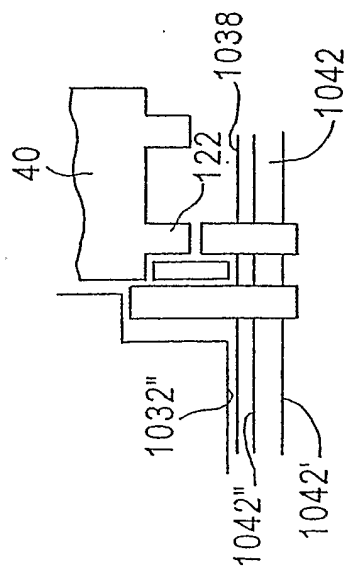


FIG. 13B

FIG. 13A

FIG. 13C



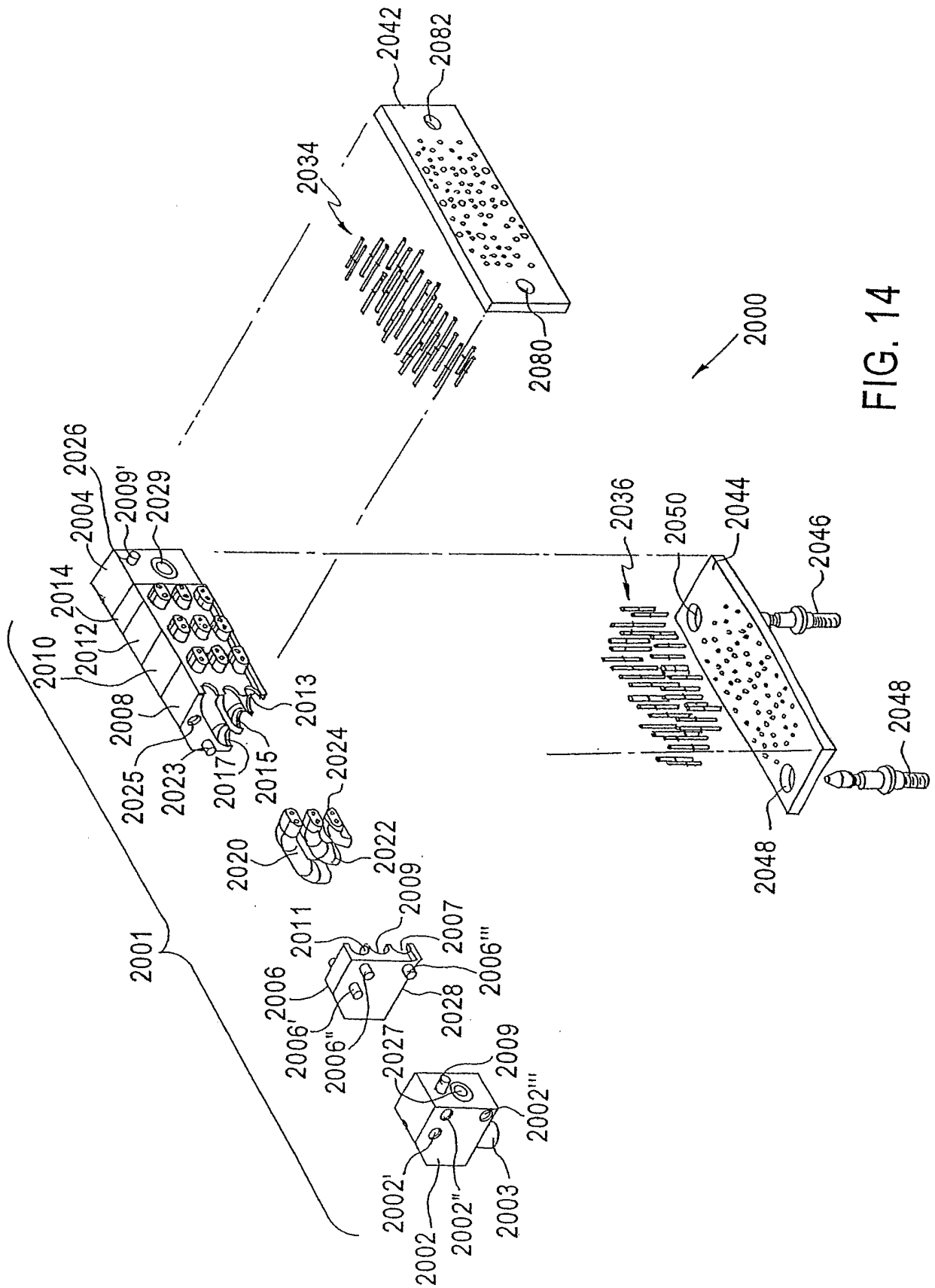


FIG. 14

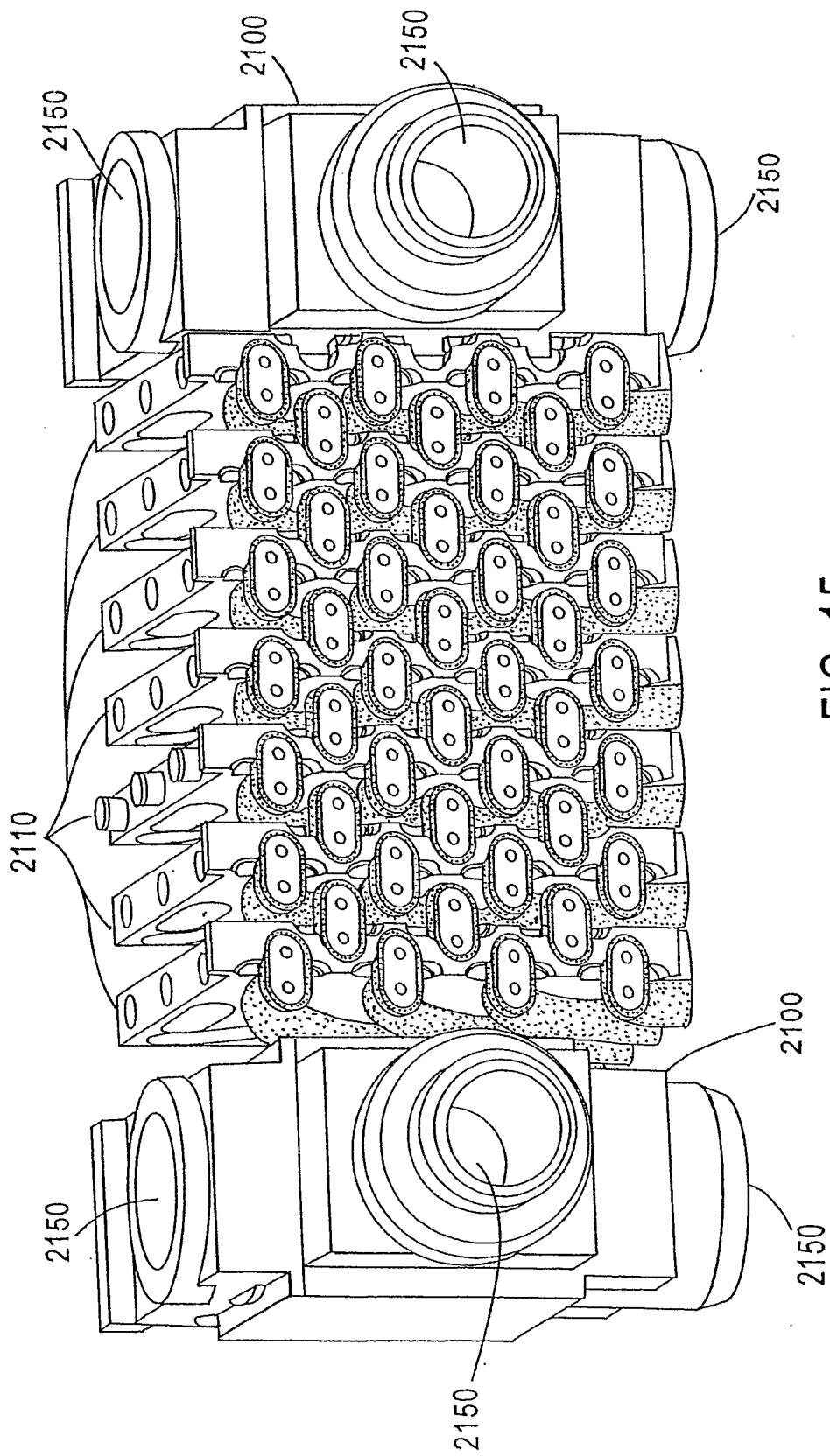


FIG. 15

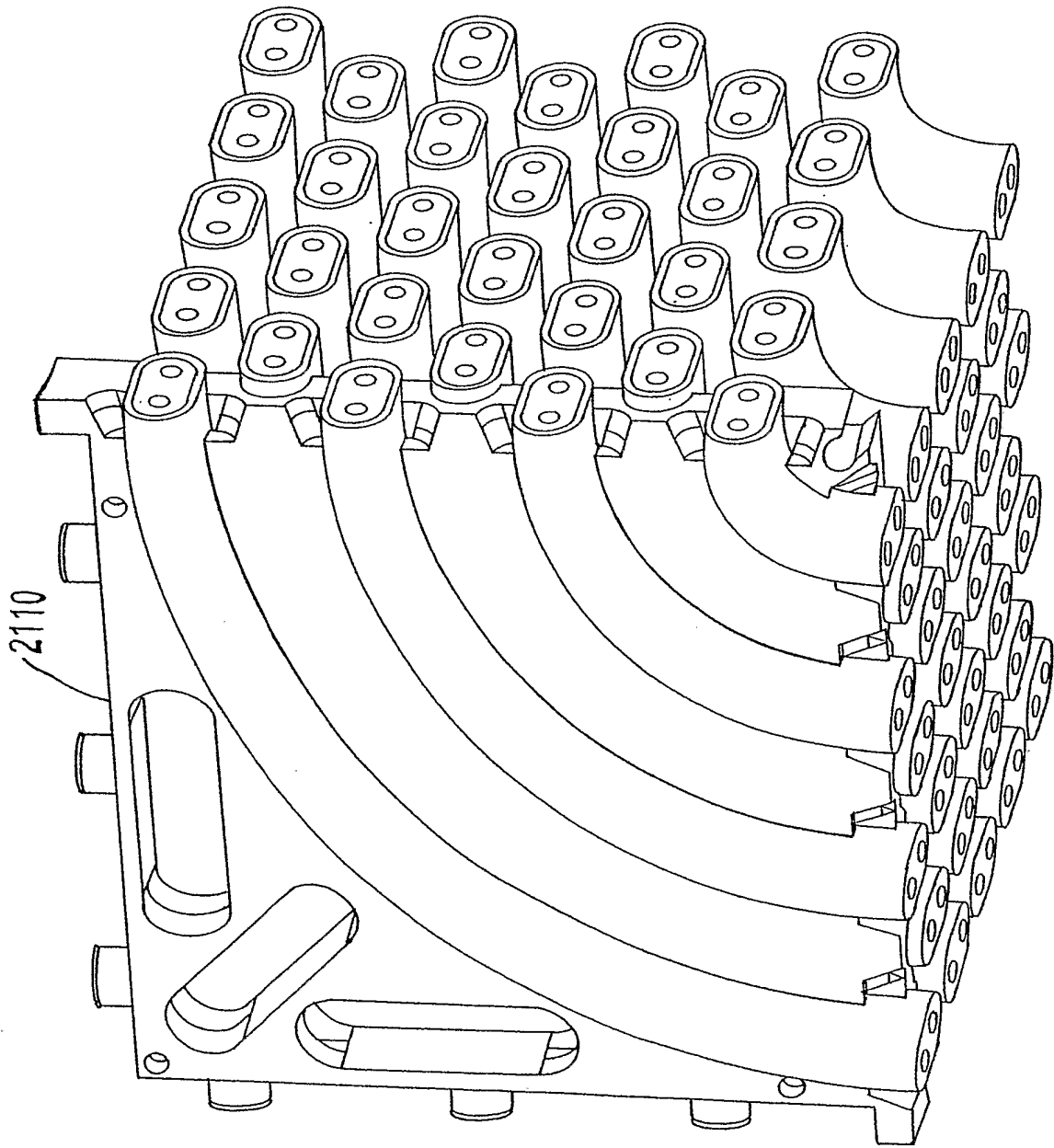


FIG. 16

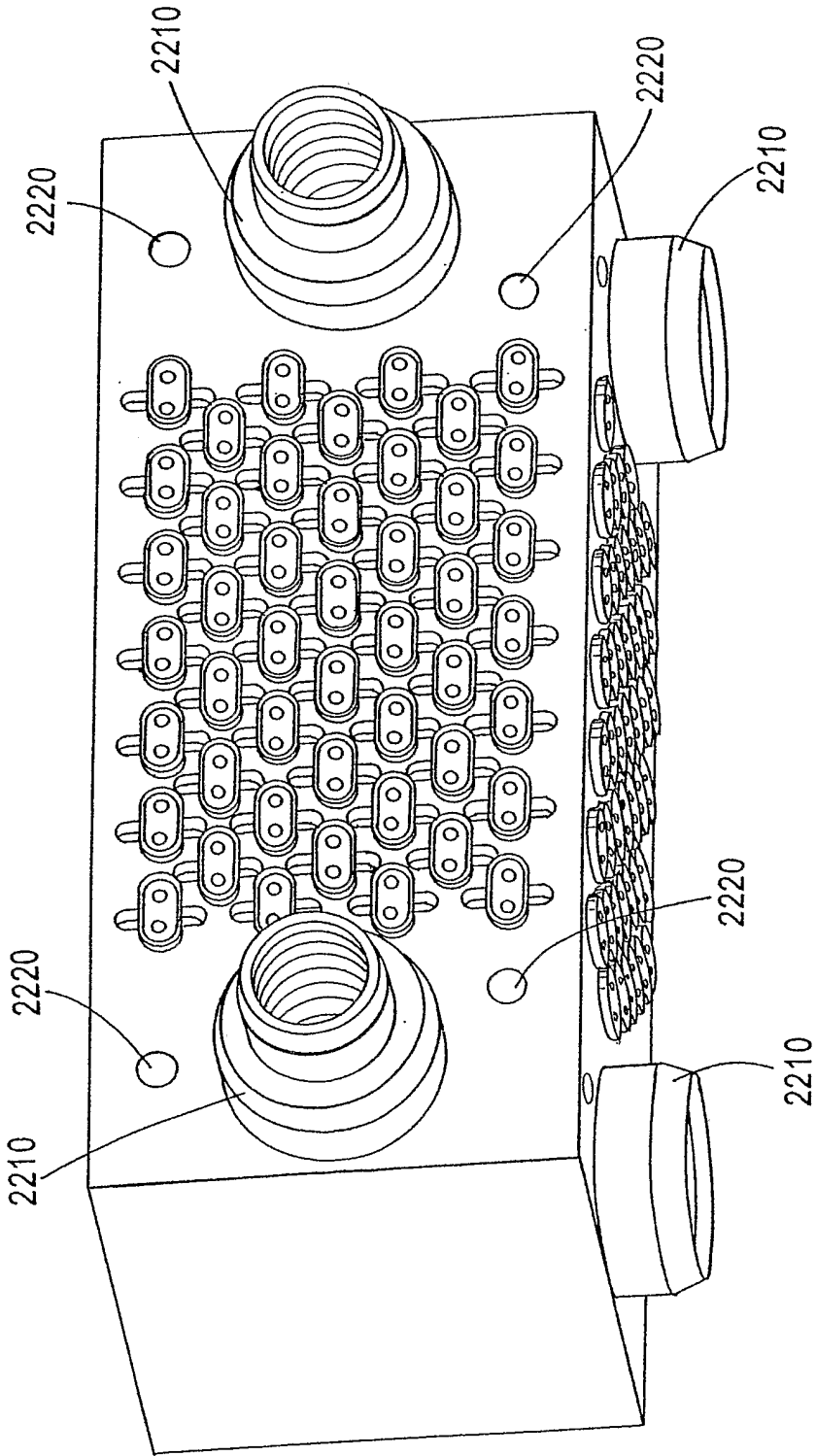


FIG. 17

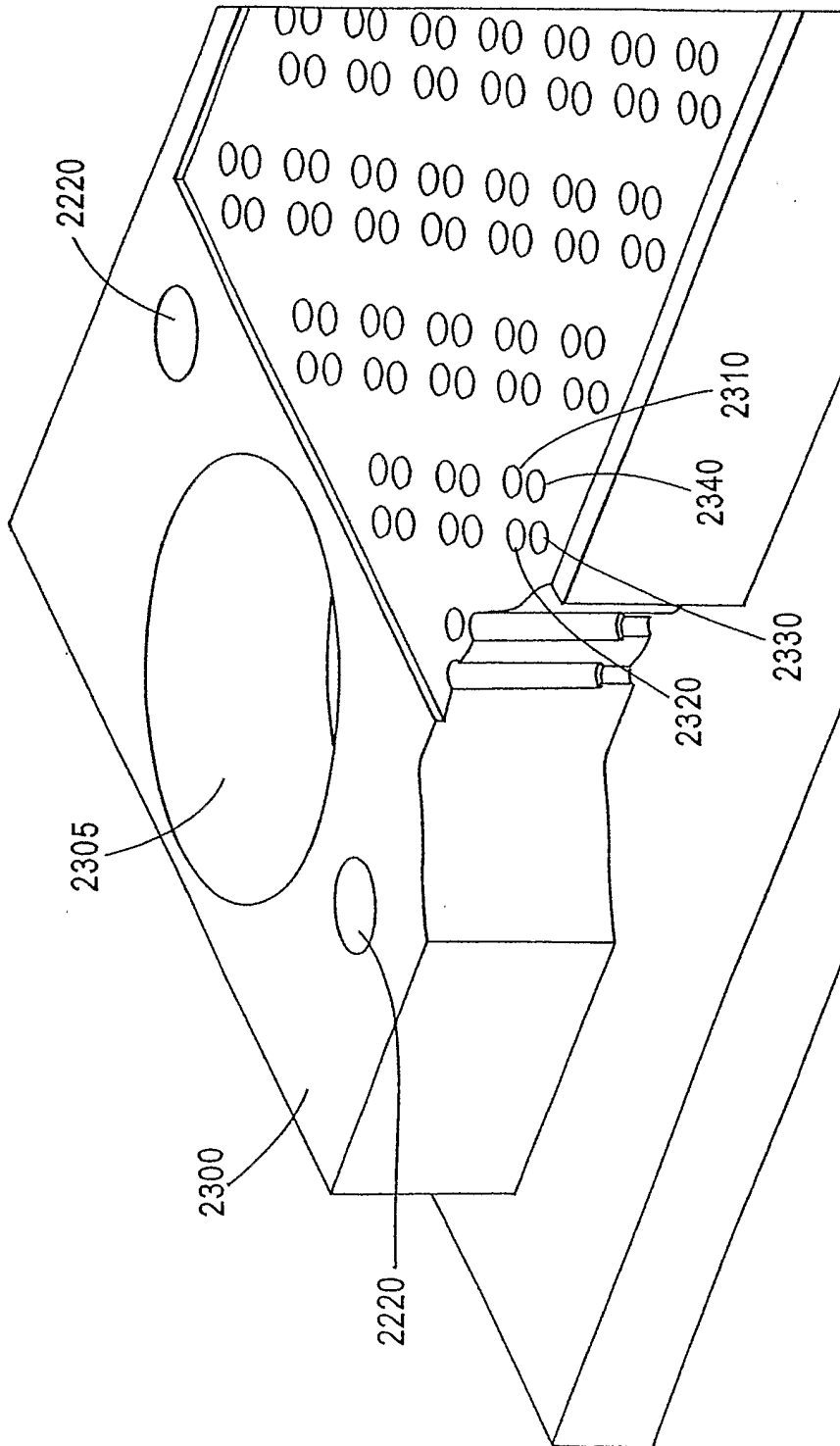


FIG. 18

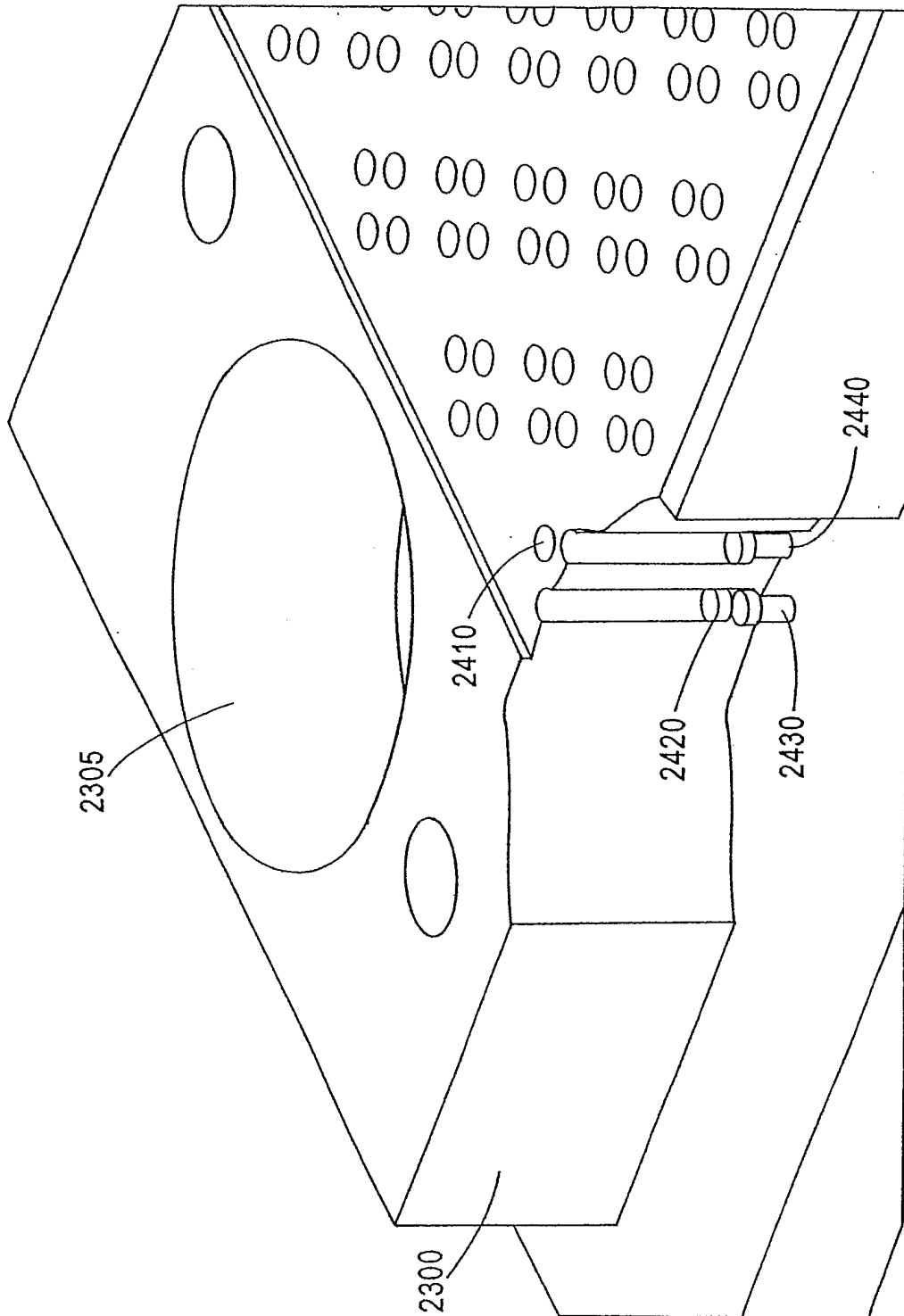


FIG. 19

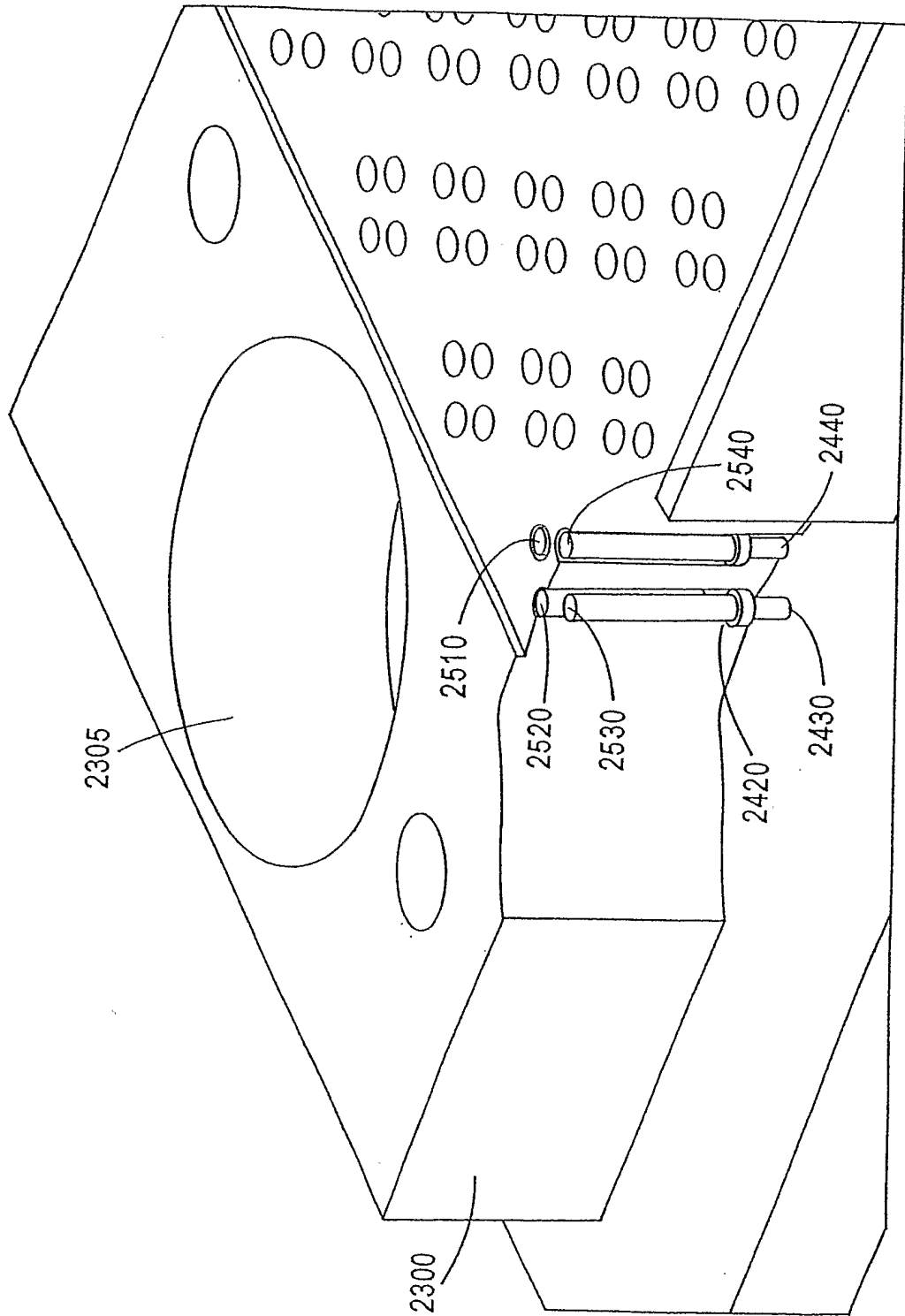


FIG. 20

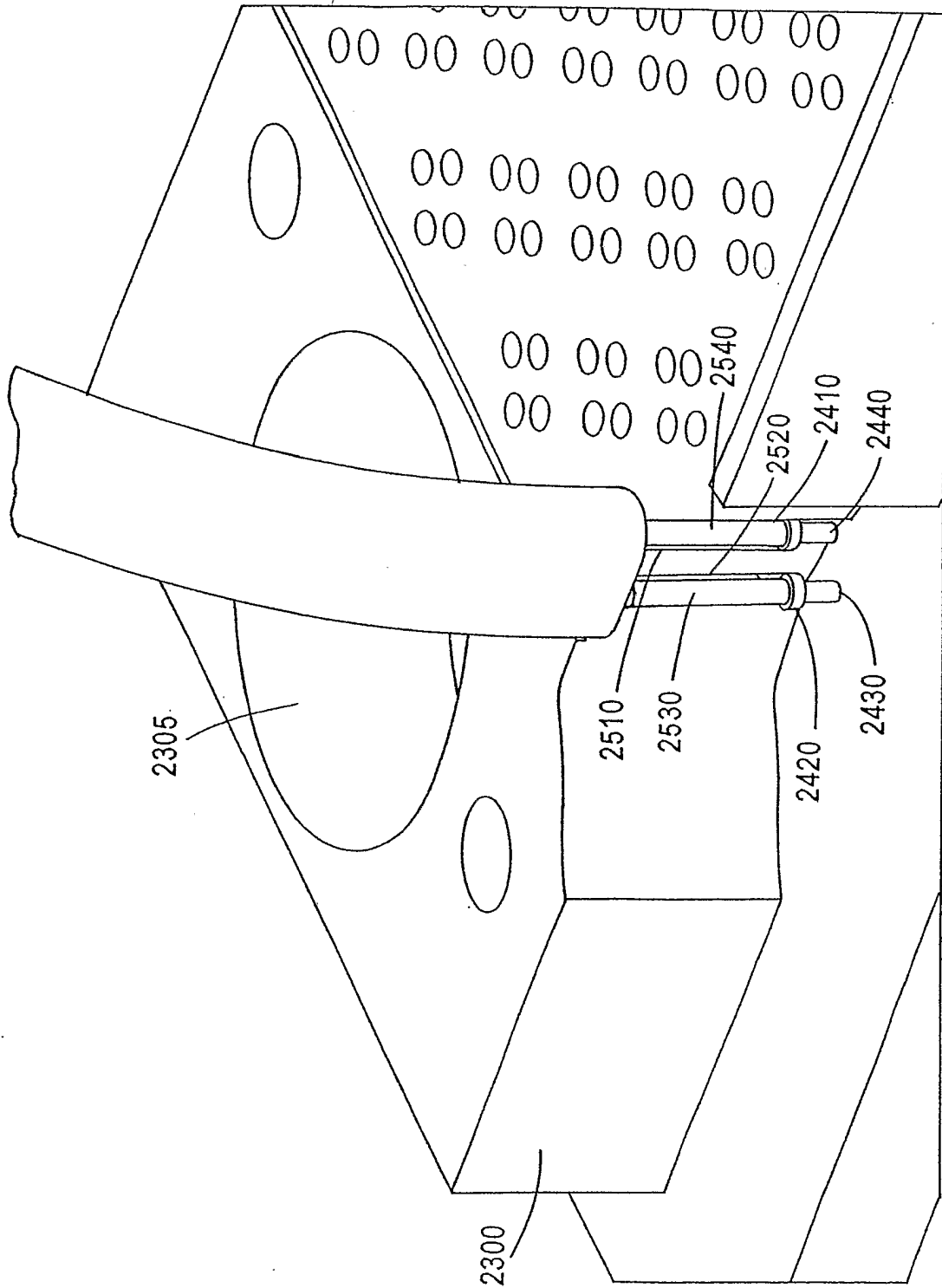


FIG. 21

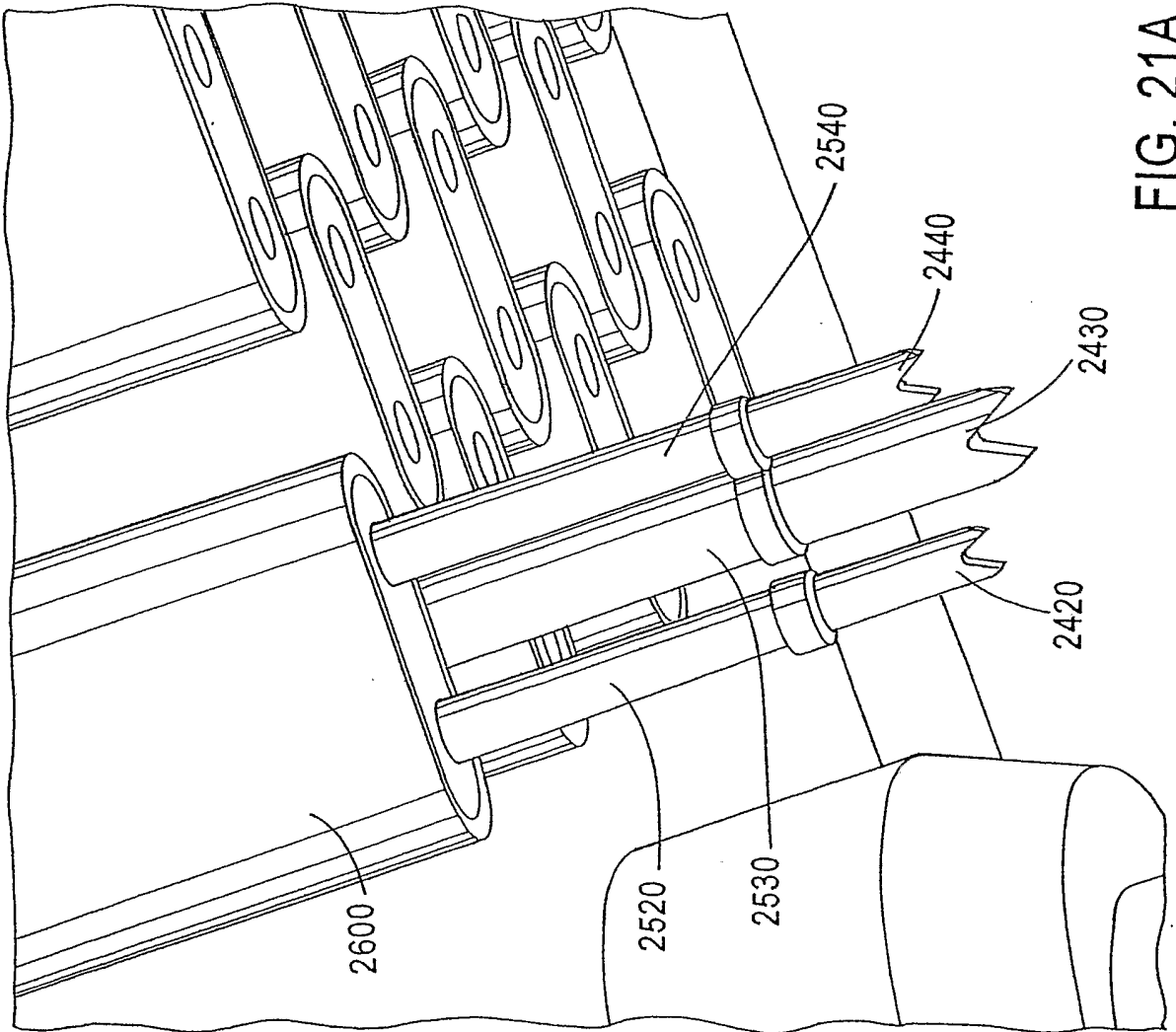


FIG. 21A

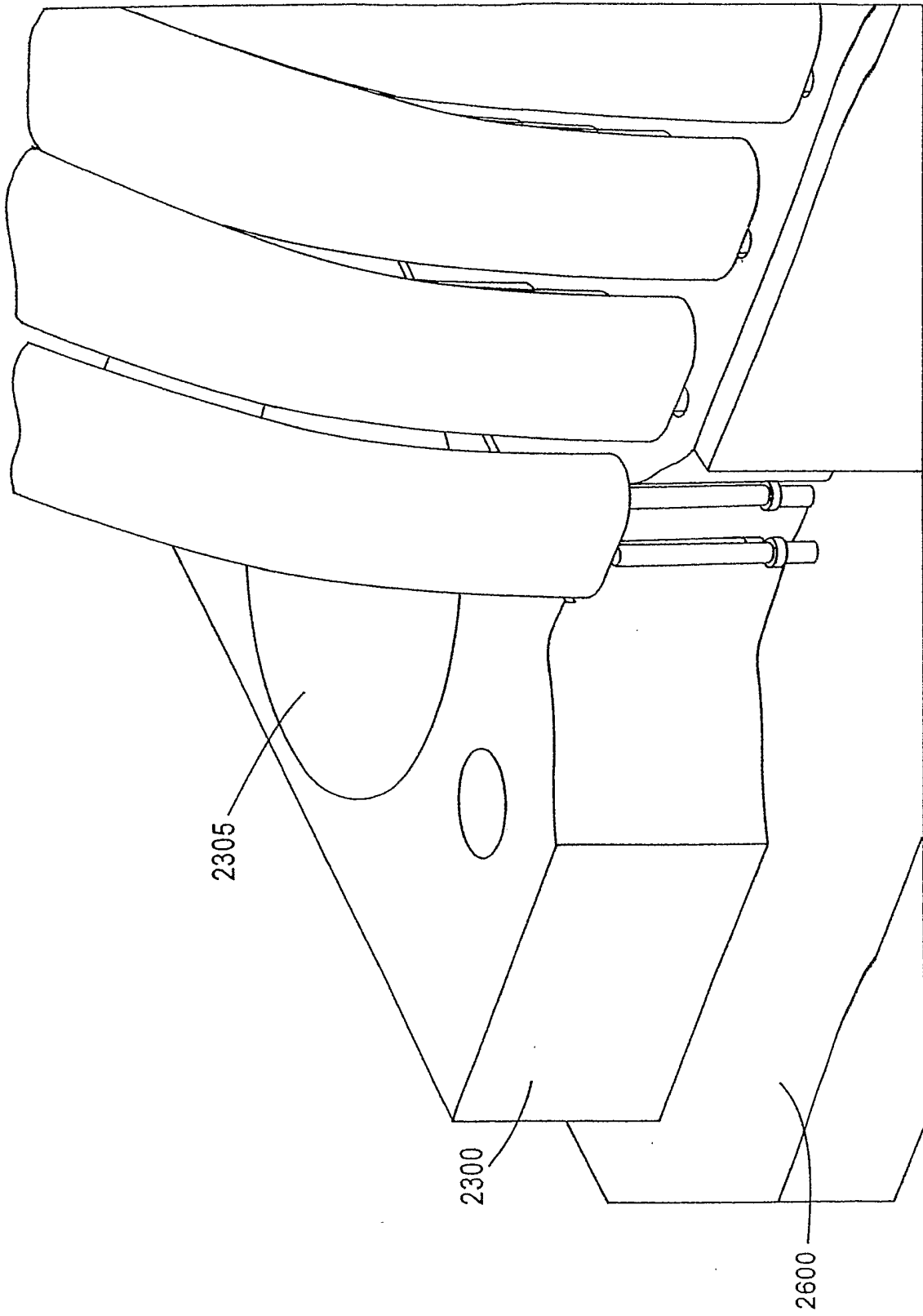


FIG. 22

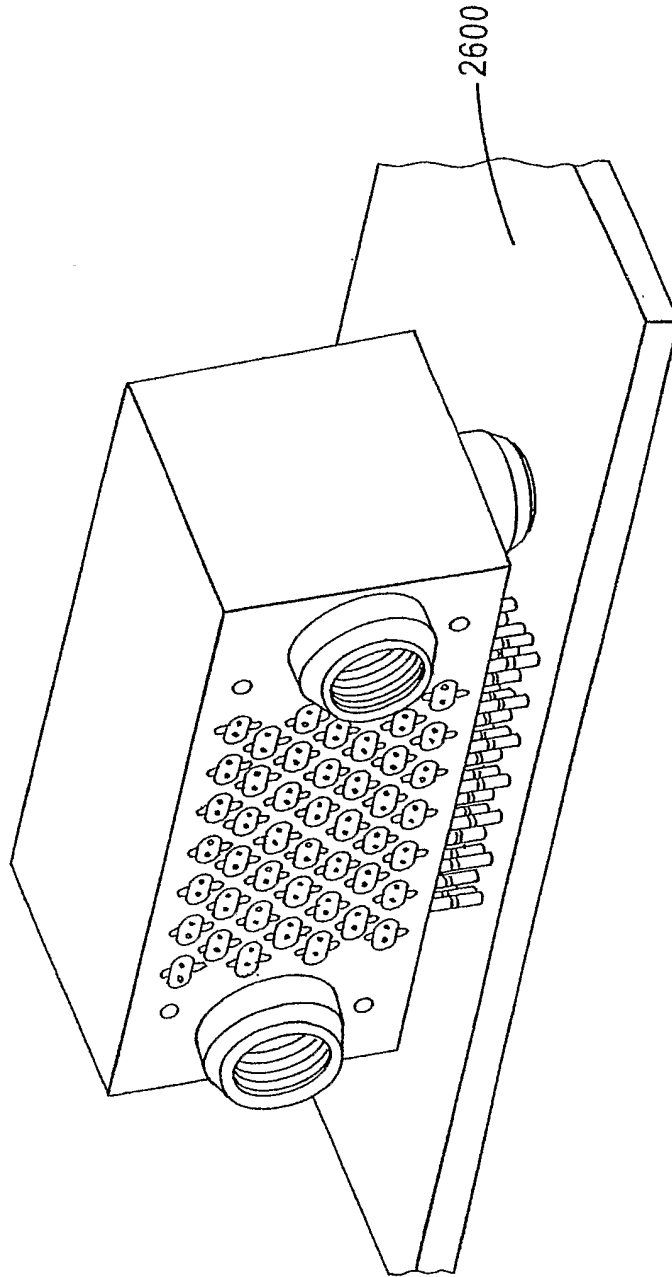


FIG. 23

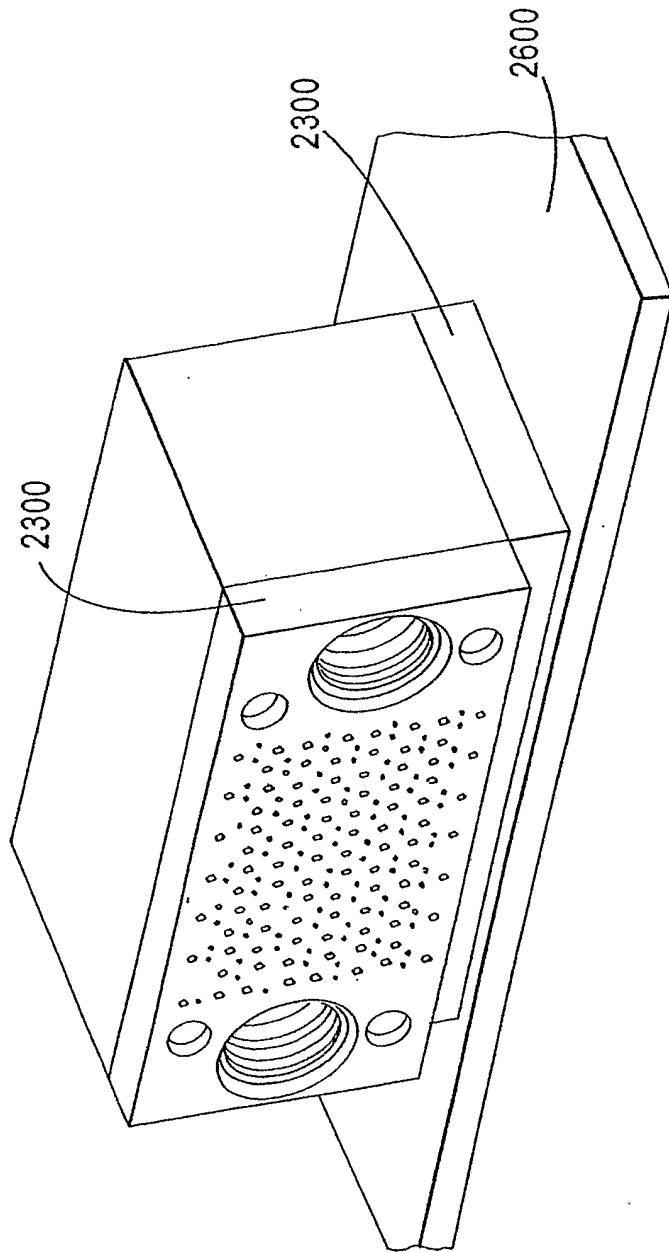


FIG. 24

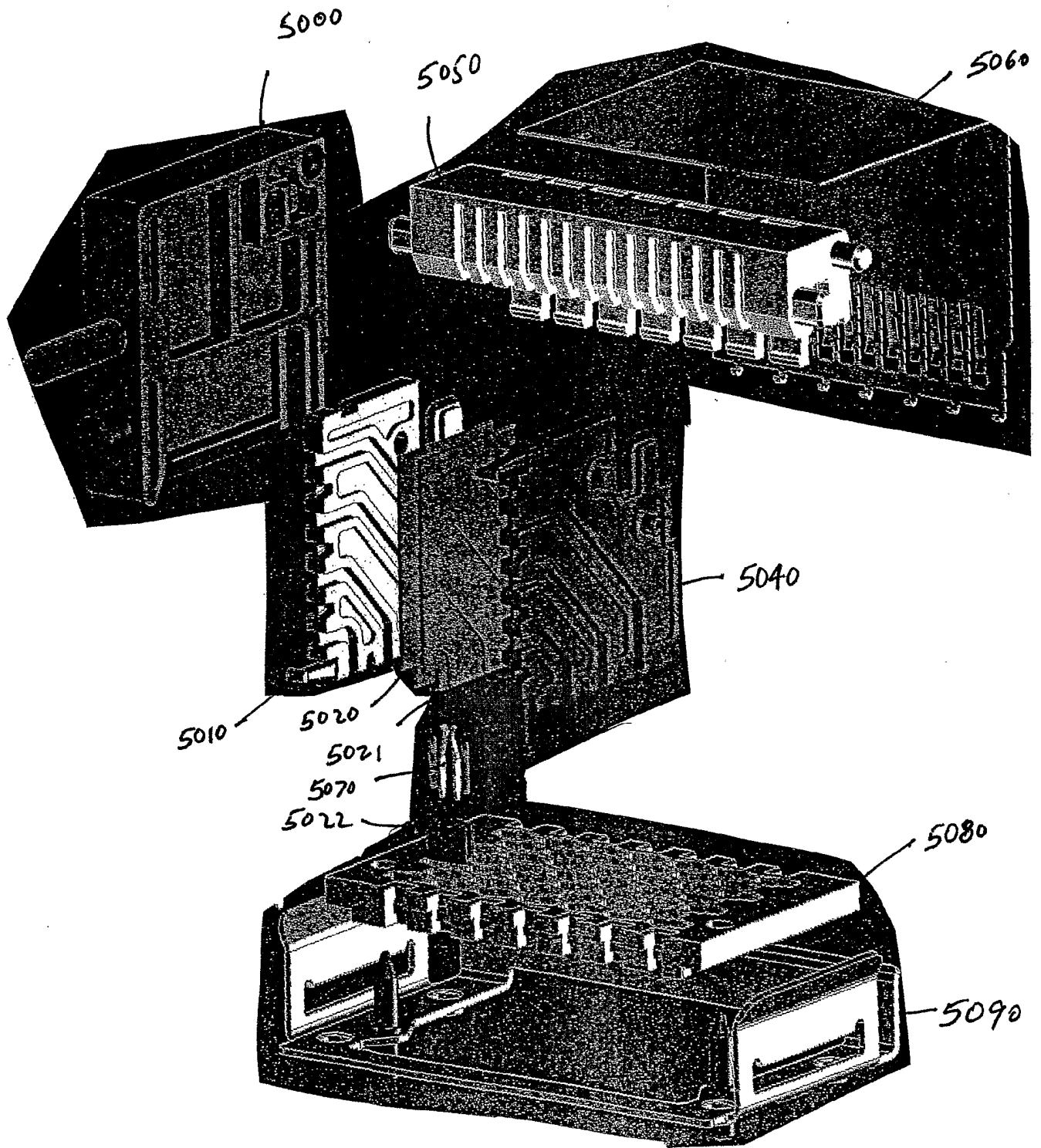


FIG. 25
27/52

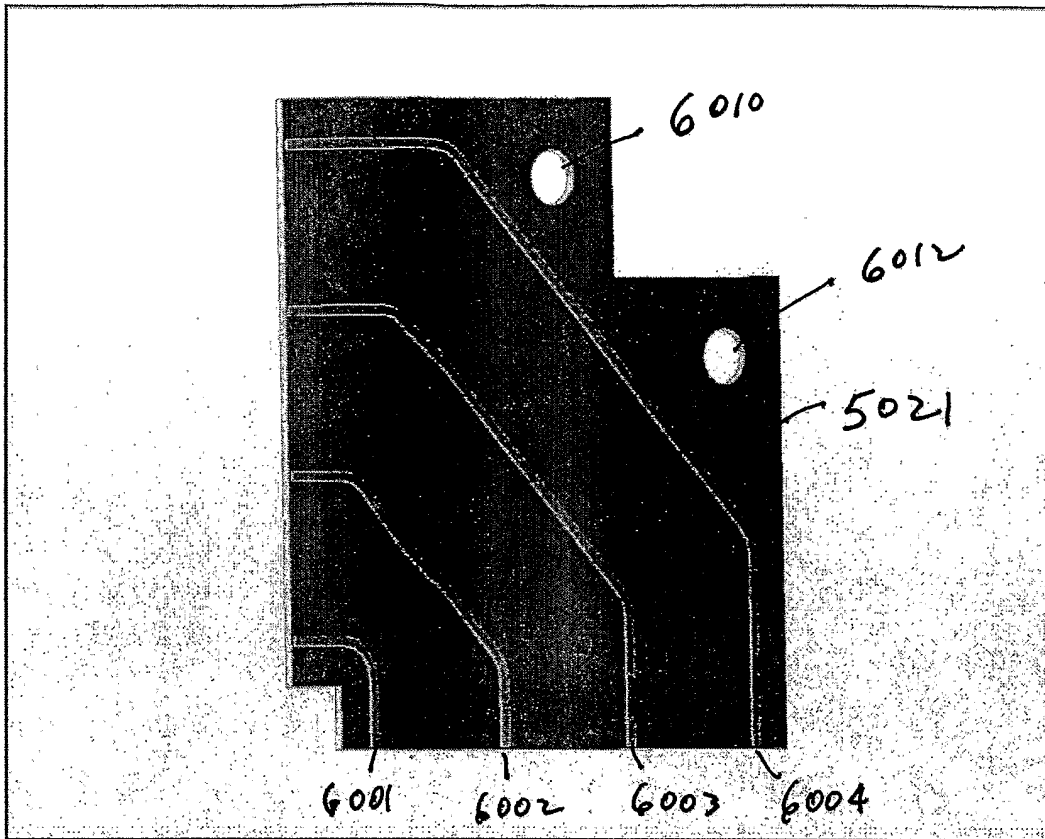


FIG. 26

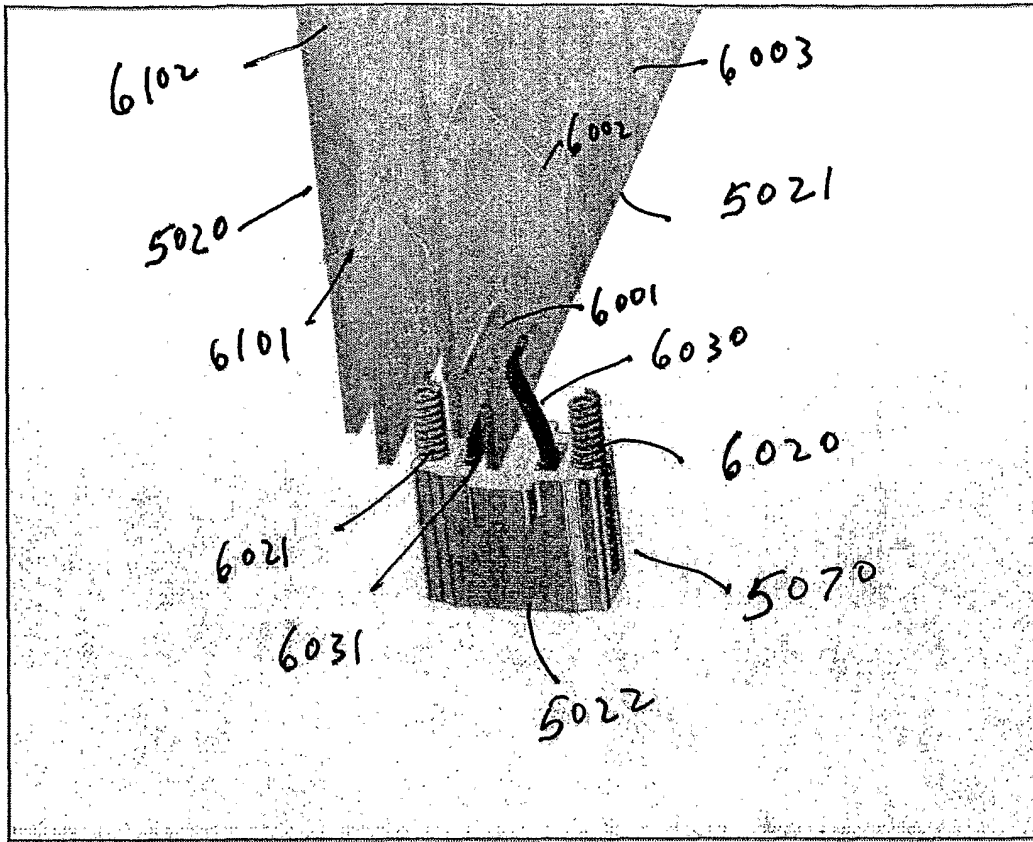
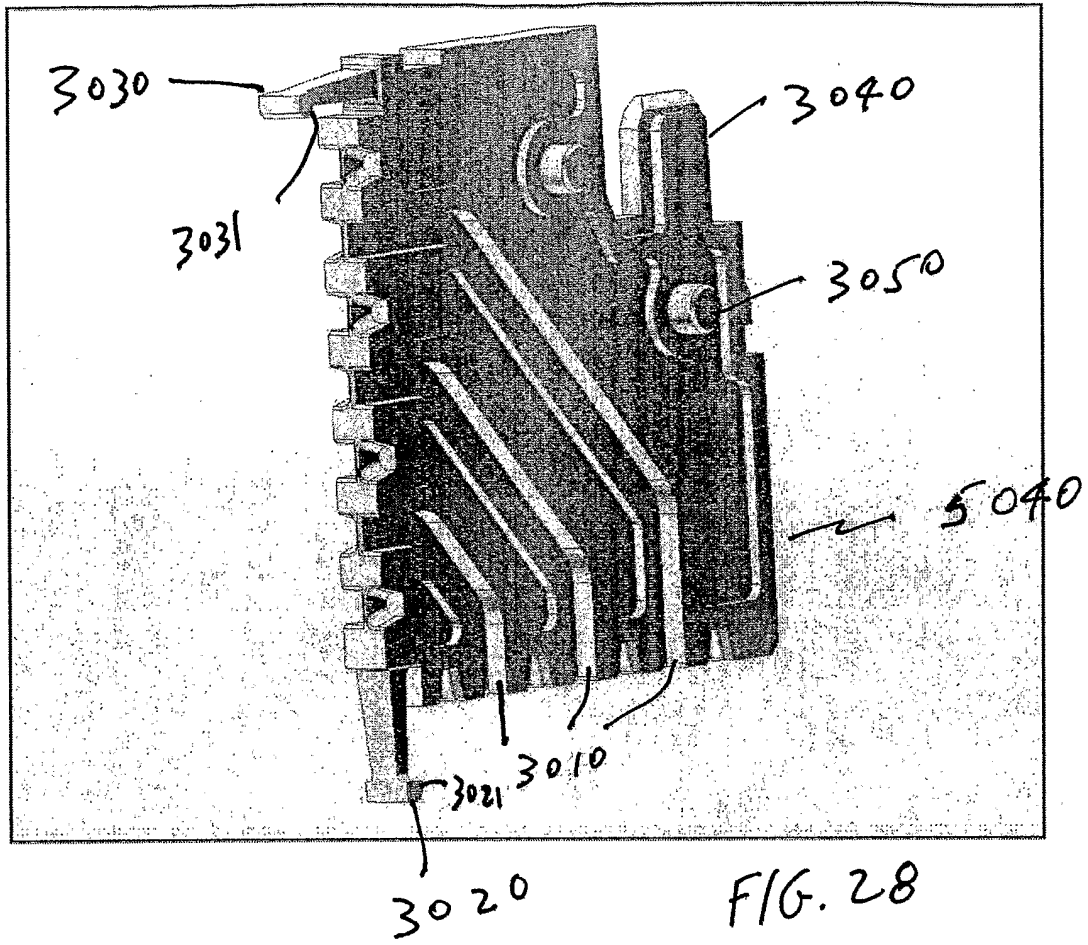


FIG. 27



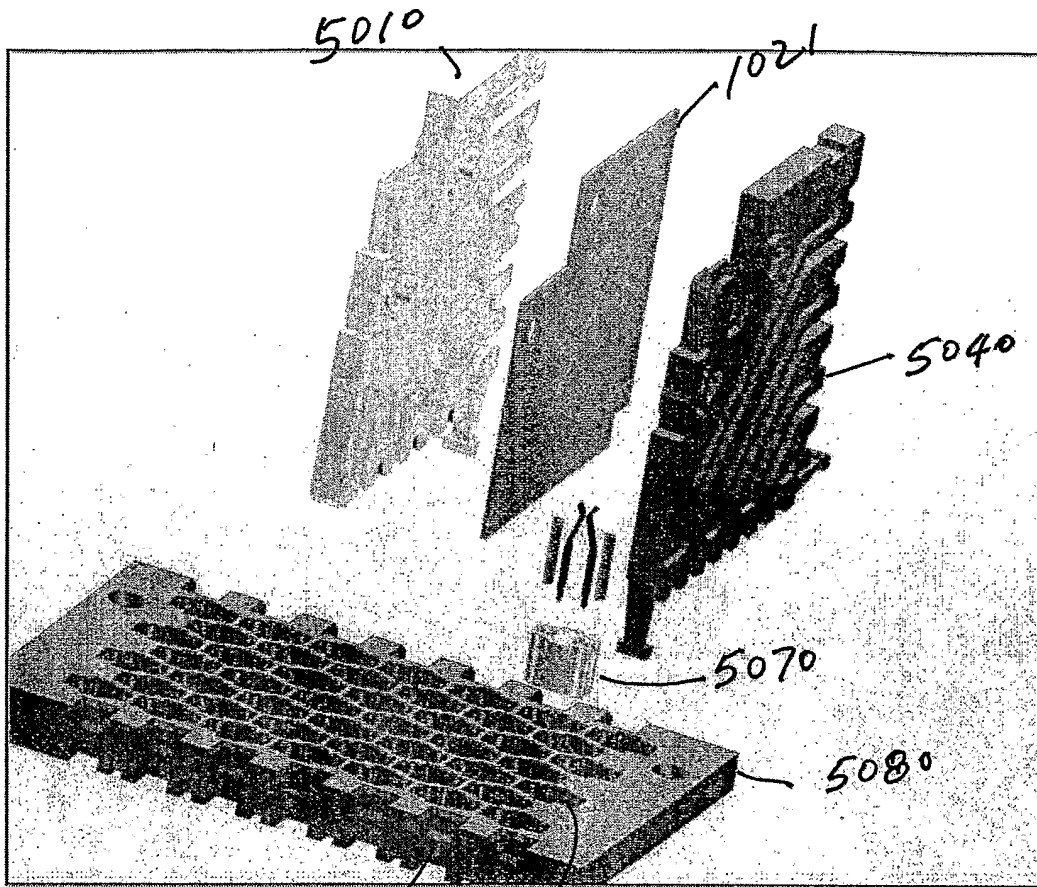


FIG. 29

4010

4020

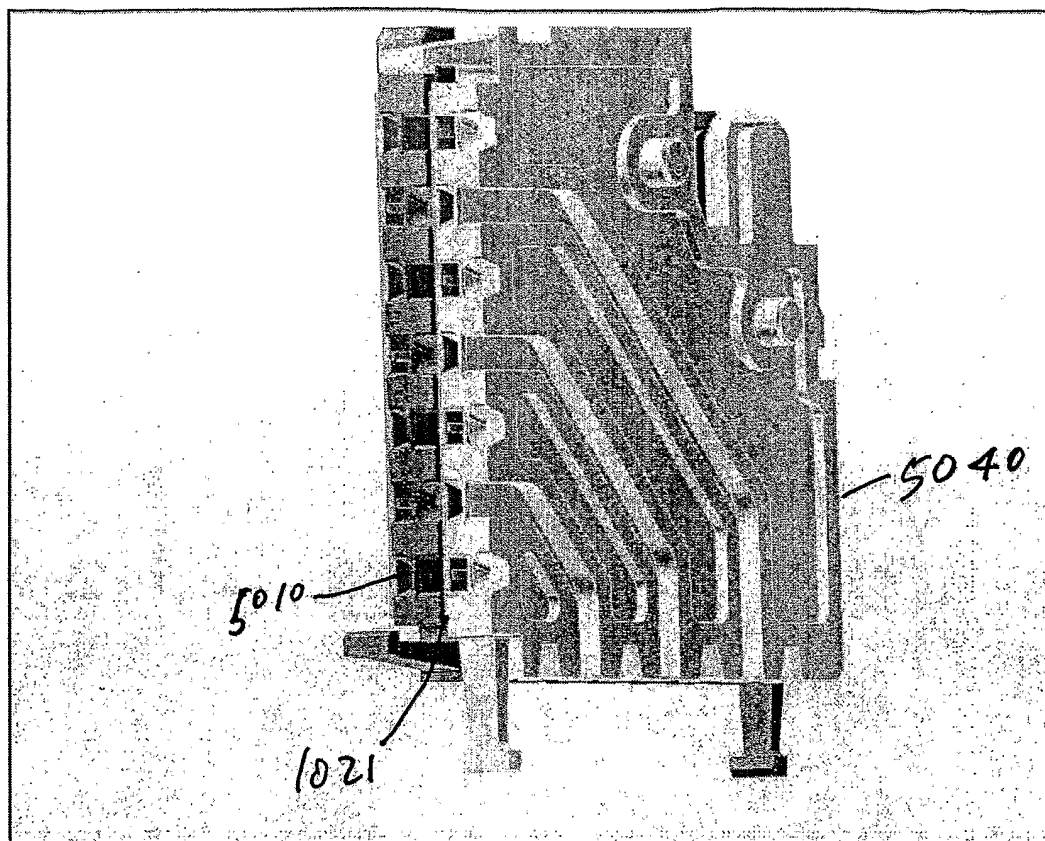


FIG. 30

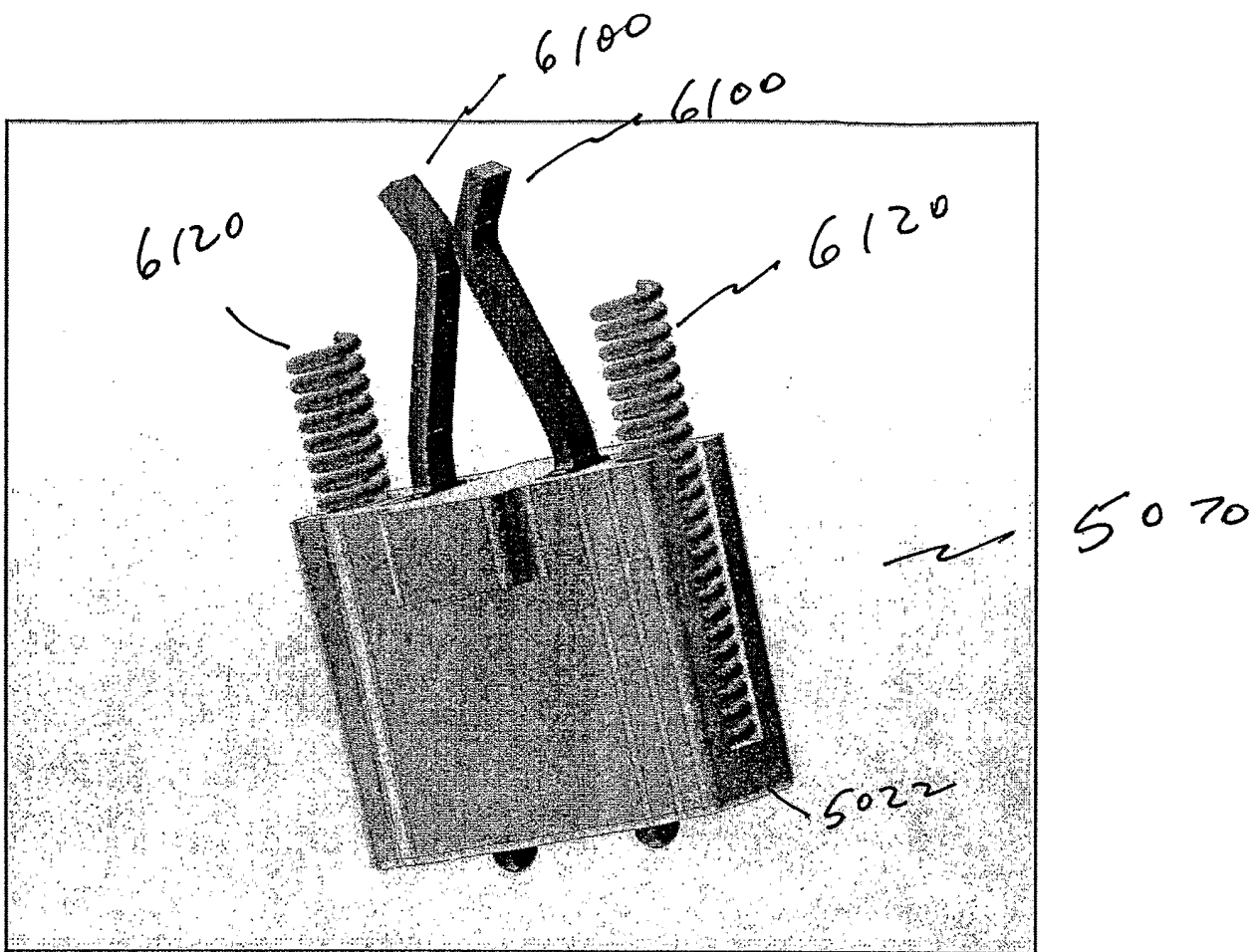


FIG. 31

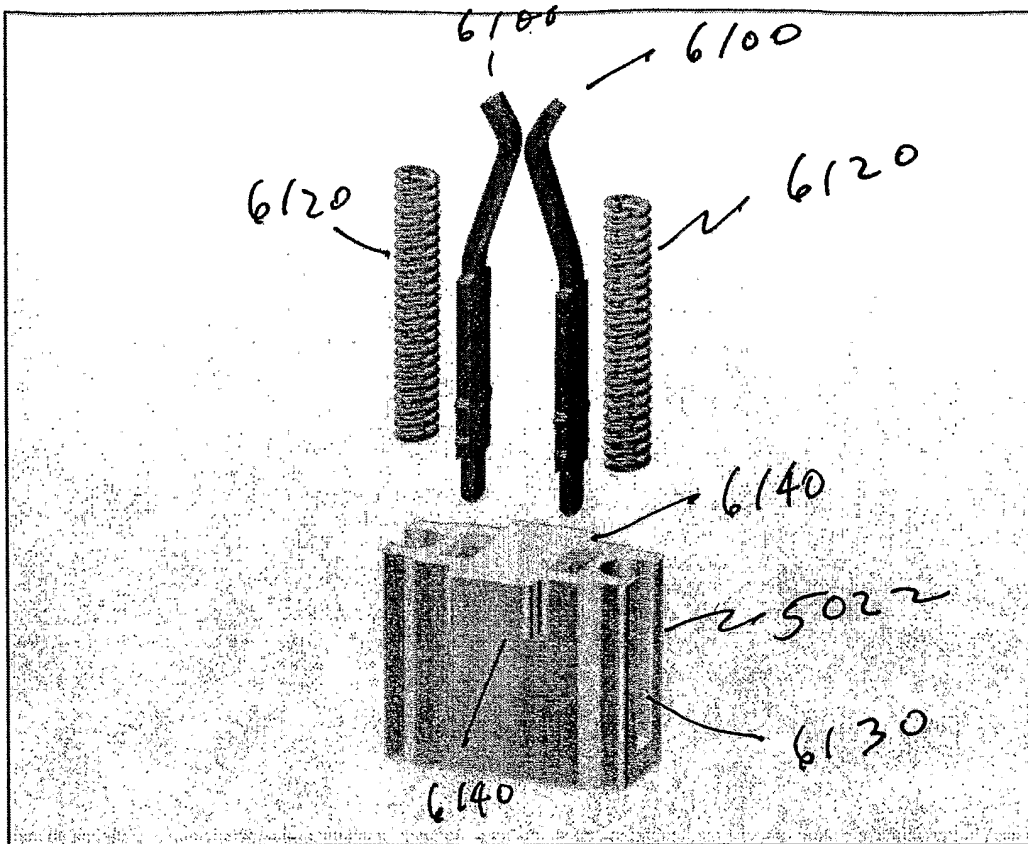


FIG. 32

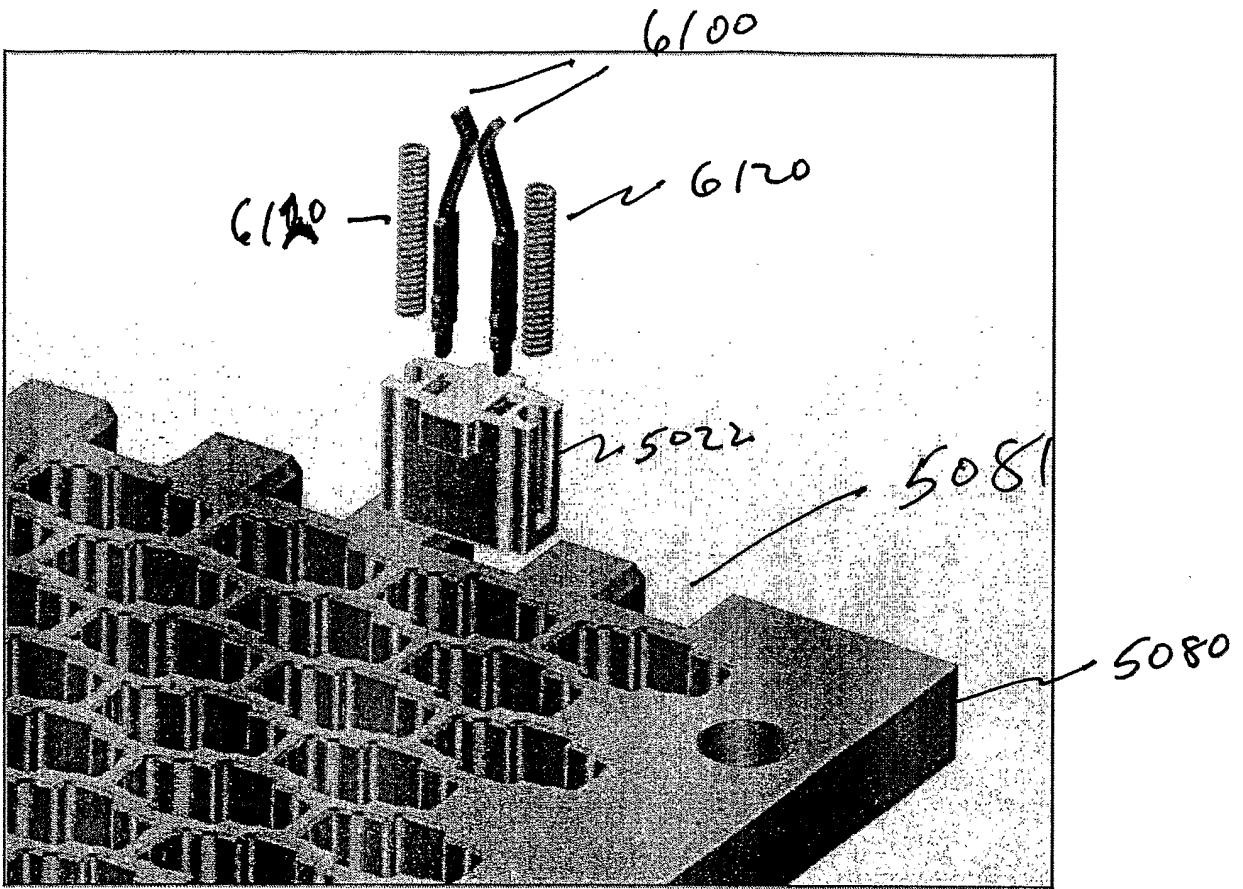


FIG. 33

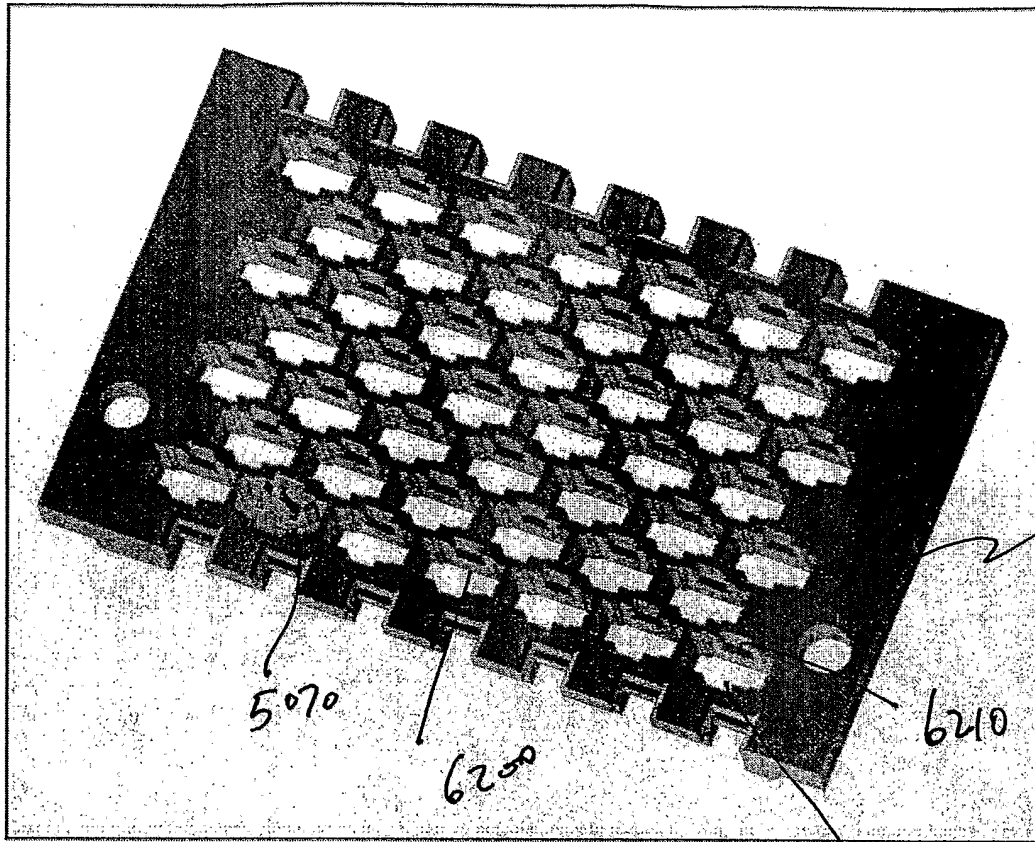
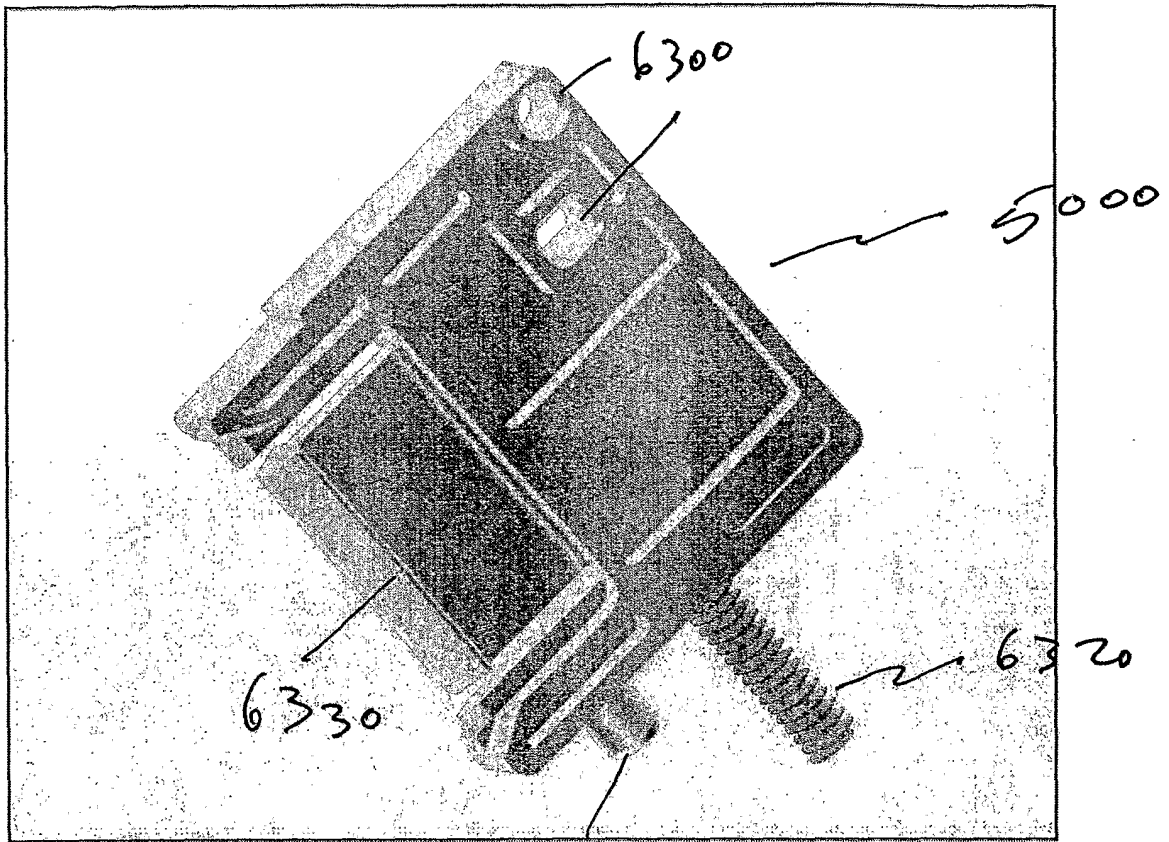


FIG. 34

6210



6310 FIG. 35

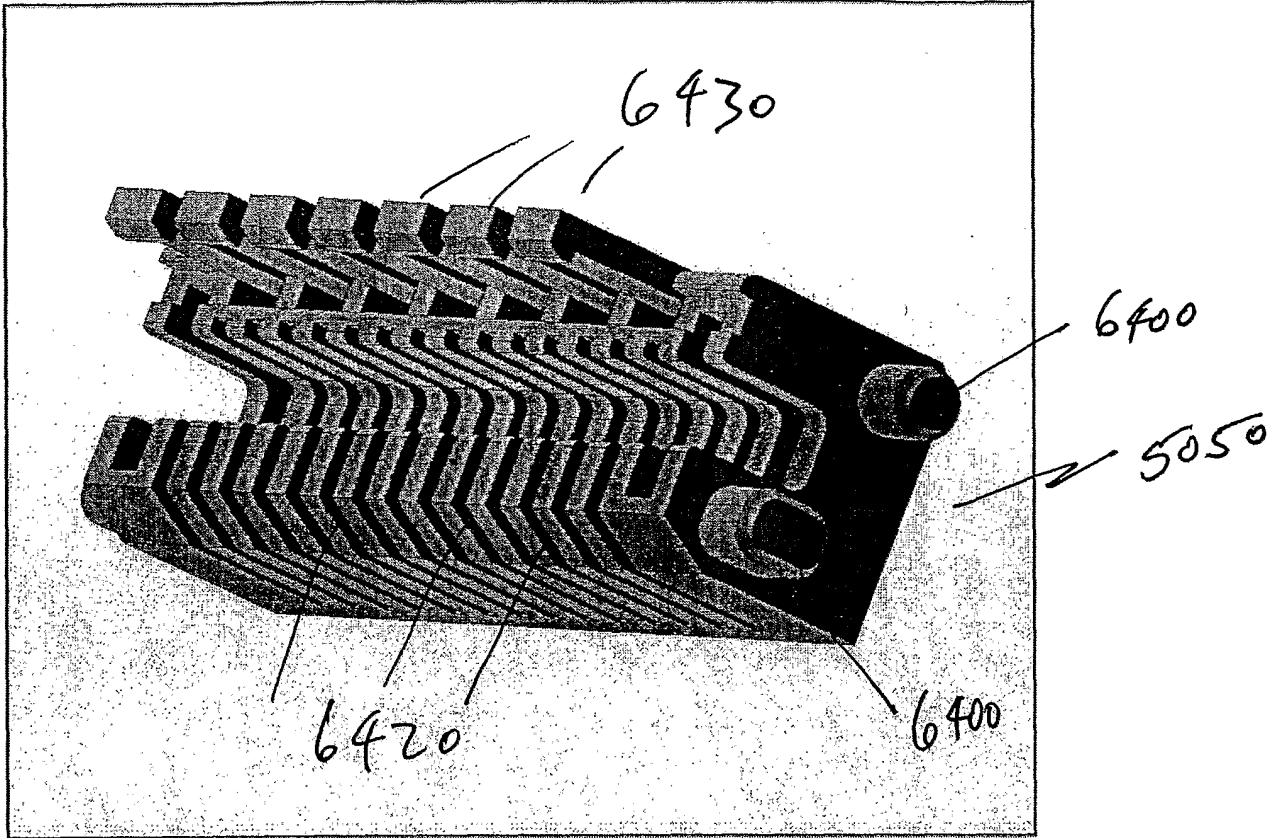


FIG. 36

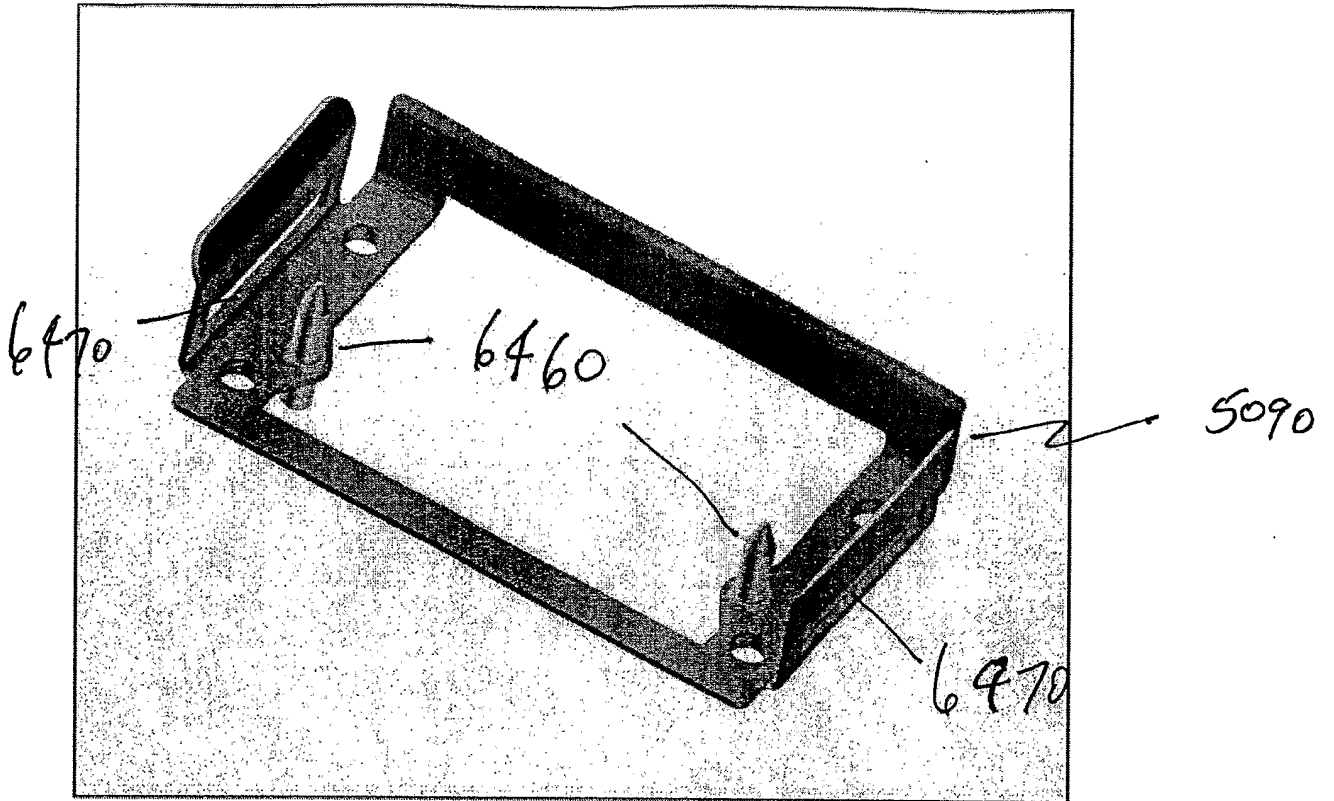


FIG. 37

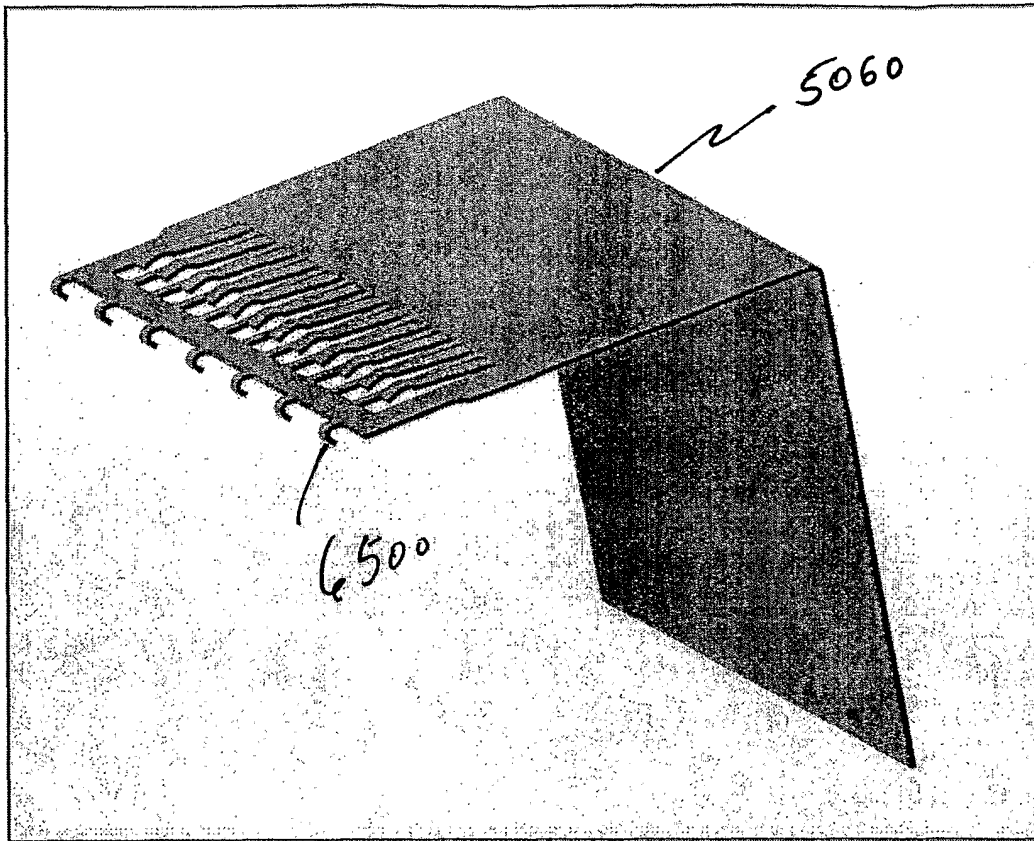


FIG. 38

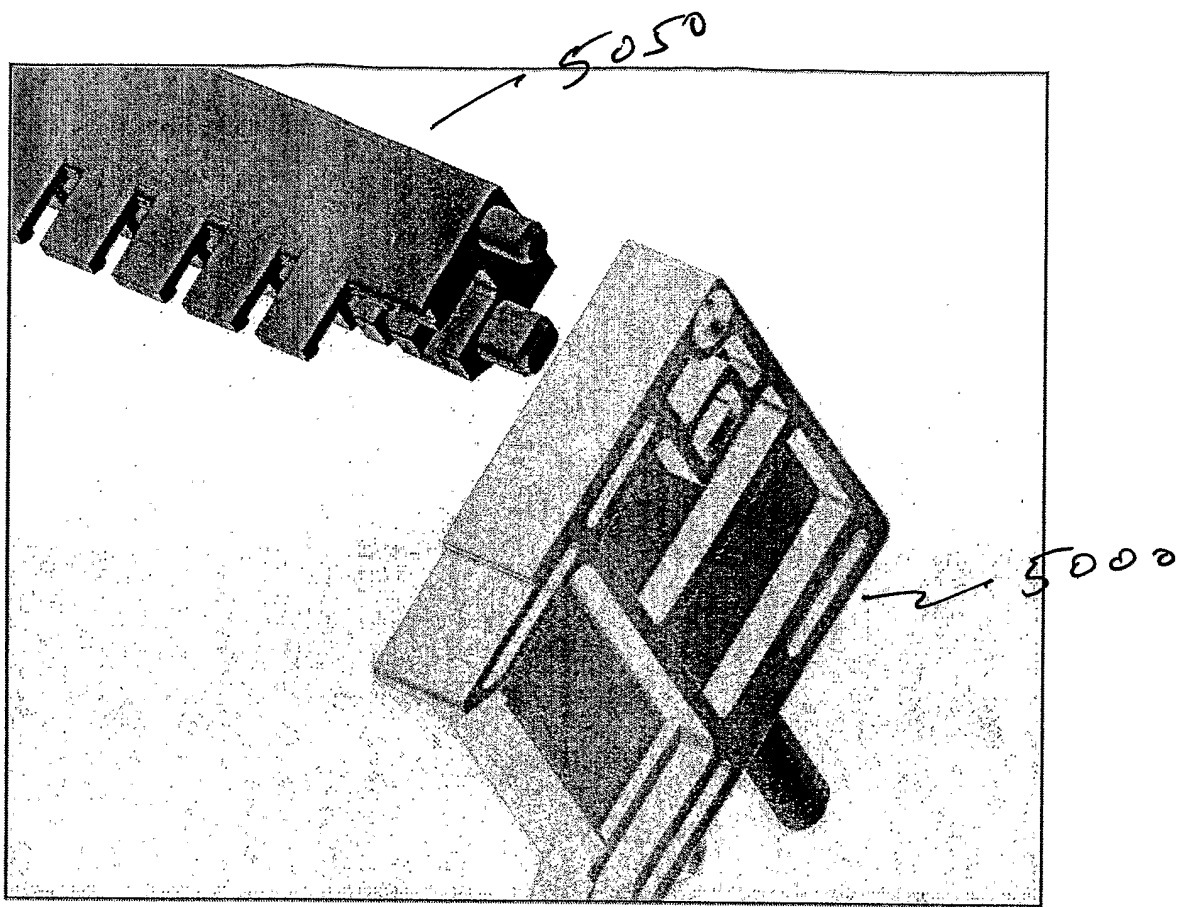


FIG. 39

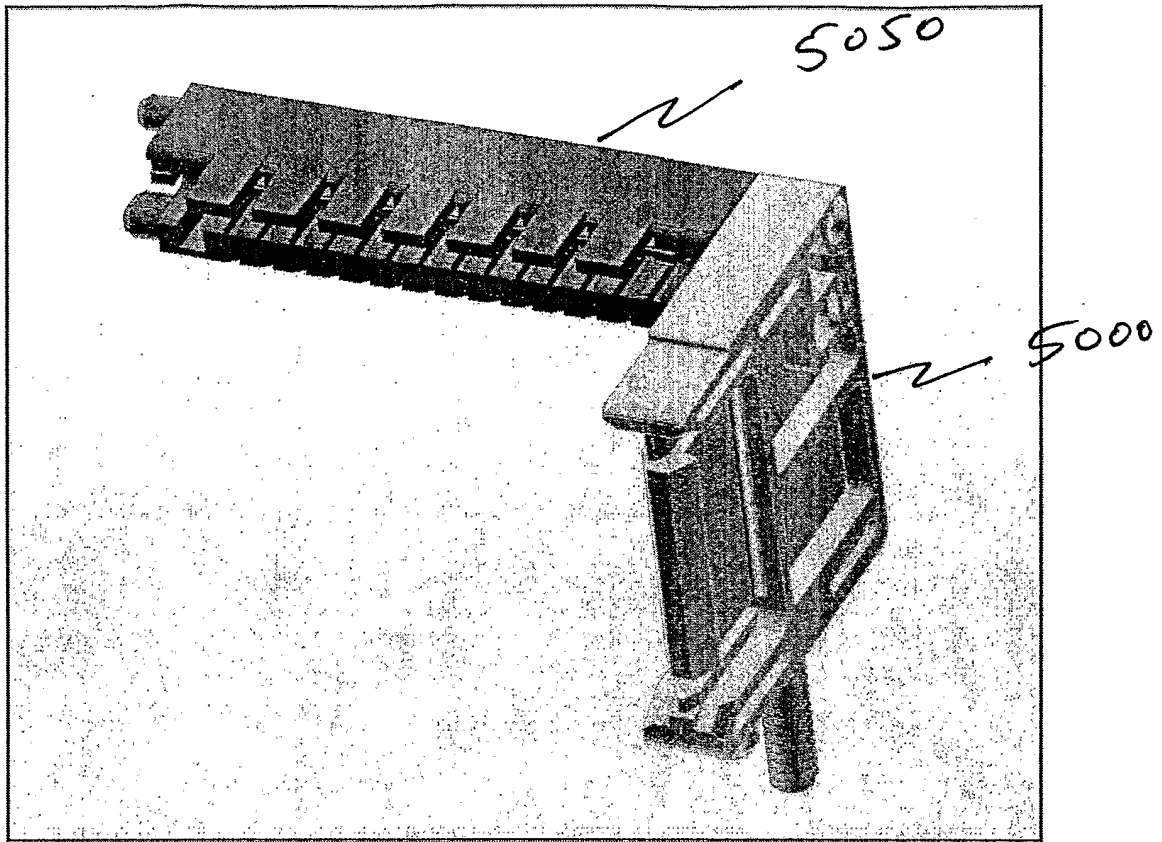


FIG. 40

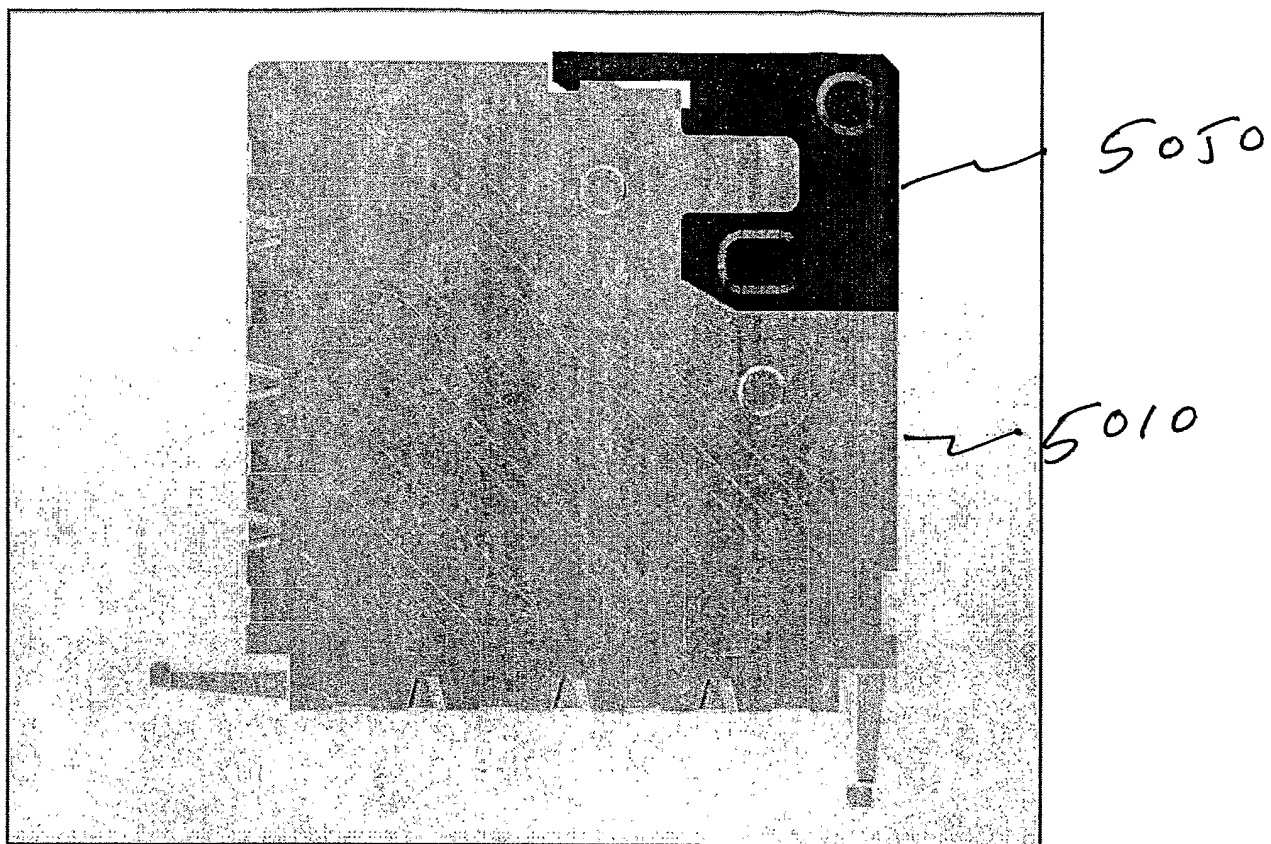


FIG. 41

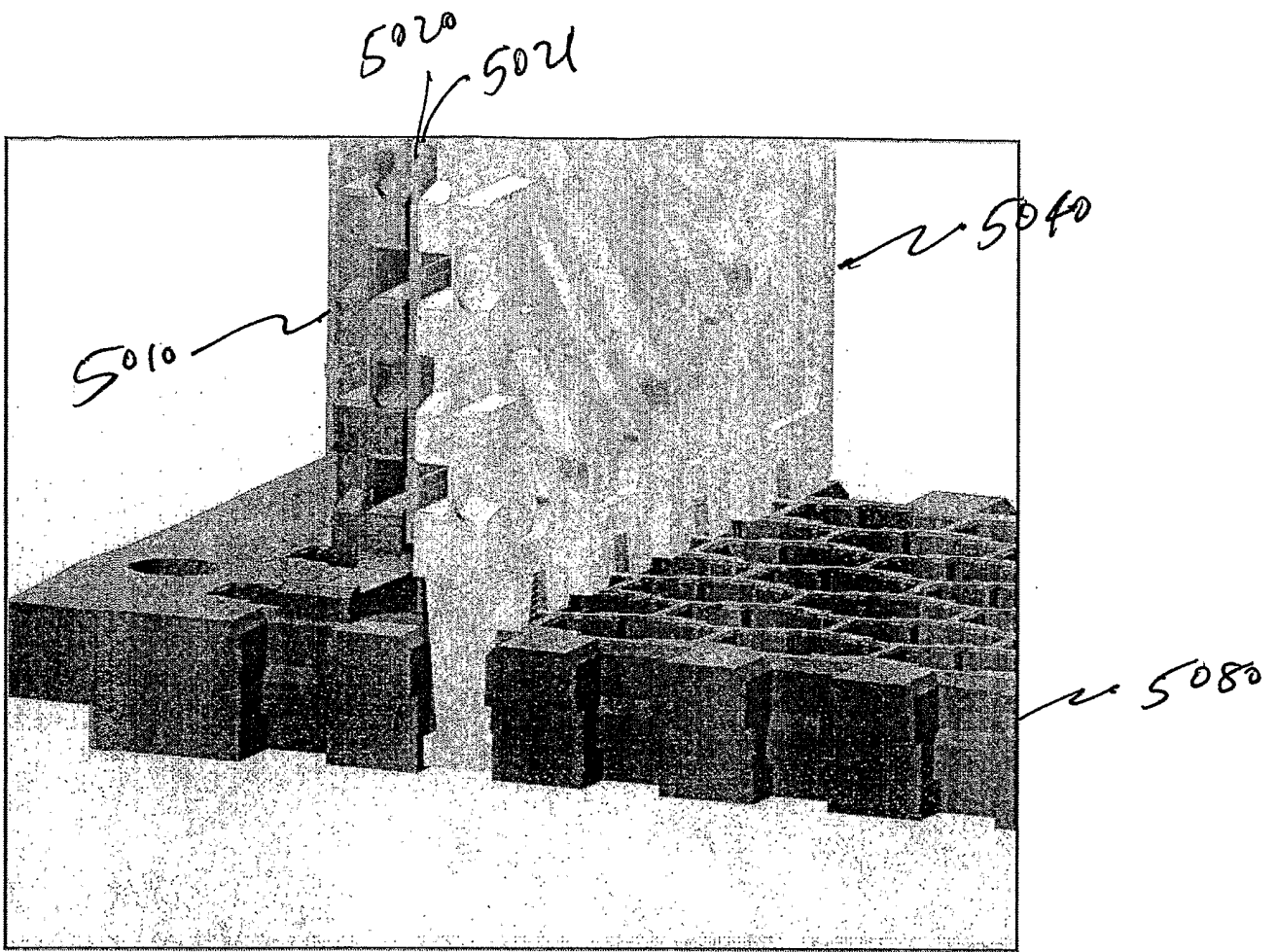


FIG. 42

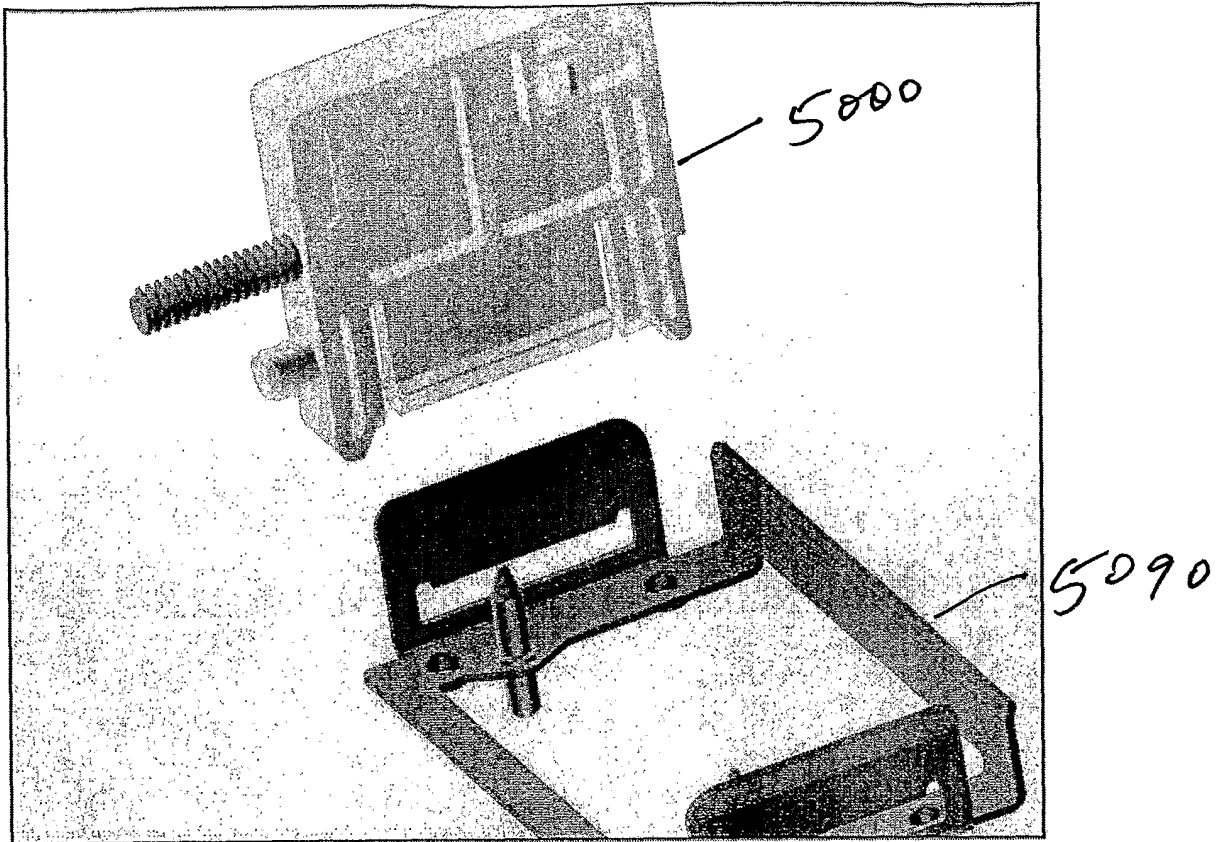


FIG. 43

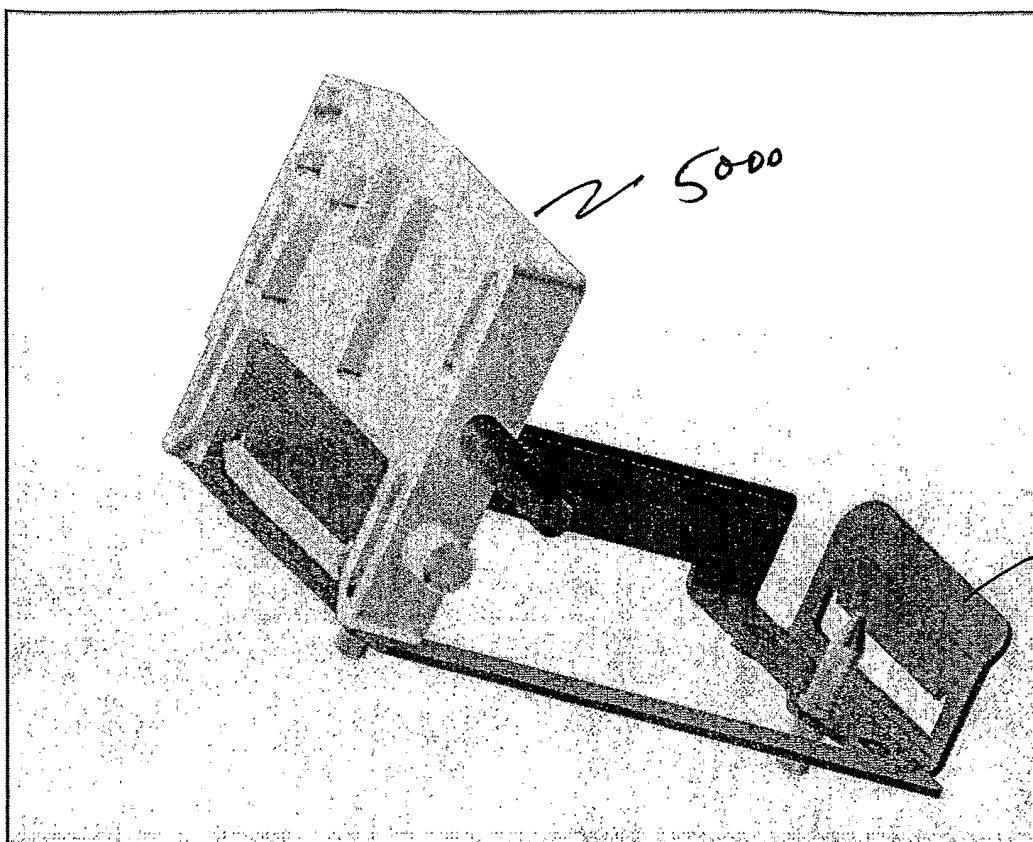
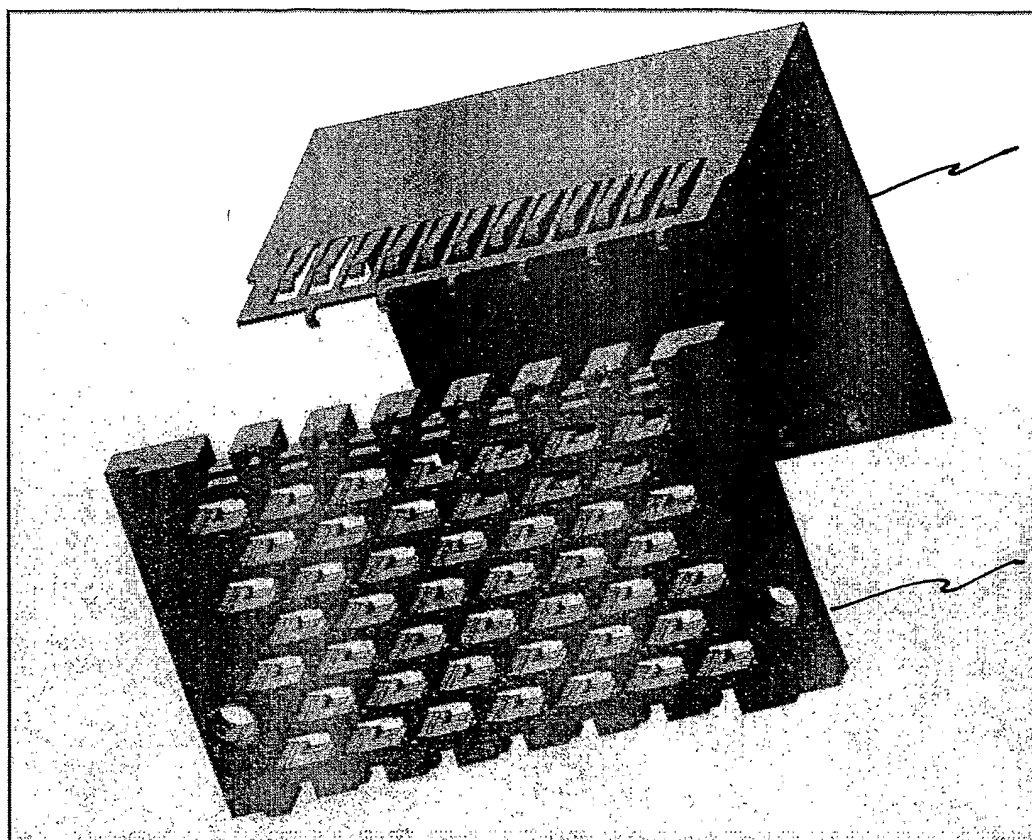


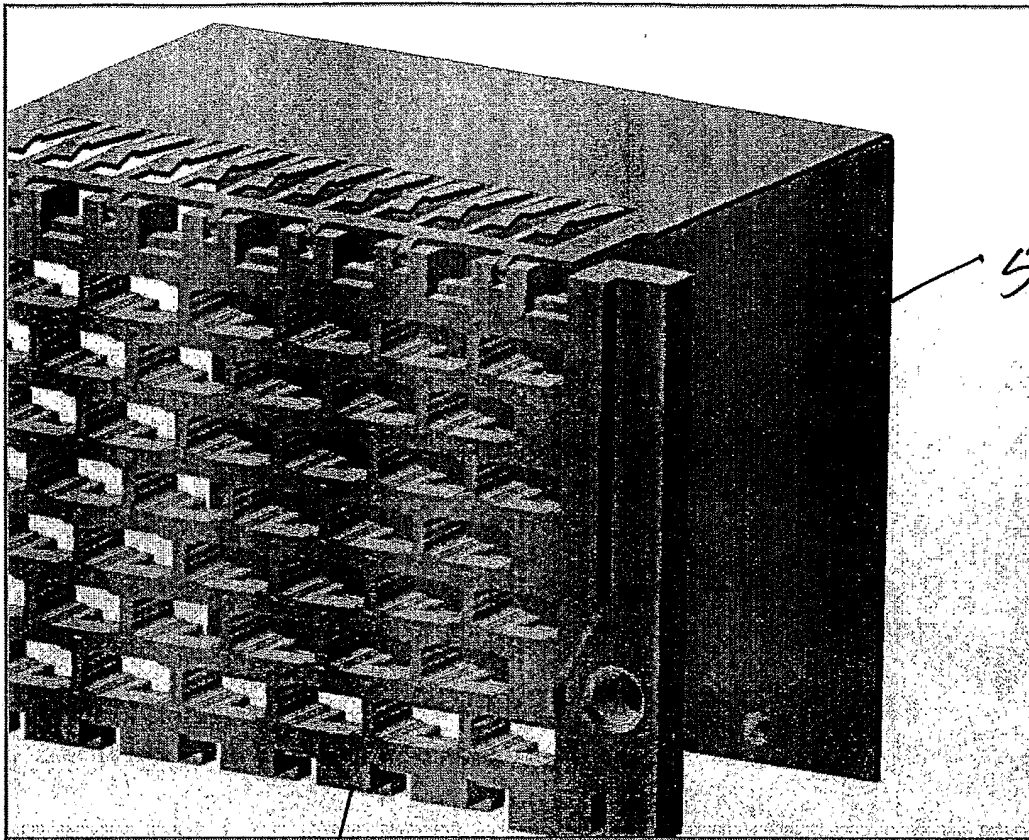
FIG. 44



5060

5080

FIG. 45



5060

FIG. 46

5080

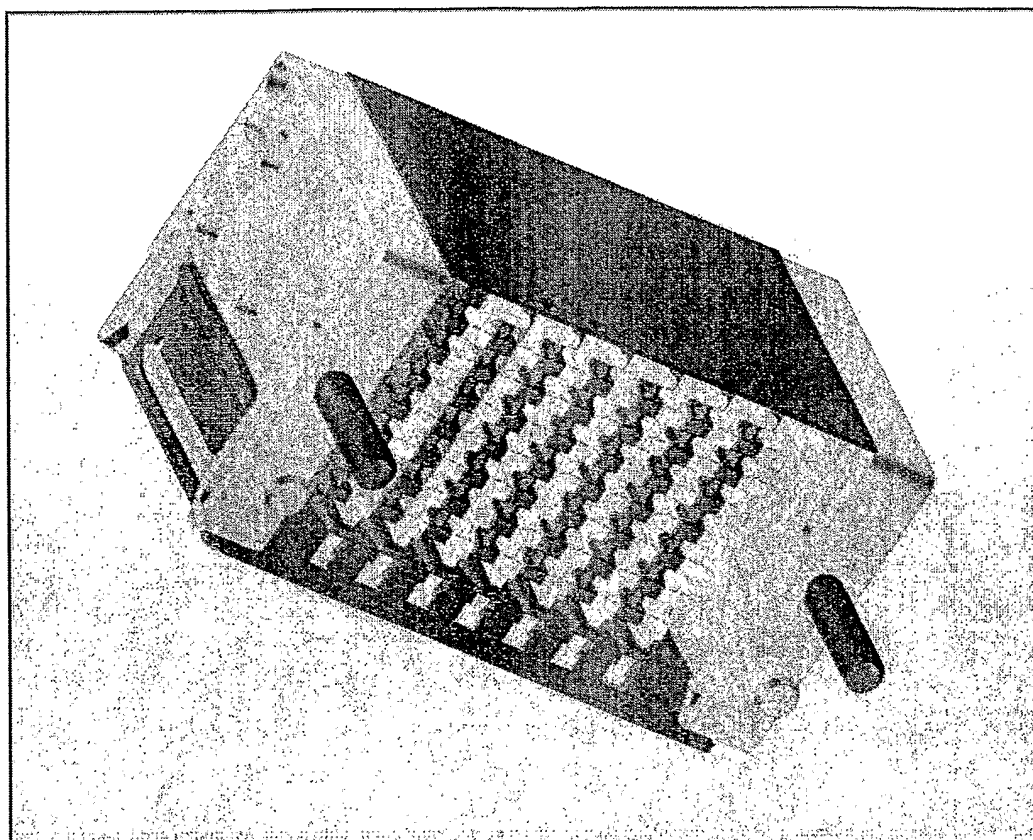


FIG. 47

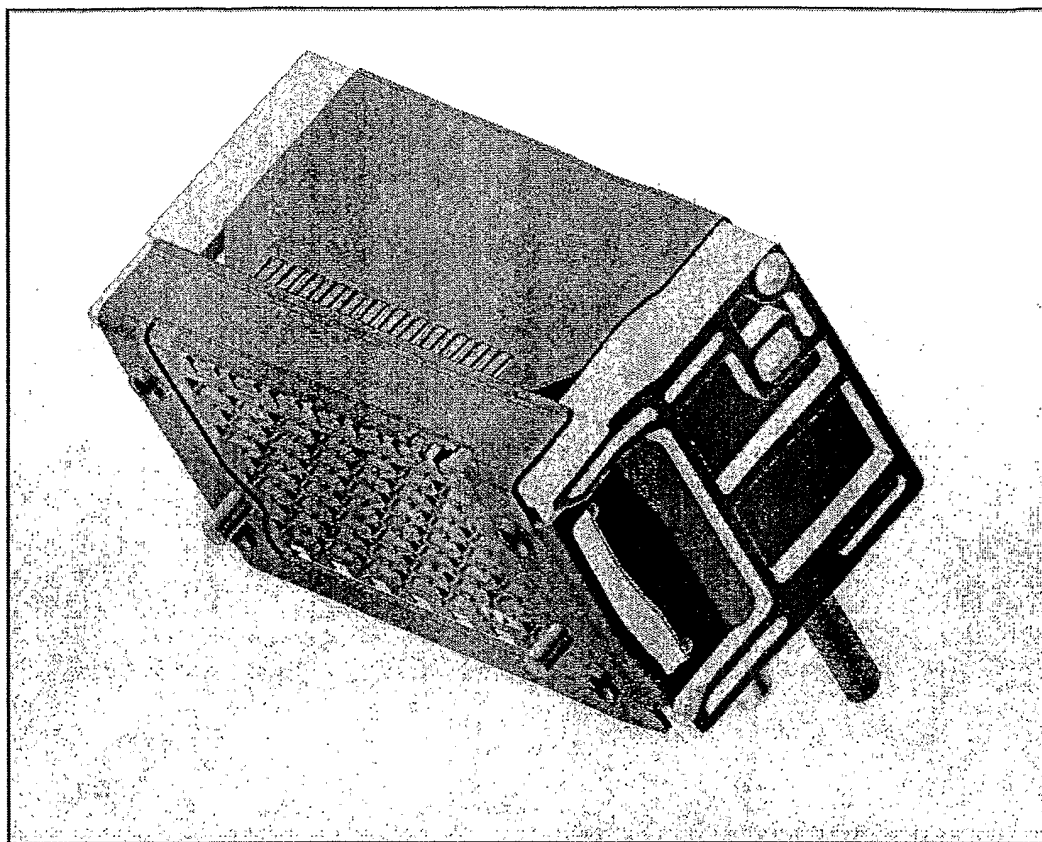


FIG. 48

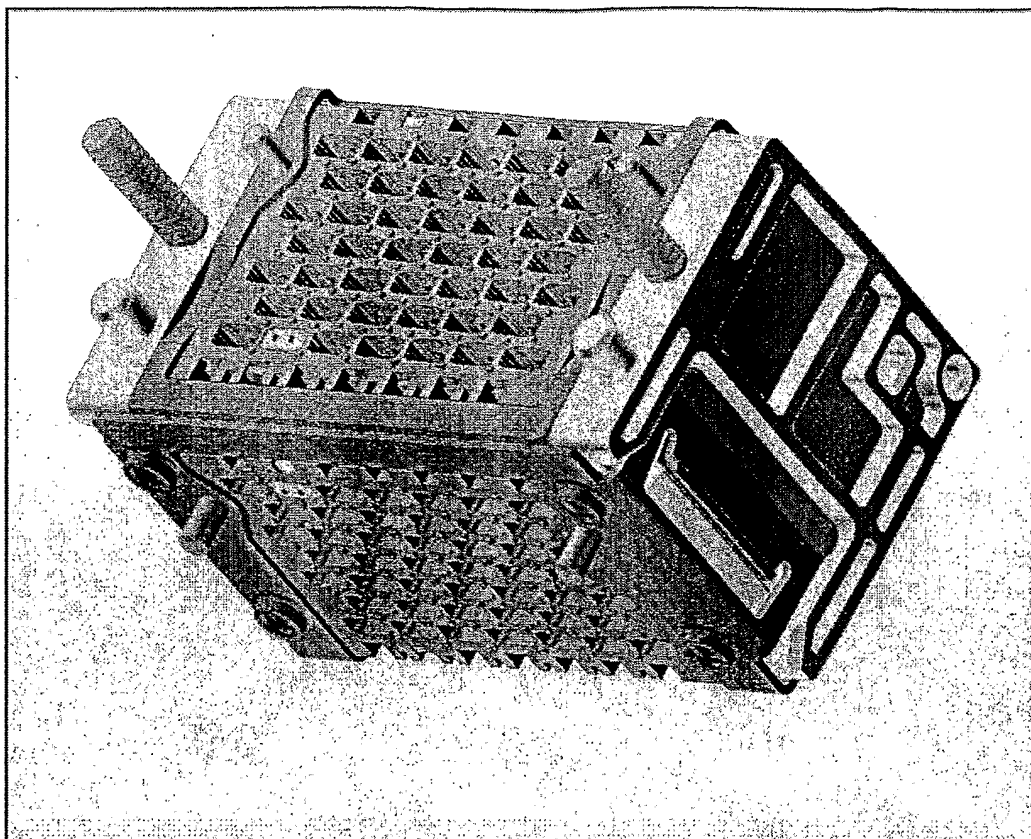


FIG. 49

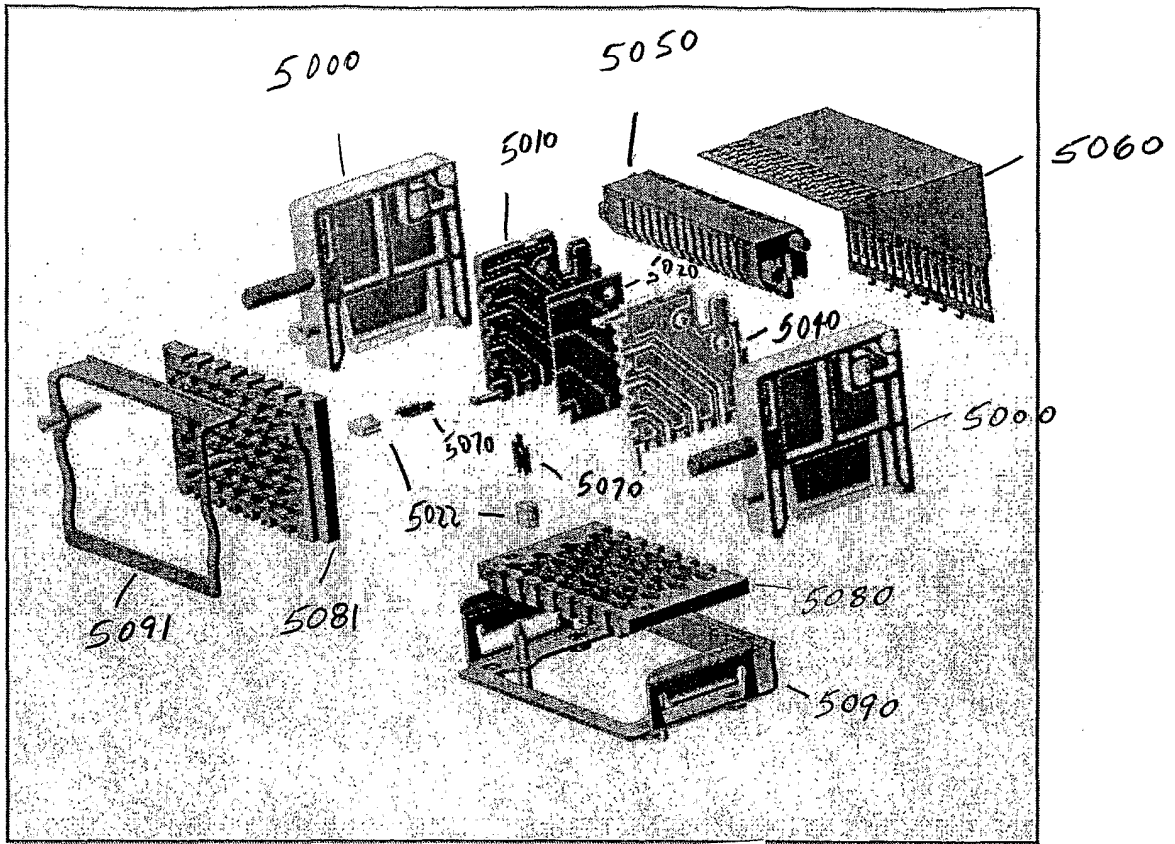


FIG. 50