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(54) **Title**: CYLINDRICAL SCR SUBSTRATE MOUNTING ARRANGEMENT

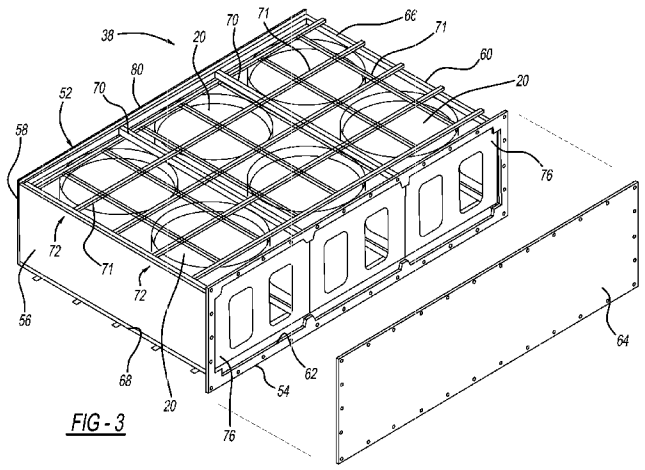


FIG - 3

(57) **Abstract**: An exhaust after-treatment system (16) includes an exhaust treatment component (18) including a primary housing (42). The primary housing (42) includes at least one array (38) including a plurality of reactor components (20). A spacer assembly (74) positioned within the interior of a reactor housing (52) supports each of the reactor components (20). The spacer assembly (74) includes a plurality of removable spacers (76, 77, 78) that cooperate to support the reactor components (20) and allow individual reactor components (20) to be removed from the reactor housing (52). The spacers (76, 77, 78) each include an inlet face (92) and an outlet face (94) that collectively cooperate to form a plurality of apertures of receiving each of the reactor components (20) and preventing the exhaust from flowing around the reactor components (20). The reactor components (20) may be easily removed from the reactor housing (52) such that the entire array (38) does not need to be removed from the exhaust treatment component (18).

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CYLINDRICAL SCR SUBSTRATE MOUNTING ARRANGEMENT

FIELD

[0001] The present disclosure relates to an exhaust after-treatment system including a cylindrical SCR substrate mounting arrangement.

BACKGROUND

[0002] This section provides background information related to the present disclosure which is not necessarily prior art.

[0003] Large-scale engines used in marine, stationary, and locomotive applications may require a plurality of exhaust treatment components to properly treat the large amounts of engine exhaust produced by these engines. In some applications, the exhaust treatment components are arranged in an array. Often times, however, the exhaust treatment components are welded between a pair of baffles, which in turn are welded to a housing that supports the exhaust treatment components. If only a single component requires servicing or replacement, however, the entire unit may need to be replaced due to the components being fixed to the housing.

SUMMARY

[0004] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0005] The present disclosure provides an exhaust after-treatment system for treating an exhaust produced by an engine. The after-treatment system includes an exhaust treatment component including a primary housing. A plurality of arrays may be positioned within the primary housing. Each of the arrays may include a plurality of reactor components positioned within a reactor housing including an open first end and an open second end. The reactor housing includes at least one sidewall between the first end and the second end that defines a first aperture that provides access to an interior of the reactor housing through a removable service panel. A spacer assembly can be positioned within the interior of the reactor housing for supporting each of the

reactor components. The spacer assembly may include a plurality of removable spacers that cooperate to support the reactor components and allow individual reactor components to be removed from the reactor housing. The spacers may each include an upper face and a lower face that collectively cooperate to form a plurality of apertures for receiving each of the reactor component and substantially prevent the exhaust from flowing around the reactor components.

[0006] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0007] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0008] Figure 1 schematically illustrates an exemplary engine exhaust system according to a principle of the present disclosure;

[0009] Figure 2 is a partial perspective view of an exhaust treatment component according to a principle of the present disclosure;

[0010] Figure 3 is a perspective view of an exemplary array of reactor components that may be housed within the exhaust treatment component illustrated in Figure 2;

[0011] Figure 4 is another perspective view of the exemplary array illustrated in Figure 3, with a support structure removed;

[0012] Figure 5 is a perspective view of an exemplary spacer assembly according to a principle of the present disclosure;

[0013] Figure 6 is a perspective view of the spacer assembly illustrated in Figure 5 supporting a plurality of reactor components according to a principle of the present disclosure;

[0014] Figure 7 is a perspective view of the array illustrated in Figure 3, with a portion of the spacer assembly removed;

[0015] Figure 8 is another perspective view of the array illustrated in Figure 3, with a portion of the spacer assembly and some reactor components removed;

[0016] Figure 9 schematically illustrates a sensor and lug assembly according to a principle of the present disclosure;

[0017] Figure 10 is a perspective view of another exemplary spacer assembly according to a principle of the present disclosure; and

[0018] Figure 11 is a perspective view of a module that forms a portion of the spacer assembly illustrated in Figure 10.

[0019] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0020] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0021] Figure 1 schematically illustrates an exhaust system 10 according to the present disclosure. Exhaust system 10 can include at least an engine 12 in communication with a fuel source (not shown) that, once consumed, will produce exhaust gases that are discharged into an exhaust passage 14 having an exhaust after-treatment system 16. Downstream from engine 12 can be disposed an exhaust treatment component 18, which can be a diesel oxidation catalyst (DOC), ammonia slip catalyst (ASC), a particulate filter (DPF) component, or, as illustrated, a selective catalytic reduction (SCR) component 20. Although not required by the present disclosure, exhaust after-treatment system 16 can further include components such as a thermal enhancement device or burner 17 to increase a temperature of the exhaust gases passing through exhaust passage 14. Increasing the temperature of the exhaust gas is favorable to achieve light-off of the catalyst in the exhaust treatment component 18 in cold-weather conditions and upon start-up of engine 12, as well as initiate

regeneration of the exhaust treatment component 18 when the exhaust treatment component 18 is a DPF.

[0022] To assist in reduction of the emissions produced by engine 12, exhaust after-treatment system 16 can include a dosing module 22 for periodically dosing an exhaust treatment fluid into the exhaust stream. As illustrated in Figure 1, dosing module 22 can be located upstream of exhaust treatment component 18, and is operable to inject an exhaust treatment fluid into the exhaust stream. In this regard, dosing module 22 is in fluid communication with a reagent tank 24 and a pump 26 by way of inlet line 28 to dose an exhaust treatment fluid such as diesel fuel or urea into the exhaust passage 24 upstream of exhaust treatment component 18. Dosing module 22 can also be in communication with reagent tank 24 via return line 30. Return line 30 allows for any exhaust treatment fluid not dosed into the exhaust stream to be returned to reagent tank 24. Flow of the exhaust treatment fluid through inlet line 28, dosing module 22, and return line 30 also assists in cooling dosing module 22 so that dosing module 22 does not overheat.

[0023] The amount of exhaust treatment fluid required to effectively treat the exhaust stream may vary with load, engine speed, exhaust gas temperature, exhaust gas flow, engine fuel injection timing, desired NO_x reduction, barometric pressure, relative humidity, EGR rate and engine coolant temperature. A NO_x sensor or meter 32 may be positioned downstream from SCR 20. NO_x sensor 32 is operable to output a signal indicative of the exhaust NO_x content to an engine electronic control unit (ECU) 34. All or some of the engine operating parameters may be supplied from ECU 34 via the engine/vehicle databus to exhaust after-treatment system controller 36. The controller 36 could also be included as part of the ECU 34. Exhaust gas temperature, exhaust gas flow and exhaust back pressure and other vehicle operating parameters may be measured by respective sensors, as indicated in Figure 1.

[0024] The amount of exhaust treatment fluid required to effectively treat the exhaust stream can also be dependent on the size of the engine 12. In this regard, large-scale diesel engines used in locomotives, marine applications,

and stationary applications can have exhaust flow rates that exceed the capacity of a single dosing module 22 and single SCR 20. Accordingly, although only a single dosing module 22 and single SCR 20 is illustrated for dosing and treating the engine exhaust, it should be understood that multiple dosing modules 22 for urea injection and SCR components 20 are contemplated by the present disclosure.

[0025] For example, now referring to Figure 2, an exemplary exhaust treatment component 18 including a plurality of arrays 38 of reactor (e.g., SCR) components 20 is illustrated. The exhaust treatment component 18 illustrated in Figure 2 may be used, for example, in a marine application where engine 12 may be a multiple (e.g., 2, 3, 4, 5, etc) megawatt engine. Exhaust treatment component 18 may include an inlet 40, a primary housing 42, and an outlet 44. Inlet 40 and outlet 44 may each include a flange 46 for connecting primary housing 42 to exhaust passage 14. Exhaust treatment fluid piping 48 may house dosing module inlet lines 28 (not shown) and return lines 30 (not shown) to a plurality of dosing modules 22 (not shown) that dose the urea exhaust treatment fluid into the exhaust stream at positions upstream of each array 38 of SCR components 20. Alternatively, piping 48 may include apertures (not shown) for supplying compressed air such that piping may act as a soot blower for removing soot and other debris from the reactor component 20 faces. Yet another alternative is that piping 48 can be configured to supply exhaust treatment fluid and compressed air such that piping 48 may act as a soot blower and exhaust treatment fluid supply conduit. Access doors (not shown) may provide access to an interior 50 of primary housing 42 so that arrays 38 and SCR components 20 may be serviced, as needed.

[0026] Now referring to Figures 3-8, an exemplary array 38 according to a principle of the present disclosure is illustrated and will be described. Each array 38 may include a reactor housing 52. Reactor housing 52 may be parallelepiped in shape, including first sidewall 54, second sidewall 56, third sidewall 58, and fourth sidewall 60. First sidewall 54 may define an aperture 62 that may be sealed by a removable service panel 64. Service panel 64 may be removed to access SCR components 20. A gasket (not shown) or filler mat (not

shown) may be positioned between service panel 64 and first sidewall 54. Although first sidewall 54 is illustrated as defining aperture 62 for service panel 64, it should be understood that each of second, third, and fourth sidewalls 60 may also be configured to define an aperture 62 for service panel 64, without departing from the scope of the present disclosure.

[0027] Reactor housing 52 is open at upper 66 and lower 68 ends thereof to allow the exhaust stream to pass through SCR components 20. A plurality of primary support beams 70 extend between first and third sidewalls 54 and 58, and provide support to a spacer assembly 74 (Fig. 5) that radially restrict movement of SCR components 20 within reactor housing 52. A plurality of secondary support beams 71 prevent SCR components 20 from moving axially within reactor housing 52. Although six SCR components 20 are illustrated in Figure 3 in two rows 72, it should be understood that any number of SCR components 20 may be housed within reactor housing 52, without departing from the scope of the present disclosure.

[0028] SCR components 20 may be supported within reactor housing 52 by a spacer assembly 74. Spacer assembly 74 is configured to allow cylindrical SCR components 20 to be supported in the parallelepiped-shaped reactor housing 52, and restrain SCR components 20 from radial movement within reactor housing 52. Although SCR components are illustrated as being cylindrical, SCR components 20 may be any non-square or non-rectangular shape known to one skilled in the art. As best shown in Figure 5, spacer assembly 74 may include a plurality of removable first, second, and third spacers 76, 77, and 78.

[0029] First and second spacers 76 and 77 may be disposed about a periphery 80 of reactor housing 52, while third spacers 78 may be positioned within an interior of reactor housing 52. First spacers 76 may be generally U-shaped and include a semi-cylindrical-shaped face 82 that is configured to engage a canister 21 of a single SCR component 20. That is, semi-cylindrical-shaped face 82 is configured to engage 180 degrees of the cylindrical surface of canister 21. First spacers 76 include a pair of lobes 83a on opposing sides of semi-cylindrical-shaped face 82 that define abutment surfaces 84a for contacting

lobes 83b and 83c of second and third spacers 77 and 78, respectively. First spacers 76 also include a pair of planar side faces 85 on opposing sides of a planar end face 86a. Side faces 85 of adjacent first spacers 76 may abut each other. Each of semi-cylindrical-shaped face 82, abutment surfaces 84a, planar side faces 85, and planar end face 86a may include a gasket seal (not shown) along entire lengths thereof.

[0030] Second spacers 77 include a pair of arc-shaped faces 88a such that second spacers 77 are configured to engage a pair of SCR components 20. Arc-shaped faces 88a are configured to engage ninety degrees of the canister 21 of each adjacent SCR component 20. Second spacers 77 are generally T-shaped, and include three lobes 83b. Arc-shaped faces 88a connect adjacent lobes 83b. Similar to first spacers 76, lobes 83b define abutment surfaces 84b for contacting lobes 83a and 83c of first and second spacers 76 and 78. Second spacers 77 are configured to be disposed between a pair of first spacers 76, with a planar end face 86b being positioned along second and third sidewalls 56 and 60 of reactor housing 52. Each of arc-shaped faces 88a, abutment surfaces 84b, and planar end face 86b may include a gasket seal (not shown) along entire lengths thereof.

[0031] Central spacers 78 may include a plurality of arc-shaped faces 88b such that central spacers 78 are configured to engage four adjacent SCR components 20. In this regard, arc-shaped faces 88b are configured to engage ninety degrees of the cylindrical surface of canisters 21 of adjacent SCR components 20. Central spacers 78 are generally cruciform, with four lobes 83c. Arc-shaped faces 88b connect adjacent lobes 83c. Similar to first and spacers 76 and 77, lobes 83c define abutment surfaces 84c for contacting lobes 83a and 83b of first and second spacers 76 and 77, respectively. Because abutment surfaces 84c contact abutment surfaces 84a of adjacent first spacers 76 simultaneously, abutment surface 84c may have a width that is approximately twice that of abutment surfaces 84a. Abutment surface 84c may have a width approximately equal to a width of central lobe 83d of second spacers 77. Each of arc-shaped faces 88b and abutment surfaces 84c may include a gasket seal (not shown) along entire lengths thereof.

[0032] Each of first, second, and third spacers 76, 77, and 78 rest between primary supports 70. In addition, each of first, second, and third spacers 76, 77, and 78 include an inlet face 92 and an outlet face 94. Collectively, inlet faces 92 and outlet faces 94 substantially prevents the flow of exhaust gas through reactor housing 52, unless the exhaust gas passes through each SCR component 20. Additionally, spacers 76, 77, and 78 may each include apertures 96 that assist in reducing a mass of spacer assembly 76, which assists in allowing 76, 77, and 78 spacers to be removed from reactor housing 52 when SCR components 20 require servicing. Spacer assembly 74 may be formed of a material such as steel, aluminum, titanium, or any other rigid material (e.g., polymeric and/or molded materials) satisfactory for supporting the mass of SCR components 20, and satisfactory for withstanding exposure to engine exhaust and exhaust treatment fluid. Preferably, spacer assembly 74 is formed of a light-weight material that enables easier servicing of reactor components 20.

[0033] As best shown in Figures 7 and 8, spacers 76, 77, and 78 are configured to be removable from reactor housing 52 such that SCR components 20 can be removed to be serviced or replaced, as necessary. To remove SCR components 20, service panel 64 is first removed from reactor housing 52. After removing service panel 64, first and second spacers 76 and 77 can be removed from reactor housing 52 to expose portions of SCR components 20 (Fig. 7). After SCR components 20 are removed (Fig. 8), second spacers 77 and third spacers 78 may be removed from reactor housing 52 to expose the remaining SCR components 20. In this manner, SCR components 20 may be easily removed from reactor housing 52 such that the entire array 38 does not need to be removed from exhaust treatment component 18. Moreover, spacer assembly 74 allows for the use of cylindrically-shaped SCR components 20 rather than square- or rectangular-shaped SCR components.

[0034] Spacer assembly 74 is dimensioned to fit within reactor housing 52. Due to tolerances in manufacturing spacer assembly 74 and reactor housing 52, however, there may be a relatively loose fit between spacers 76, 77, and 78 such that upper faces 92 and lower faces 94 do not collectively substantially

prevent the flow of exhaust therethrough. Additionally, it should be understood that reactor housing 52 may include various sensor devices coupled thereto for monitoring exhaust temperature, exhaust pressure, NOx amounts, oxygen amounts, and the like.

[0035] Referring to Figure 9, reactor housing 52 is illustrated as having a sensor boss 98 fixed to an outer surface 100 of one of first, second, and third sidewalls 56, 58, and 60. Sensor boss 98 may be welded, brazed, or fixed to outer surface 100 in any manner known to one skilled in the art. Sensor boss 98 may be threaded (not shown), and adapted to receive sensor device 102 having a corresponding threading (not shown). A plurality of apertures (not shown) may provide communication between sensor device 102 and an interior of reactor housing 52. Additionally, sensor boss 98 may peripherally surround a central aperture 104. The plurality of apertures (not shown) that provide communication between sensor device 102 and the interior of reactor housing may be formed in outer surface 100 between central aperture 104 and sensor boss 98. It should be understood that sensor device 102 seals the sensor boss 98 and prevents the escape of exhaust from reactor housing 52 into the atmosphere.

[0036] At central aperture 104 may be positioned a lug 106 welded or brazed to outer surface 100. A through-hole 108 of lug 106 may be threaded (not shown) for receipt of a threaded bolt 110. As bolt 110 is threaded into lug 106, bolt 110 may extend into reactor housing 52 and abut one of first and second spacers 76 and 77. Abutting bolt 110 with first and spacers 76 and 77 forces spacers 76 and 77 into tighter arrangement with each adjacent spacers 76, 77, or 78 to ensure that spacer assembly 74 is snugly arranged within reactor housing 52 such that bolt 110 acts as a tightening device. In this manner, upper and lower faces 92 and 94 of spacer assembly 74 can substantially prevent exhaust gases from flowing therethrough. In other words, for the exhaust gases to pass through reactor housing 52, the exhaust gases must flow through SCR components 20. Although the use of sensor device 102 is described above as being operable to seal sensor boss 98, it should be understood that some other type of sealing device may be used other than sensor device 102. For example, a sealing cap may be used in place of sensor

device 102, which results in sensor boss 98 with abutting bolt 110 merely being used as a means to force spacers 76 and 77 into tight alignment without allowing the exhaust gas to escape reactor housing 52 into the atmosphere.

[0037] In another configuration illustrated in Figure 10, the tightening device can be embodied as a rotatable spring-loaded pin 111 that extends through central aperture 104. The spring-loaded pin 111 may include a wedge-shaped member 113 at an end thereof that is positioned in the gap between the reactor housing 52 and spacer 76 or 77. Because pin 111 is spring-loaded, the pin 111 will want to rotate and as the pin 111 rotates, the wedge 113 can fill the gap between the housing 52 and the spacer 76 or 77 to force spacers 76 and 77 into tighter arrangement with each adjacent spacers 76, 77, or 78 to ensure that spacer assembly 74 is snugly arranged within reactor housing 52.

[0038] Now referring to Figures 11 and 12, another exemplary spacer assembly 112 is illustrated. Spacer assembly 112 is similar to spacer assembly 74 in that spacer assembly 112 is designed to support SCR components 20 within reactor housing 52. The spacers of spacer assembly 112, however, are configured as a plurality of removable modules 114, with each module 114 housing an SCR component 20.

[0039] Modules 114 may be cubic-shaped including first, second, third, and fourth side walls 116, 118, 120, and 122, respectively. End walls 124 may be positioned at opposing ends of modules 114. End walls 124 may each include a centrally-disposed aperture 126 for receipt of SCR component 20. Side walls 116-122 and end walls 124 may be formed of materials such as steel, aluminum, titanium, or any other material known to one skilled in the art that is able to withstand exposure to engine exhaust and the reagents used by after-treatment system 16.

[0040] End walls 124 may include a plurality of alignment features 128. As best illustrated in Figure 12, alignment features 128 may be formed along edges 130 of end walls 124, and may be defined by an elongate projection 132 and elongate recess 134. Elongate projection 132 and elongate recess 134 are operable to mate with a corresponding projection 132 or recess 134 formed on an adjacent module 114. In this manner, modules 114 may be properly aligned

within reactor housing 52. Additionally, alignment features 128 assist in locking adjacent modules 114 together to prevent radial and axial movement within reactor housing 52.

[0041] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

CLAIMS

What is claimed is:

1. An exhaust after-treatment system for treating an exhaust produced by an engine, comprising:

an exhaust treatment component including a primary housing;

a reactor housing positioned within the primary housing, the reactor housing including an open inlet end, an open outlet end, and sidewalls that extend between the inlet and outlet ends;

a first aperture formed in one of the side walls for providing access to an interior of the reactor housing;

a removable service panel covering the first aperture;

a plurality of cylindrically-shaped reactor components positioned within the reactor housing for treating the exhaust; and

a spacer assembly positioned within the interior of the reactor housing for supporting each of the reactor components, the spacer assembly including a plurality of removable spacers that cooperate to radially support the reactor components and allow individual reactor components to be removed from the reactor housing through the first aperture, the spacers each including an inlet face that collectively cooperate with one another to form a plurality of apertures for receiving each of the reactor components and substantially preventing the exhaust from flowing around the reactor components.

2. The exhaust after-treatment system of Claim 1, wherein the removable spacers include first spacers, second spacers, and third spacers, the first and second spacers extending about a periphery of the reactor housing, and the third spacers being positioned between the first and second spacers.

3. The exhaust after-treatment system of Claim 2, wherein the first spacers include a pair of first lobes on opposing sides of a semi-cylindrically-shaped face, the semi-cylindrically-shaped face contacting one of the cylindrically-shaped reactor components along 180 degrees of its circumference.

4. The exhaust after-treatment of Claim 2, wherein the second spacers include a plurality of second lobes connected by arc-shaped faces, the arc-shaped faces each contacting one of the cylindrically-shaped reactor components along 90 degrees of its circumference.

5. The exhaust after-treatment system of Claim 2, wherein the third spacers include four lobes connected by arc-shaped faces, the arc-shaped faces each contacting a different one of the cylindrically-shaped reactor components along 90 degrees of its circumference.

6. The exhaust after-treatment system of Claim 1, wherein the spacers are configured as removable modules, each module configured to support one of the reactor components along its circumference.

7. The exhaust after-treatment system of Claim 6, wherein the inlet faces of the modules include alignment features along edges thereof.

8. The exhaust after-treatment system of Claim 7, wherein the alignment features are defined by an elongate projection and an elongate recess, the elongate projections and elongate recesses configured to mate adjacent modules.

9. The exhaust after-treatment system of Claim 1, wherein the reactor components are selected from the group consisting of selective-catalytic reduction (SCR) components, diesel oxidation catalysts (DOC), and ammonia slip catalysts (ASC).

10. The exhaust after-treatment system of Claim 1, further comprising:

a second aperture formed in at least one of the sidewalls of the reactor housing; and

a tightening device extending through the second aperture that contacts one of the spacers and forces the spacers into tight contact with one another.

11. The exhaust after-treatment system of Claim 10, wherein the tightening device includes a lug positioned at the second aperture, the lug having a through-hole formed therein; and

a bolt positioned in the through-hole, the bolt being adjustable relative to the lug to extend into the interior of the reactor housing and contact one of the spacers.

12. The exhaust after-treatment system of Claim 10, wherein the tightening device includes a rotatable spring-loaded pin extending through the aperture and a wedge attached to the pin that contacts one of the spacers.

13. An exhaust after-treatment system for an engine producing an exhaust, comprising:

an exhaust treatment component including a primary housing;

a reactor housing positioned within the primary housing, the reactor housing including an open inlet end, an open outlet end, and sidewalls that extend between the inlet and outlet ends;

a first aperture formed in one of the side walls for providing access to an interior of the reactor housing;

a removable service panel covering the first aperture;

a plurality of cylindrically-shaped reactor components positioned within the reactor housing for treating the exhaust;

a spacer assembly positioned within the interior of the reactor housing for supporting each of the reactor components, the spacer assembly including a plurality of spacers that cooperate to radially support the reactor components and allow individual reactor components to be removed from the reactor housing through the first aperture;

wherein the spacers each include a plurality of lobes that define reactor component contact faces, the lobes and contact faces of adjacent spacers cooperating to form cylindrical apertures for receiving the cylindrically-shaped reactor components; and

each of the spacers including an inlet face and an outlet face, the inlet and outlet faces collectively preventing the exhaust from flowing around the reactor components.

14. The exhaust after-treatment system of Claim 13, wherein the removable spacers include first spacers, second spacers, and third spacers, the first and second spacers extending about a periphery of the reactor housing, and the third spacers being positioned between the first and second spacers.

15. The exhaust after-treatment system of Claim 14, wherein the first spacers include a pair of first lobes on opposing sides of a semi-cylindrically-shaped contact face, the semi-cylindrically-shaped contact face contacting 180 degrees of one of the cylindrically-shaped reactor components.

16. The exhaust after-treatment of Claim 14, wherein the second spacers include a plurality of second lobes connected by arc-shaped contact faces, the arc-shaped contact faces each contacting 90 degrees of a pair of the cylindrically-shaped reactor components.

17. The exhaust after-treatment system of Claim 14, wherein the third spacers include a plurality of third lobes connected by arc-shaped contact faces, the arc-shaped contact faces each contacting 90 degrees of four of the cylindrically-shaped reactor components.

18. The exhaust after-treatment system of Claim 13, wherein the reactor components are selective-catalytic reduction (SCR) components.

19. The exhaust after-treatment system of Claim 13, further comprising:

a second aperture formed in at least one of the sidewalls of the reactor housing; and

a tightening device extending through the second aperture that contacts one of the spacers and forces the spacers into tight contact with one another.

20. The exhaust after-treatment system of Claim 19, wherein the tightening device includes a lug positioned at the second aperture, the lug having a through-hole formed therein; and

a bolt positioned in the through-hole, the bolt being adjustable relative to the lug to extend into the interior of the reactor housing and contact one of the spacers.

21. The exhaust after-treatment system of Claim 19, wherein the tightening device includes a rotatable spring-loaded pin extending through the aperture and a wedge attached to the pin that contacts one of the spacers.

22. The exhaust after-treatment system of Claim 11, further comprising a plurality of reactor housings positioned within the primary housing, each reactor housing including a spacer assembly and a plurality of reactor components.

23. The exhaust after-treatment system of Claim 18, further comprising a reagent dosing system, the reagent dosing system including reagent dosing piping positioned upstream of each of the reactor housings for dosing a reagent exhaust treatment fluid into the exhaust upstream of each of the reactor components.

24. The exhaust after-treatment system of Claim 18, further comprising a soot blower, the soot blower including a piping system positioned upstream of

each of the reactor housings for injecting compressed air at each of the reactor components.

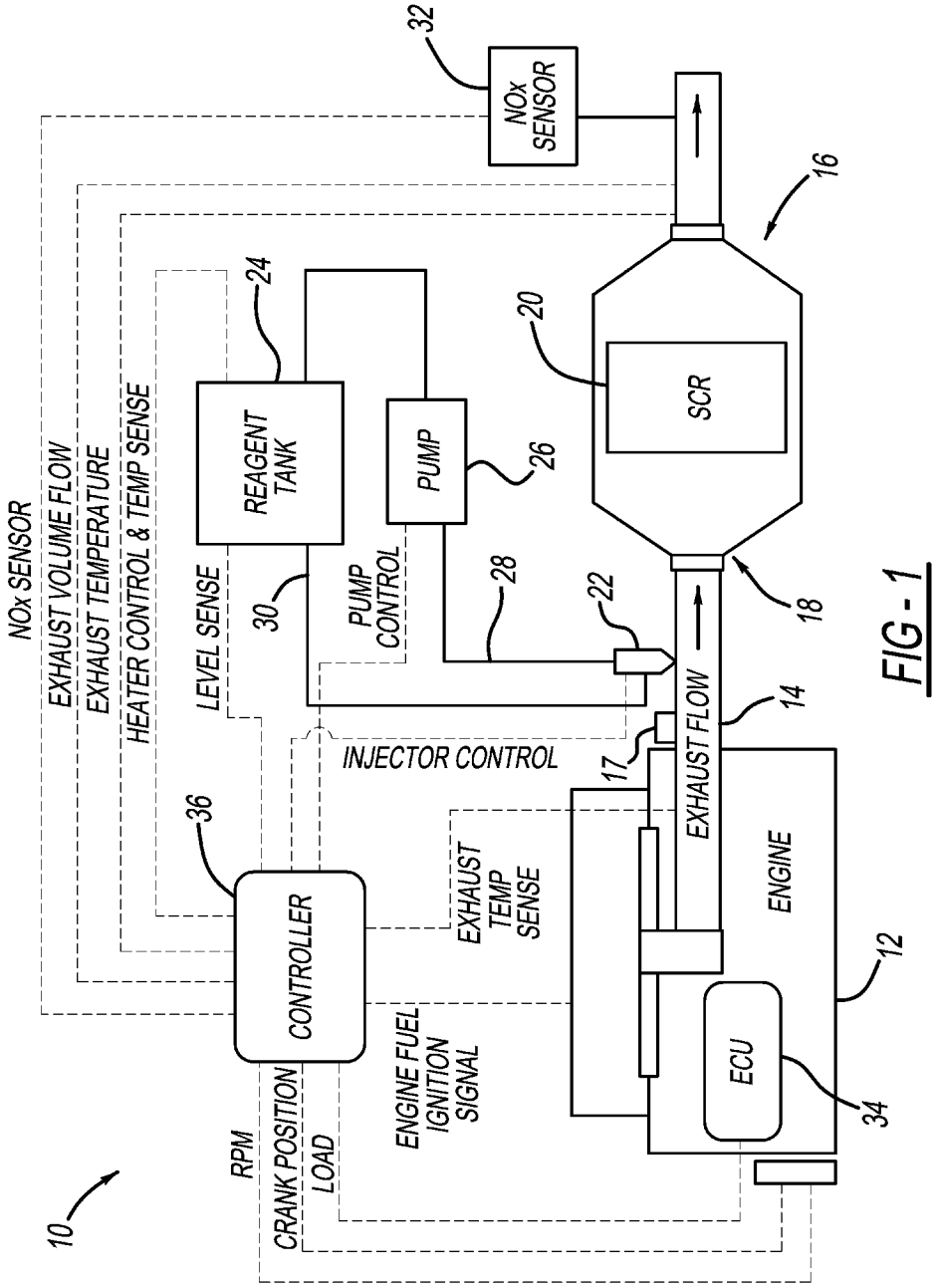

32
NOx SENSOR
16
20
SCR
24
REAGENT TANK
PUMP
26
NOx SENSOR
EXHAUST VOLUME FLOW
EXHAUST TEMPERATURE
HEATER CONTROL & TEMP SENSE
LEVEL SENSE
30
PUMP CONTROL
28
22
18
14
INJECTOR CONTROL
17
EXHAUST FLOW
36
CONTROLLER
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ENGINE
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ECU
34
ENGINE FUEL IGNITION SIGNAL
RPM
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LOAD
10

FIG - 1

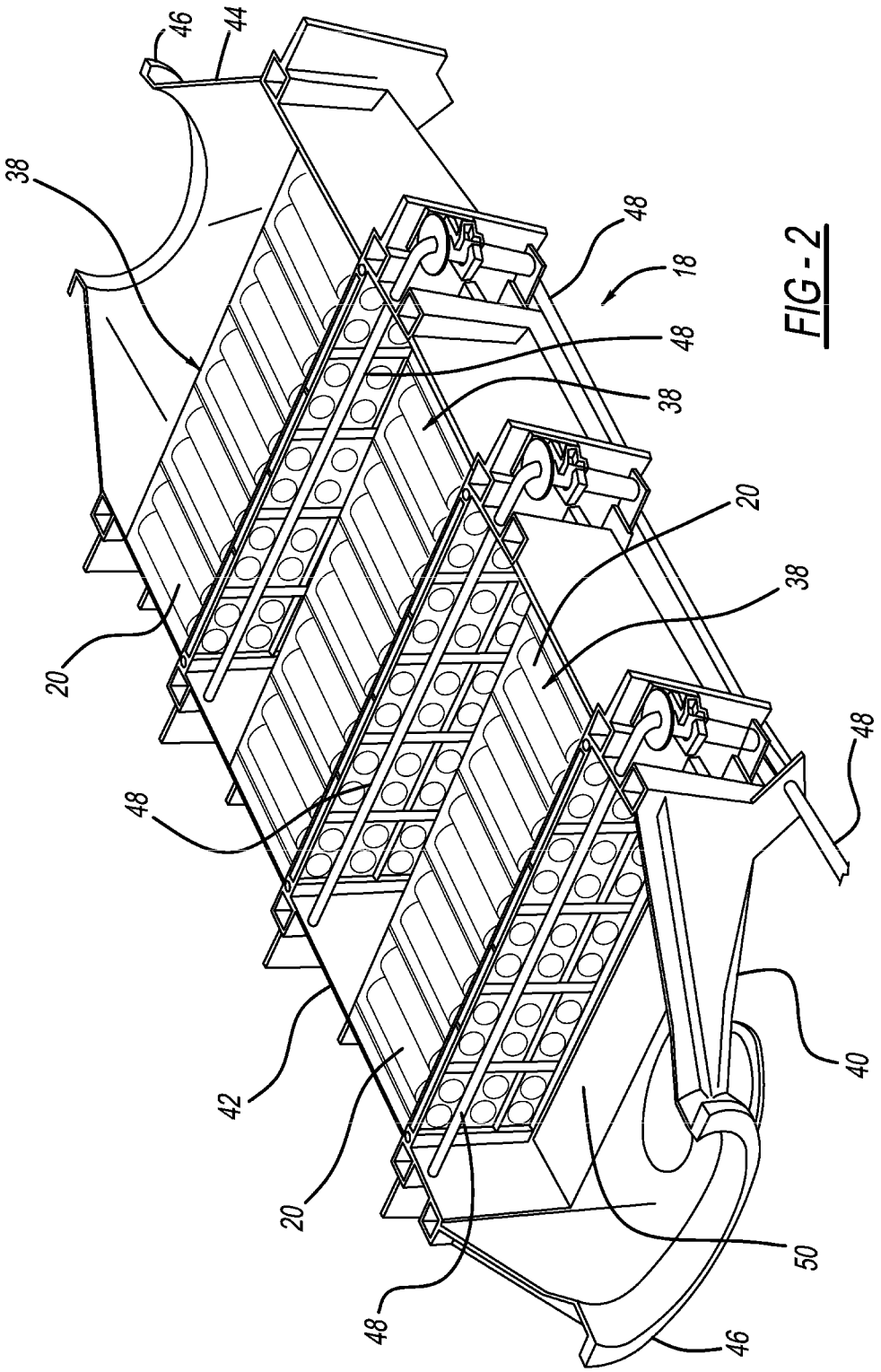


FIG - 2

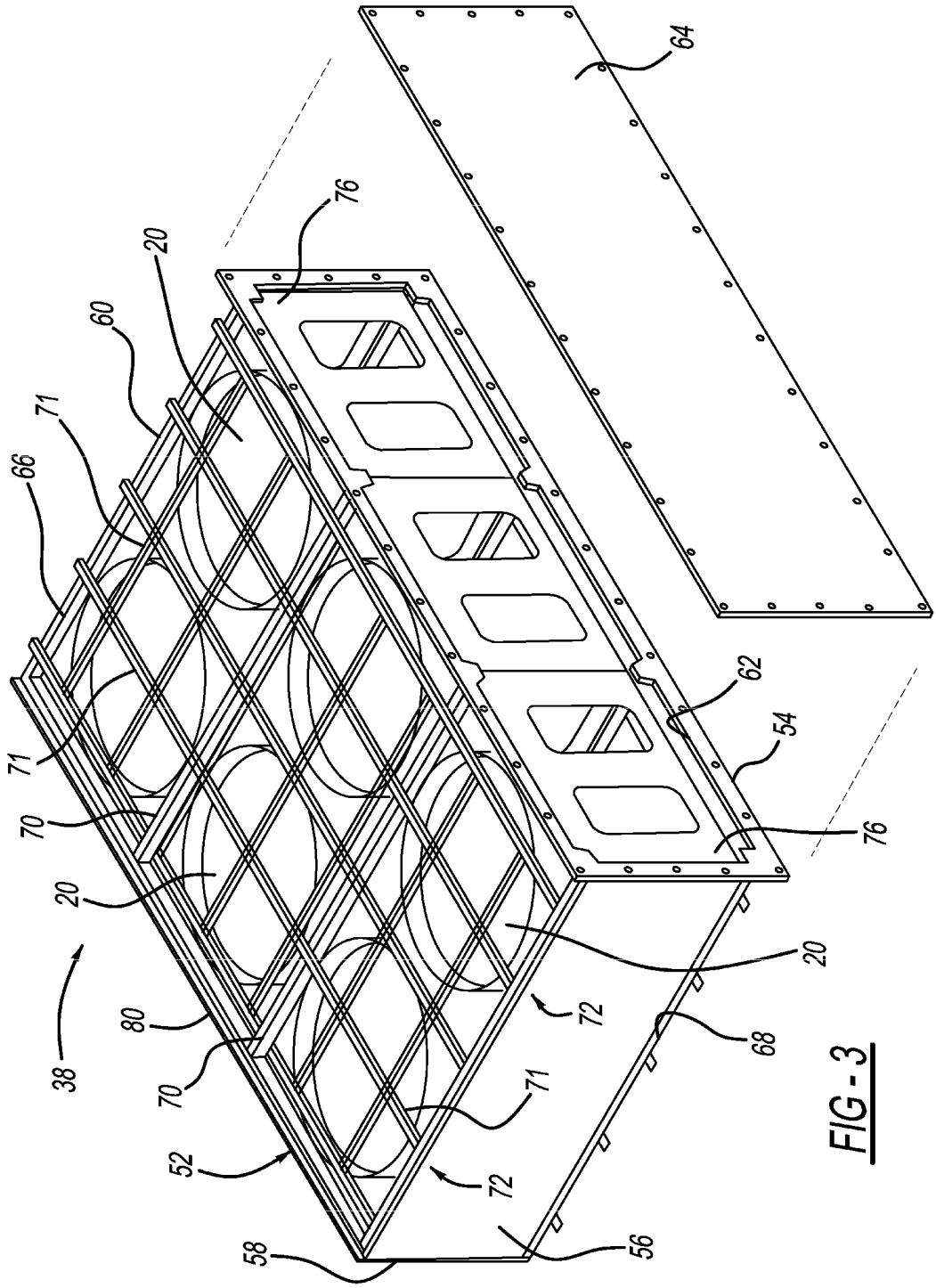


FIG - 3

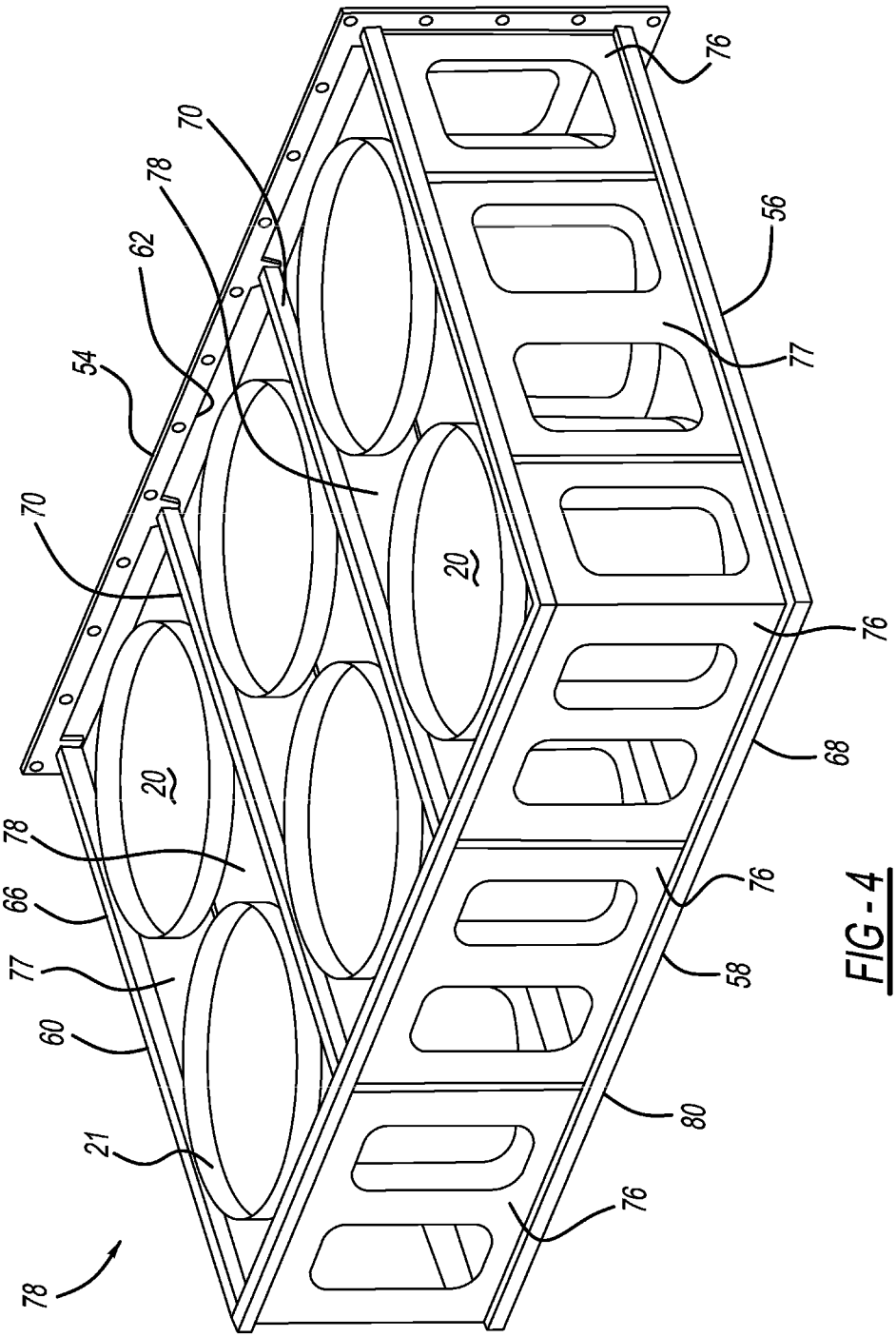


FIG - 4

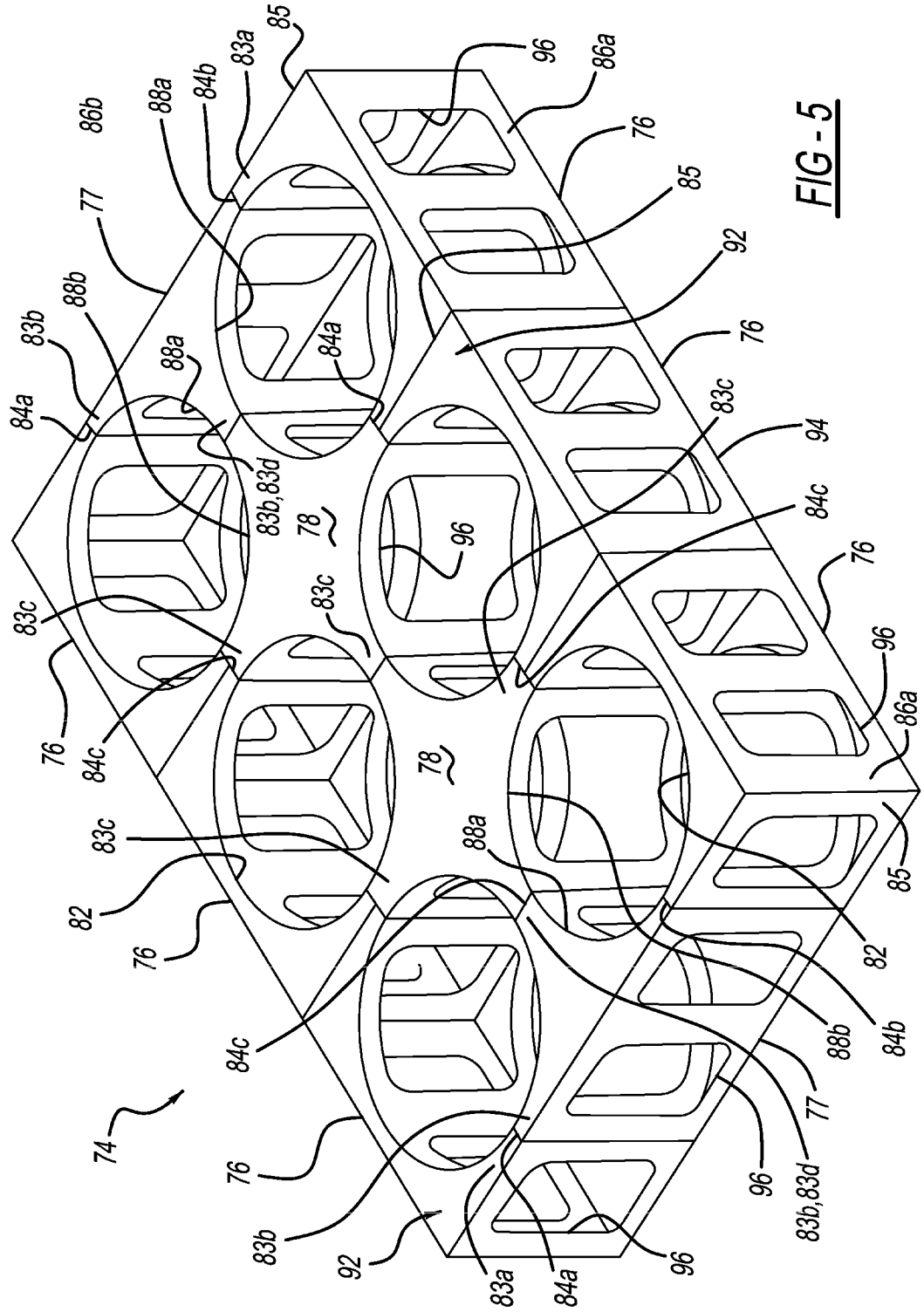

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86b
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88b
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94
96

FIG - 5

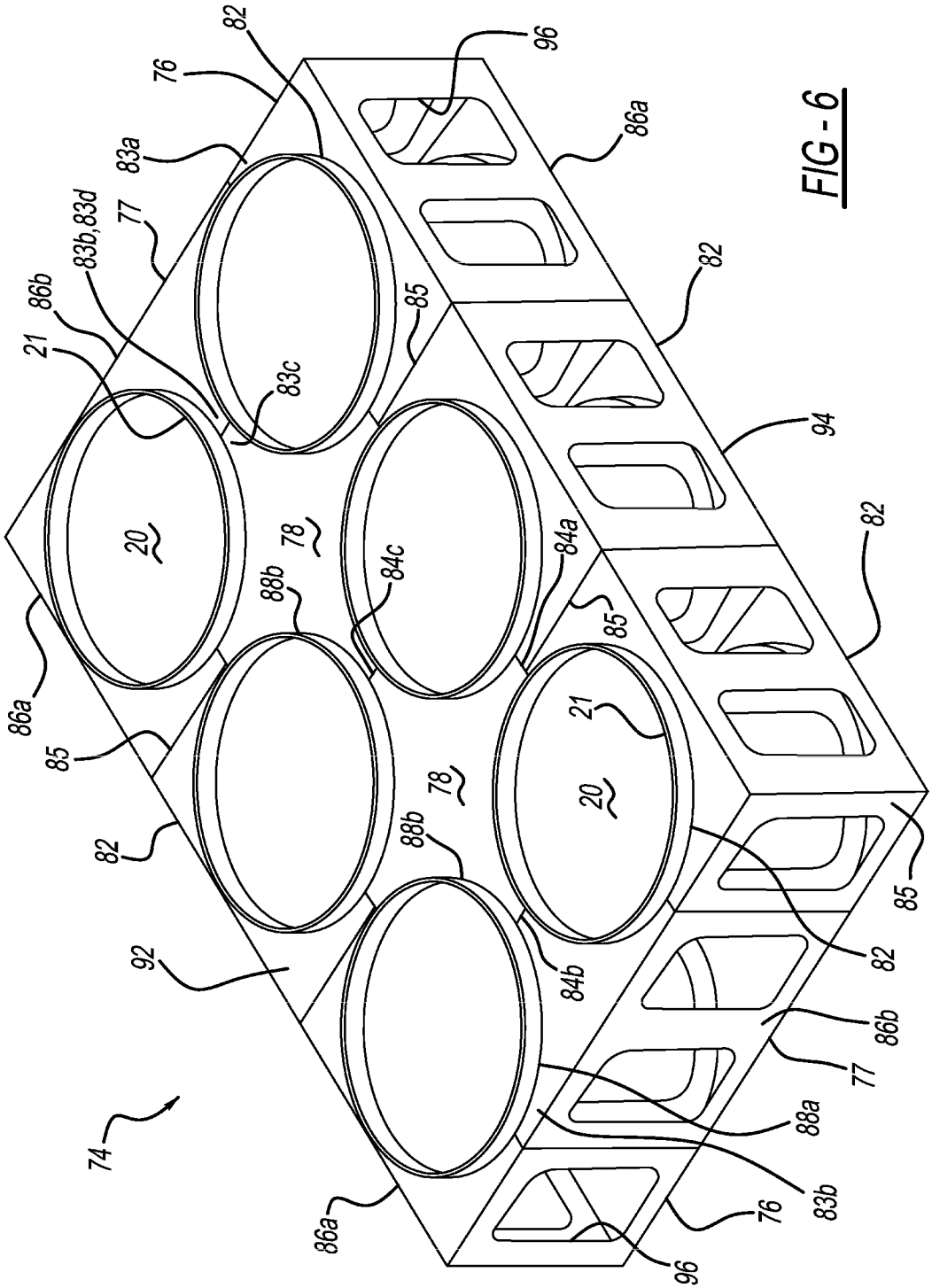

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FIG - 6

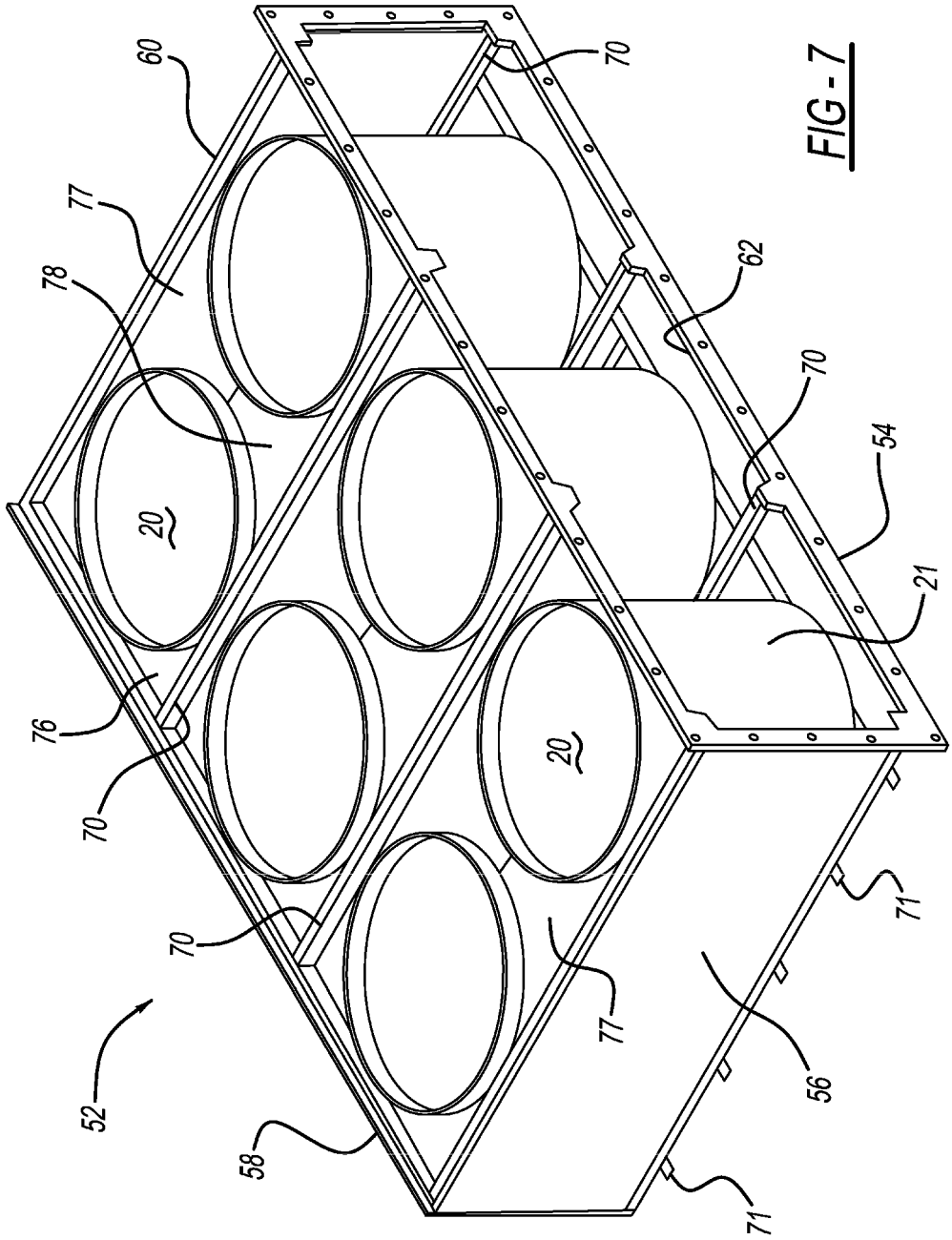


FIG - 7

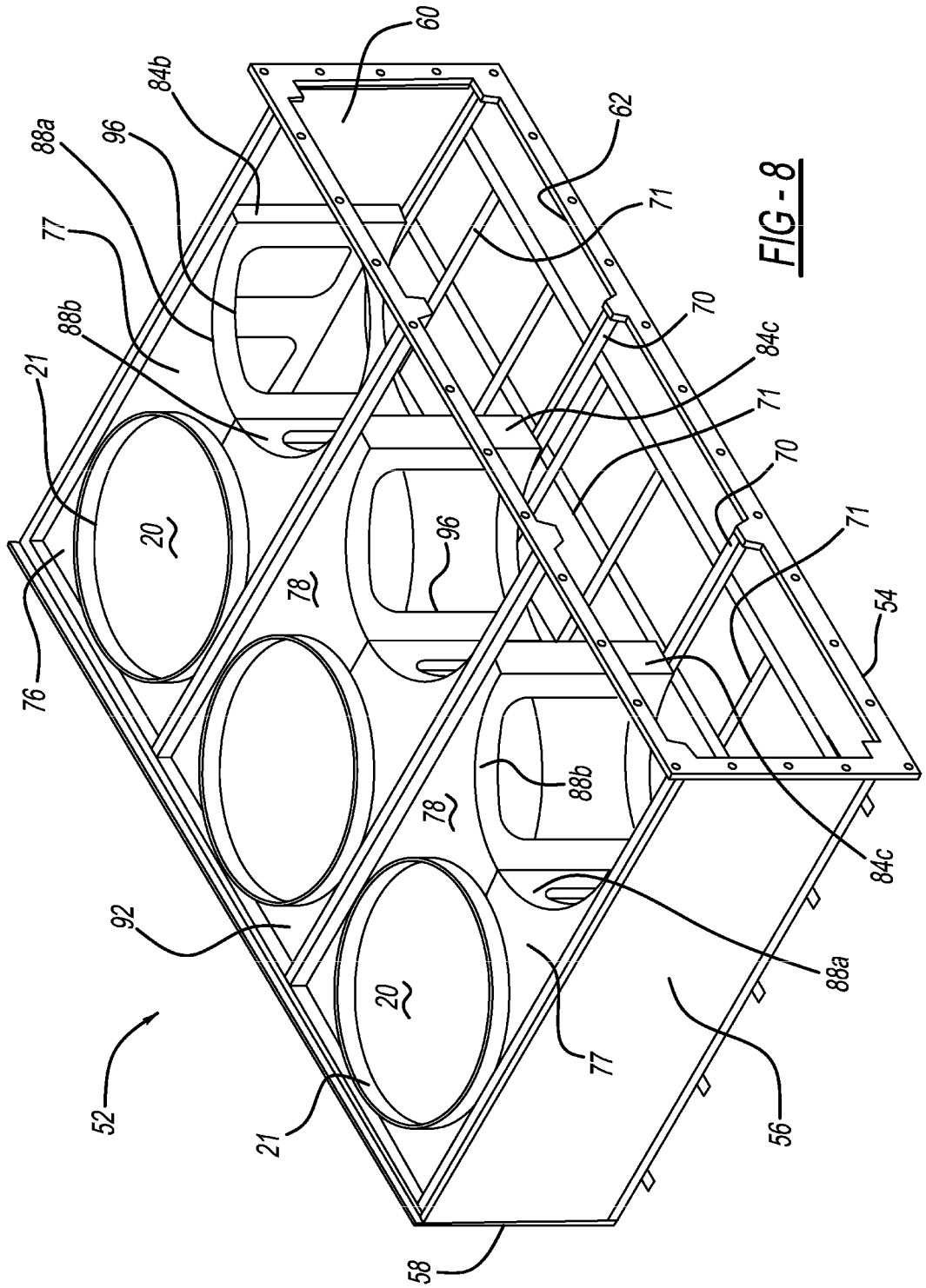
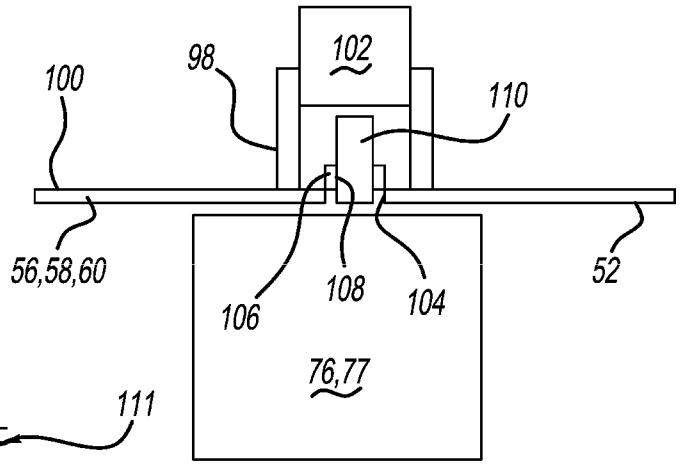

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FIG - 8

FIG - 9



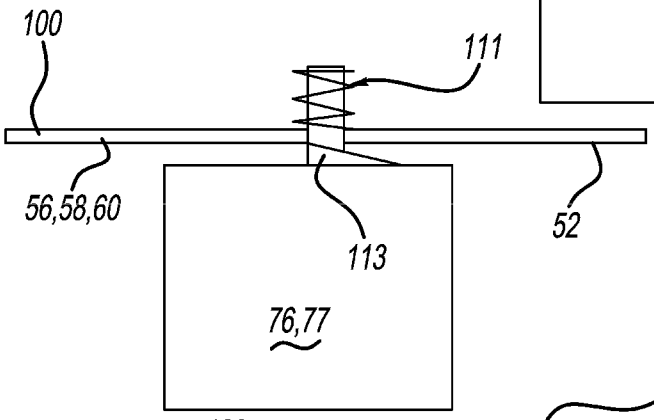


FIG - 10

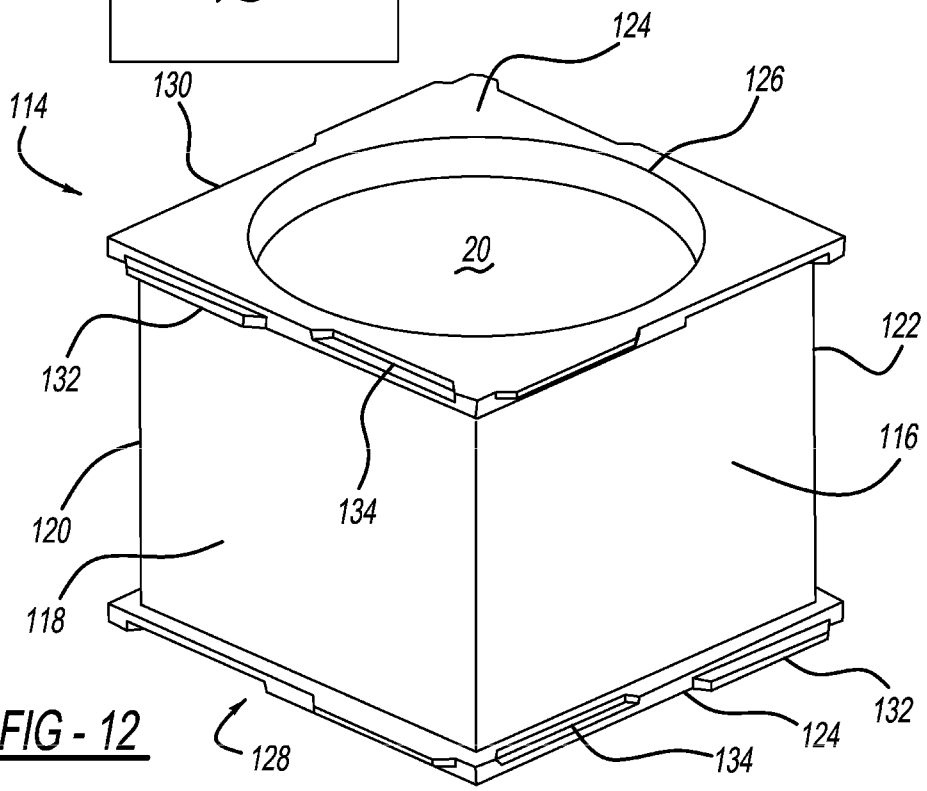


FIG - 12

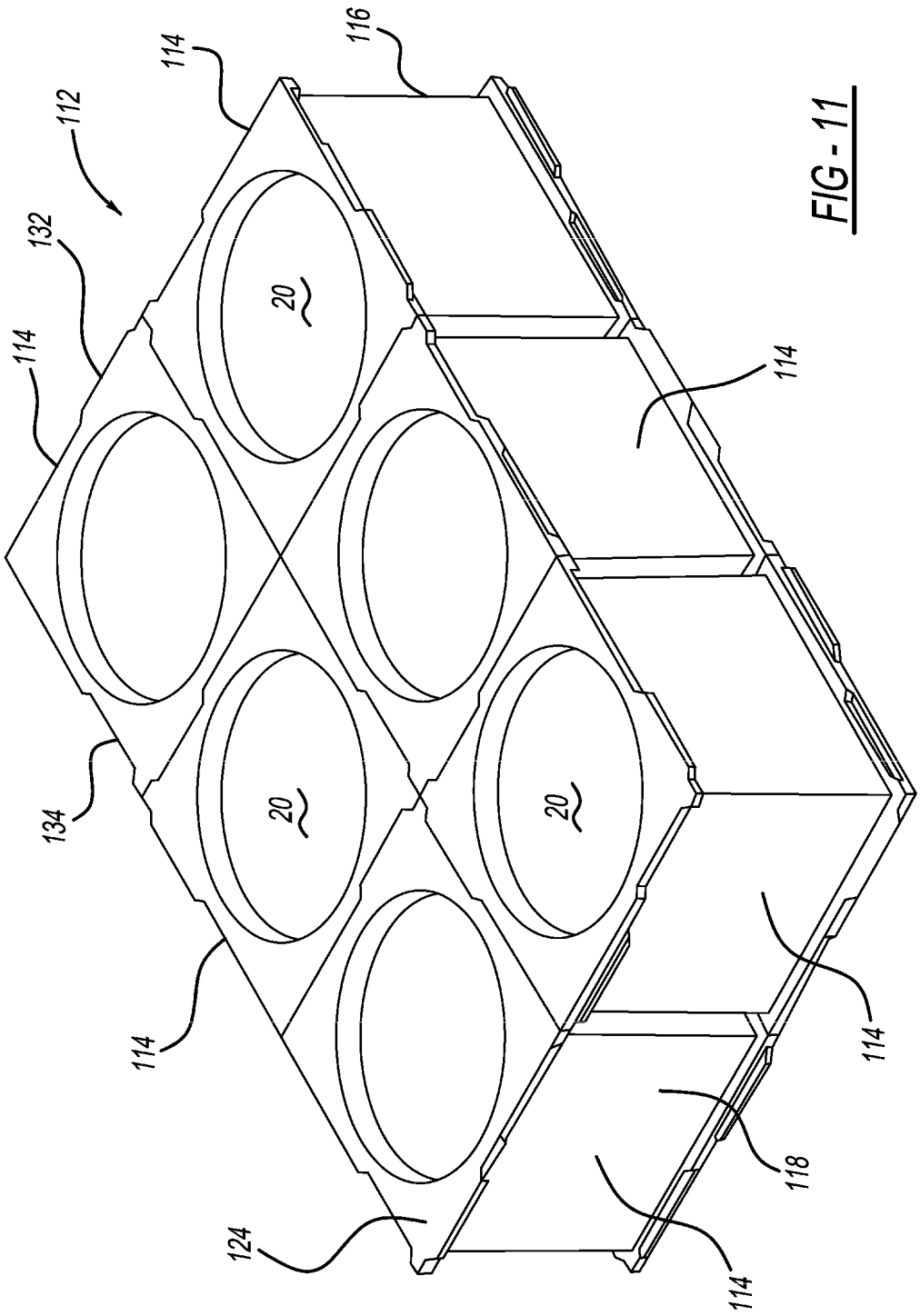


FIG - 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2014/072589

A. CLASSIFICATION OF SUBJECT MATTER

F01N 13/18(2010.01)i; F01N 3/021(2006.01)i; F01N 3/26(2006.01)i; F01N 3/28(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNKI, CNABS, SIPOABS, DWPI CPC: F01N3/0211, F01N3/0217, F01N3/2839, F01N3/2853, F01N13/011, F01N13/017, F01N2350/00, F01N2450/30 FT: 3G091/HA11, 3G091/HA26, 3G091/HA27, 3G091/HA32, 3G091/HA33 spacer, remov+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CH 689687 A5 (HUG ENG AG) 31 August 1999 (1999-08-31) see description, column 5, line 36 to column 8, line 36 and figures 1 to 13	1-24
A	CA 2240553 A1 (ELDADA MAZEN VICTOR) 07 January 2000 (2000-01-07) see the whole document	1-24
A	CN 103573372 A (CATERPILLAR INC) 12 February 2014 (2014-02-12) see the whole document	1-24
A	CN 103189606 A (TENNECO AUTOMOTIVE OPERATING CO INC) 03 July 2013 (2013-07-03) see the whole document	1-24
A	US 7157060 B1 (MIRATECH CORP) 02 January 2007 (2007-01-02) see the whole document	1-24

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 November 2014	**24 November 2014**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA(ISA/CN) **6,Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China**	**KANG,Hongyan**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62085293**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2014/072589

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CH	689687	A5	31 August 1999	DE	29600681	U1	11 April 1996
CA	2240553	A1	07 January 2000		Non	e	
CN	103573372	A	12 February 2014	US	2014044612	A1	13 February 2014
				DE	102013012336	A1	13 February 2014
CN	103189606	A	03 July 2013	JP	2014500924	A	16 January 2014
				US	8516802	B2	27 August 2013
				DE	112011103624	T5	08 August 2013
				KR	20130058757	A	04 June 2013
				WO	2012058056	A2	03 May 2012
				WO	2012058056	A3	05 July 2012
				US	2012102931	A1	03 May 2012
US	7157060	B1	02 January 2007		Non	e	