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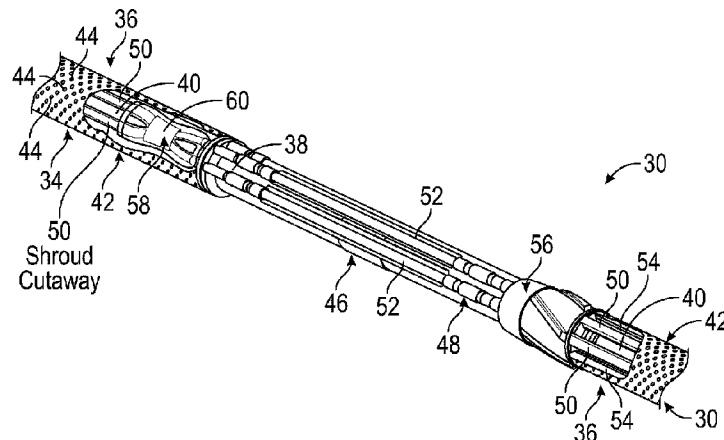
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(54) Titre : FLUX DE MELANGE ENTRE DES TUBES DE TRANSPORT D'UN SYSTEME DE CONDUIT COLLECTIF DE
TUBES MULTI-TRANSPORT

(54) Title: COMMINGLING FLOW BETWEEN TRANSPORT TUBES OF A MULTI-TRANSPORT TUBE SHUNT SYSTEM



(57) **Abrégé/Abstract:**

A technique facilitates gravel packing along a borehole. According to an embodiment, a shunt system is positioned along a sand screen system. The shunt system comprises a plurality of transport tubes and a plurality of packing tubes. A manifold is coupled to the plurality of transport tubes and to the plurality of packing tubes at a corresponding sand screen joint of the sand screen system. The manifold serves to separate a portion of the gravel slurry flowing through the plurality of transport tubes and to direct the portion into the corresponding packing tubes. Additionally, a commingler is positioned along the plurality of transport tubes at a location separate from the manifold. The commingler has an internal chamber where gravel slurry is received from uphole transport tube sections and is commingled before flowing into downhole transport tube sections.



ABSTRACT

A technique facilitates gravel packing along a borehole. According to an embodiment, a shunt system is positioned along a sand screen system. The shunt system comprises a plurality of transport tubes and a plurality of packing tubes. A manifold is coupled to the plurality of transport tubes and to the plurality of packing tubes at a corresponding sand screen joint of the sand screen system. The manifold serves to separate a portion of the gravel slurry flowing through the plurality of transport tubes and to direct the portion into the corresponding packing tubes. Additionally, a commingler is positioned along the plurality of transport tubes at a location separate from the manifold. The commingler has an internal chamber where gravel slurry is received from uphole transport tube sections and is commingled before flowing into downhole transport tube sections.

PATENT APPLICATION

COMMINGLING FLOW BETWEEN TRANSPORT TUBES OF A MULTI-TRANSPORT TUBE SHUNT SYSTEM

BACKGROUND

[0002] Gravel packs are used in wells for removing particulates from inflowing hydrocarbon fluids. Generally, a completion having a plurality of sand screen joints is deployed downhole in a wellbore and a gravel pack is formed around the completion. In some applications, shunt systems are used to facilitate distribution of the gravel pack. As an example, an open hole shunted gravel pack screen system may be configured with two transport tubes and two packing tubes in a 2x2 shunt system. Such a system effectively has two independent gravel packing systems in which each transport tube operates independently of the other and each transport tube has a dedicated packing tube along each screen joint. However, if one of the independent transport tubes becomes inoperable, the functionality of half the system is lost, and this increases the risk of an incomplete gravel pack.

[0003] Attempts have been made to limit this risk by commingling the transport slurry where the slurry is exposed to both the transport tubes and packing tubes along each sand screen joint. Such systems utilize concentric shunt systems having annular commingling volumes, which accommodate this mixing at the interface between transport tubes and packing tubes. However, the commingling of slurry at this interface between transport tubes and packing tubes may be undesirable in a variety of applications.

SUMMARY

[0004] In general, a system and methodology are provided for facilitating gravel packing along a borehole. According to an embodiment, a shunt system is positioned along a sand screen system. The shunt system comprises a plurality of transport tubes and a plurality of packing tubes. A manifold is coupled to the plurality of transport tubes and to the plurality of packing tubes at a corresponding sand screen joint of the sand screen system. The manifold serves to separate a portion of the gravel slurry flowing through the plurality of transport tubes and to direct the portion into the corresponding packing tubes. Additionally, a commingler is positioned along the plurality of transport tubes at a location separate from the manifold. The commingler has an internal chamber where gravel slurry is received from uphole transport tube sections and is commingled before flowing into downhole transport tube sections.

[0005] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0007] Figure 1 is an orthogonal view of a well system having a sand screen system combined with a shunt system, according to an embodiment of the disclosure;

[0008] Figure 2 is an illustration similar to that of Figure 1 but showing cutaway portions, according to an embodiment of the disclosure;

[0009] Figure 3 is an illustration of a portion of the well system showing an example of a commingler disposed along transport tubes, according to an embodiment of the disclosure;

[0010] Figure 4 is a schematic illustration of a sand screen system having a plurality of sand screen joints combined with an example of a shunt system, according to an embodiment of the disclosure;

[0011] Figure 5 is a schematic illustration of an example of a manifold combined with a commingler, according to an embodiment of the disclosure;

[0012] Figure 6 is a schematic illustration of a sand screen system having a plurality of sand screen joints combined with another example of a shunt system, according to an embodiment of the disclosure;

[0013] Figure 7 is a schematic illustration of another example of a shunt system, according to an embodiment of the disclosure;

[0014] Figure 8 is a schematic illustration of another example of a shunt system, according to an embodiment of the disclosure;

[0015] Figure 9 is a schematic illustration of a sand screen system having a plurality of sand screen joints combined with another example of a shunt system, according to an embodiment of the disclosure;

[0016] Figure 10 is a schematic illustration of an example of a manifold combined with a dual commingler, according to an embodiment of the disclosure;

[0017] Figure 11A is an orthogonal view of a well system having a sand screen system combined with a shunt system, according to another embodiment of the disclosure; and

[0018] Figure 11B is a comparison of jumper tubes shown in the system of Figure 1 and a conjoined commingled jumper shown in the system of Figure 11A, according to one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0019] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0020] The disclosure herein generally involves a system and methodology to facilitate formation of gravel packs in wellbores and thus the subsequent improved production of well fluids. According to an embodiment, a system and methodology are provided for facilitating gravel packing along a borehole. A sand screen system may be constructed with a plurality of sand screen joints having screens or filters for filtering inflowing production fluid during production of the well fluids. To facilitate the gravel packing operation, a shunt system is positioned along the sand screen system.

[0021] The shunt system may comprise a plurality of transport tubes and a plurality of packing tubes. A manifold is coupled to the plurality of transport tubes and to the plurality of packing tubes at a corresponding sand screen joint of the sand screen system. The manifold serves to separate a portion of the gravel slurry flowing through the plurality of transport tubes and to direct the portion into the corresponding packing tubes. In some embodiments, a manifold may be positioned along each sand screen joint

such that the corresponding packing tubes are able to ensure proper gravel packing along the annulus surrounding each sand screen joint. Additionally, a commingler is positioned along the plurality of transport tubes at a location separate from the manifold. The commingler has an internal chamber where gravel slurry is received from uphole transport tube sections and is commingled before flowing into downhole transport tube sections. By way of example, at least one commingler may be positioned along each sand screen joint. In some embodiments, the manifold and the commingler are positioned at opposite ends of each sand screen joint.

[0022] In various applications, the commingler is positioned to commingle gravel slurry received from two or more transport tube sections without interfacing with the packing tubes. The commingler(s) may be used with a variety of shunt systems to facilitate commingling of the gravel slurry at a location separate from the manifold. By way of example, the commingler(s) may be used with 2x2 shunt systems, 3x2 shunt systems, 4x2 shunt systems, or other configurations of shunt systems. The overall configuration enables a reduction of pumping pressures and a reduction in carrier fluid leak-off during gravel packing operations.

[0023] Referring generally to Figures 1 and 2, an embodiment of a well system 30 is illustrated. The well system 30 may be deployed in a variety of boreholes 32, e.g. wellbores. According to the illustrated embodiment, the well system 30 comprises a sand screen system 34 having a plurality of sand screen joints 36. Depending on the application, the sand screen joints 36 may be constructed in a variety of configurations. By way of example, each sand screen joint 36 may comprise a base pipe 38 having appropriate perforations and/or inflow control devices through which production fluid may flow to an interior of the base pipe 38 during production operations. It should be noted that the perforations and/or inflow control devices also may be used to facilitate the return of carrier fluid from the gravel slurry during gravel packing operations.

[0024] Each sand screen joint 36 also may comprise a filter 40, e.g. a sand screen, positioned around each base pipe 38 to filter particulates from the inflowing well fluids

before the well fluids pass through the perforations/inflow control devices of the base pipe 38. In some embodiments, a shroud 42 may be positioned around the filter 40 along each sand screen joint 36. Each shroud 42 also contains perforations 44 to accommodate fluid flow therethrough. Sequential sand screen joints 36 may be connected together via a suitable coupler 46, e.g. a box and pin end style connection.

[0025] In the embodiment illustrated, the well system 30 further comprises a shunt system 48 positioned along the sand screen system 34. By way of example, the shunt system 48 may comprise a plurality of transport tubes 50 routed along each sand screen joint 36. The transport tubes 50 of sequential sand screen joints 36 may be coupled together in fluid communication via, for example, jumper tubes 52. At least portions of the shunt system 48 may be located radially between each filter 40 and each corresponding shroud 42.

[0026] The shunt system 48 also comprises a plurality of packing tubes 54 which may be disposed along, for example, each sand screen joint 36 to deliver a portion of the gravel slurry to the annulus surrounding the corresponding sand screen joint 36. As a gravel slurry is flowed along the transport tubes 50, a portion of that gravel slurry may be directed from the transport tubes 50 and into the corresponding packing tubes 54 via a manifold 56.

[0027] With additional reference to Figure 3, the shunt system 48 further comprises a commingler 58 positioned along the plurality of transport tubes 50 at a location separate from the manifold 56. The commingler 58 has an internal chamber 60 where gravel slurry received from uphole transport tube sections 62 (of the plurality of transport tubes 50) is commingled before flowing into downhole transport tube sections 64 (of the plurality of transport tubes 50). The internal chamber 60 is placed in fluid communication with uphole transport tube sections 62 via inlets 66 and with downhole transport tube sections 64 via outlets 68. The internal chamber 60 provides a cavity for bringing together flow of gravel slurry from the two or more transport tubes 50 and for mixing the gravel slurry flows before redistributing the gravel slurry downstream through

the commingler outlets 68. By way of example, the commingler 58 and the internal chamber 60 may be positioned on one side of the sand screen joint 36 rather than being constructed as an annular volume encircling the sand screen joint 36.

[0028] Depending on the application, the commingler 58 may be positioned at a variety of locations along the corresponding sand screen joint 36. In the example illustrated, however, the commingler 58 is positioned generally on the pin-end of the corresponding sand screen joint 36. As further illustrated schematically in Figure 4, the commingler 58 may be positioned at the pin-end of each sand screen joint 36 so as to deliver commingled gravel slurry to the next sequential manifold 56 located on the next sequential sand screen joint 36.

[0029] In this example, the shunt system 48 comprises at least one manifold 56 and at least one commingler 58 located along each corresponding sand screen joint 36. The packing tubes 54 extend from the corresponding manifold 56 and are routed along the corresponding sand screen joint 36 to ensure delivery of gravel slurry along the surrounding annulus. As further illustrated in Figure 5, each manifold 56 serves to separate a portion of the gravel slurry into the corresponding packing tubes 54 while directing the remainder of the gravel slurry downstream to the next sequential commingler 58.

[0030] It should be noted that addition of the commingler 58 enables the addition of one or more transport tubes 50 so as to reduce the pumping pressure utilized for a given gravel pack distance. As further illustrated in Figure 5, the additional or secondary transport tube 50 (or additional tubes 50) is not coupled with a packing tube 54 but instead directly passes through the manifold 56 via a pass through 70. In this example, the three transport tubes 50 direct their gravel slurry into the next sequential commingler 58 for commingling within internal chamber 60.

[0031] By adding one secondary transport tube 50, as illustrated in Figures 5 and 6, the shunt system 48 may be considered a 3x2 shunt system while the addition of two

secondary transport tubes 50 to the 2x2 system may be considered a 4x2 shunt system. Other numbers of additional transport tubes 50 also can be added according to the parameters of a given system and/or application. In addition to reducing pumping pressure, the additional transport tubes 50 in combination with the location of the commingler 58 can greatly reduce leak-off of carrier fluid during a gravel packing operation.

[0032] Gravel slurry is generally a combination of proppant and carrier fluid; and leak-off refers to the loss of carrier fluid to the wellbore annulus without a corresponding loss of proppant. The result is an undesirable increase in proppant concentration within the gravel slurry. Leak-off occurs where nozzles 72 of the packing tubes 54 communicate to the wellbore annulus (see Figure 7).

[0033] In a 2x2 shunt system, the distance from the manifold 56 to the first packing tube nozzle 72 is the shortest distance for leak-off. Once the annulus is gravel packed around a given sand screen joint 36, the proppant will pack the inside of the corresponding packing tubes 54 back to the manifold 56, thus creating resistance to leak-off. However, there is a limit to the distance downstream of the manifold 56 that the first packing tube nozzle 72 can be placed to achieve a desired gravel pack between the first packing tube nozzle 72 and the next closest nozzle 72 of the previous uphole sand screen joint 36. The leak-off distance for the additional transport tube(s) 50 (e.g. the middle transport tube 50 labeled transport tube #3 in Figure 7) is equivalent to the distance between the first packing tube nozzle 72 and the manifold 56 plus the distance from the manifold 56 to the corresponding commingler 58.

[0034] It should be noted the corresponding commingler 58 may be located above the manifold 56 on, for example, the next sequential uphole sand screen joint 36, as illustrated in Figure 7. In other embodiments, however, the manifold 56 may be located above the corresponding commingler 58, as illustrated in Figure 8. Accordingly, the maximum leak-off distance achievable is one half the length of a sand screen joint 36 plus the distance to the first packing tube nozzle 72. It should be noted that throughout

this description the term “above” refers to a relative position uphole and the term “below” refers to a relative position downhole. In one or more embodiments of the present disclosure, the proximity of the commingler 58 to the manifold 56 may exhibit maximum leak-off performance if the commingler 58 is located approximately midway between two manifolds 56 of adjacent screen joints 36.

[0035] According to an example, a sand screen joint 36 may be 38 feet in length and a first nozzle distance may be 6 feet. In this scenario, a maximum leak-off distance for the middle transport tube 50 (tube #3) would be $38/2+6 = 25$ feet. This increased leak-off resistance for the additional/secondary transport tubes greatly improves the system reliability especially for extended reach gravel packs, e.g. gravel packs greater than 6000 feet or even greater than 10000 feet. It should be noted the distances and sizes used in this example are provided merely for purposes of explanation and the actual distances and sizes can vary substantially.

[0036] Referring generally to Figures 9 and 10, another embodiment of well system 30 is illustrated. In this embodiment, the shunt system 48 is structured as a 2x2x2 shunt system, which is accomplished by installing two commingling volumes in the form of a dual commingler 74 having two comminglers 58. The dual commingler 74 may be located at a distance upstream or downstream of a corresponding manifold 56, e.g. at some distance away from the interface between the transport tubes 50 and the packing tubes 54.

[0037] The embodiment further utilizes an additional (secondary) transport tube 50 alongside each of the transport tubes 50 that would exist in a 2x2 shunt system configuration. The dual commingler 74 creates two independent gravel pack pathways and provides a secondary transport tube 50 to each primary transport tube 50. In the illustrated arrangement, the secondary transport tube 50 has a sufficiently long leak-off path to eliminate leak-off concern, thus providing an especially useful configuration for use in extended reach gravel pack applications.

[0038] In the example illustrated, each primary transport tube 50 is coupled with a corresponding packing tube 54 while each secondary transport tube 50 passes through the manifold 56 to the corresponding commingler 58 of the dual commingler 74. In other words, each primary transport tube 50 and its corresponding secondary transport tube 50 is placed in fluid communication with one of the comminglers 58 of the dual commingler 74 as illustrated. The secondary transport tubes 50 effectively provide additional transport tubes with long leak-off distances to ensure that two transport tubes 50 always communicate to a toe of the well.

[0039] Each commingler 58 receives gravel slurry flow from one of the primary and one of the secondary transport tubes 50 and redistributes the gravel slurry downstream into the same two transport tubes 50. Effectively, each commingler 58 of the dual commingler 74 contributes to reducing pumping pressure during gravel packing through the shunt system 48 while homogenizing the gravel slurry in the corresponding, e.g. partnered, transport tubes 50. If plugging occurs in a primary transport tube 50, each commingler 58 is able to help reestablish flow of gravel slurry downstream of the plug in the blocked transport tube 50.

[0040] Depending on the parameters of a given well application, the components and configuration of the sand screen system 34 may vary. For example, the sand screen system 34 may utilize different numbers of sand screen joints 36 connected sequentially along various types of boreholes, e.g. horizontal or otherwise deviated wellbores. Each sand screen joint 36 may utilize different types of filters, flow control devices, shrouds, and/or other components. Similarly, the shunt system 48 may comprise transport tubes 50 and packing tubes 54 of various sizes and numbers. The manifolds 56 and comminglers 58 also may be utilized along the shunt system 48 in various patterns and arrangements. The size and configuration of each manifold 56 and each commingler 58 also may vary according to the parameters of a given gravel packing and/or production operation. In some well applications, the manifold 56 and/or commingler 58 may be located on various other components such as on an intermediate pup joint located between sand screen joints. Additionally, shunt system components may be located on

some sand screen joints, e.g. every other sand screen joint. For example, a commingler or comminglers 58 may be spaced out along the shunt system 48, e.g. placed on every other sand screen joint 36.

[0041] Referring now to Figure 11A, an orthogonal view of a well system 30 having a sand screen system 34 combined with a shunt system 48, according to one or more embodiments of the present disclosure is shown. As specifically shown in Figure 11A, the commingler 58 may be integrated into a conjoined commingled jumper 76 of the shunt system 48, according to one or more embodiments of the present disclosure. As shown in Figure 11A, transport tubes 50 of sequential sand screen joints 36 may be coupled together in fluid communication via the conjoined commingled jumper 76, which includes a commingler 58, as previously described, integrated with two jumper tubes 52, according to one or more embodiments of the present disclosure. Further, for the sake of clarity, Figure 11B shows a comparison of a pair of jumper tubes 52 and the conjoined commingled jumper 76, according to one or more embodiments of the present disclosure. As previously described, the pair of jumper tubes 52 may be implemented in embodiments of the present disclosure where the commingler 58 is built into the screen joint 36, and the conjoined commingled jumper 76 may be implemented in embodiments of the present disclosure where the commingler 58 is built into the jumper tubes 52. Advantageously, building the commingler 58 into the jumper tubes 52 via the conjoined commingled jumper 76 in accordance with one or more embodiments of the present disclosure provides a more affordable assembly than building the commingler 58 into the screen joint 36. Further, one or more embodiments of the present disclosure that include a conjoined commingled jumper 76 in the sand screen system 34 enjoy a smaller footprint over embodiments of the present disclosure that include a commingler 58 built into the screen joint 36. This smaller footprint may translate into more preferable storage and inventory management logistics.

[0042] Moreover, a commingler 58 may be sporadically placed in the sand screen system 34 in one or more embodiments of the present disclosure. For example, one or more sand screen joints 36 of the sand screen system 34 may not be associated with a

commingler 58 at all (either in the sand screen joint 36 itself or in the associated jumper tubes 52) in one or more embodiments of the present disclosure. Indeed, one or more comminglers 58 may be spaced along the well system 30 at every sand screen joint 36, every couple of joints 36, every few joints 36, every several joints 36, every 10 joints 36, every 20 joints 36, or one commingler 58 may be positioned per zone within the completion, or several comminglers 58 may be positioned within each zone of the completion, or any number of sporadic placements. All such embodiments are contemplated and are within the scope of the present disclosure.

[0043] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

1. A system for use in a well, comprising:
 - a sand screen system having a plurality of sand screen joints; and
 - a shunt system positioned along the sand screen system, the shunt system comprising:
 - a plurality of transport tubes;
 - a plurality of packing tubes;
 - a plurality of jumper tubes, which fluidly couple transport tubes of sequential sand screen joints of the plurality of sand screen joints together;
 - a manifold coupled to the plurality of transport tubes and to the plurality of packing tubes to separate a portion of a gravel slurry flowing through the plurality of transport tubes into the plurality of packing tubes; and
 - a commingler positioned along the plurality of transport tubes or the plurality of jumper tubes at a location separate from the manifold, the commingler having an internal chamber where gravel slurry, received from uphole transport tubes sections of the plurality of transport tubes, is commingled before flowing into downhole transport tubes sections of the plurality of transport tubes.
2. The system as recited in claim 1, wherein the commingler is located uphole relative to the manifold.
3. The system as recited in claim 1, wherein the manifold is located uphole relative to the commingler.
4. The system as recited in claim 1, wherein the commingler is positioned along the plurality of transport tubes, and is located on a first sand screen joint of the

plurality of sand screen joints, and the manifold is located on a second sand screen joint of the plurality of sand screen joints.

5. The system as recited in claim 1, wherein the manifold comprises a plurality of manifolds with at least one manifold positioned on each sand screen joint.
6. The system as recited in claim 5, wherein the commingler comprises a plurality of comminglers with at least one commingler positioned on at least one sand screen joint.
7. The system as recited in claim 6, wherein a dual commingler is positioned along at least one sand screen joint.
- 1
8. The system as recited in claim 1, wherein the shunt system further comprises a secondary transport tube which passes through the manifold.
9. The system as recited in claim 1, wherein the shunt system further comprises a plurality of secondary transport tubes which pass through the manifold.
10. The system as recited in claim 1, wherein the commingler is positioned along the plurality of jumper tubes in a conjoined commingled jumper.
- 1
11. A method, comprising:

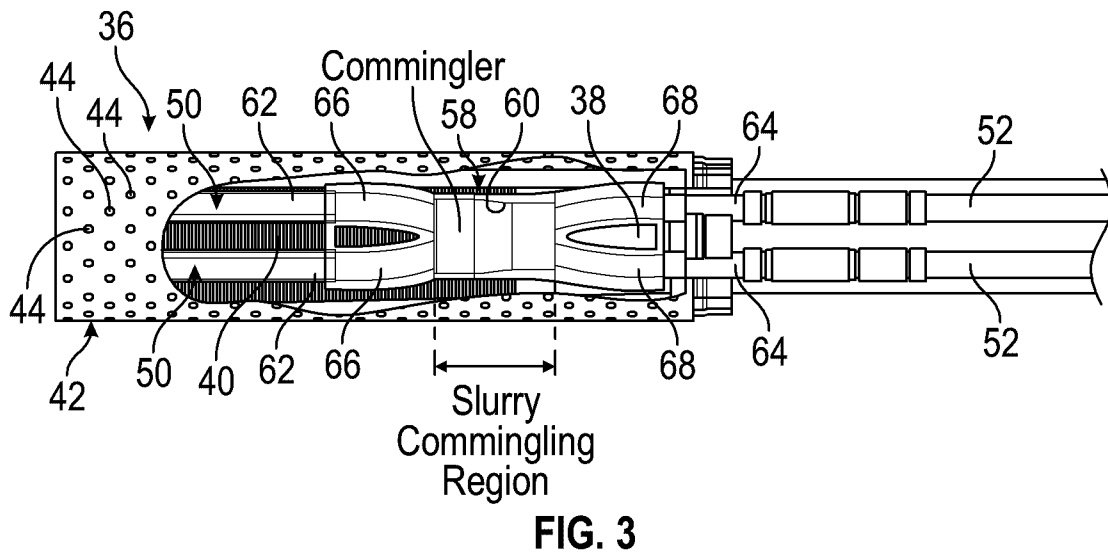
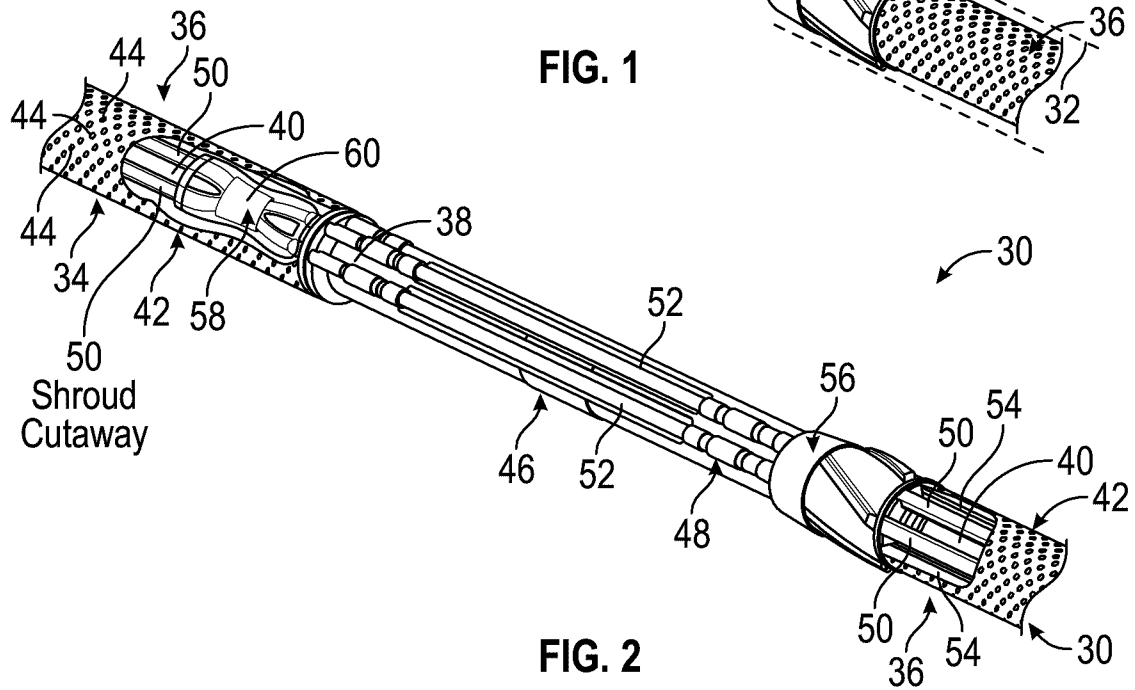
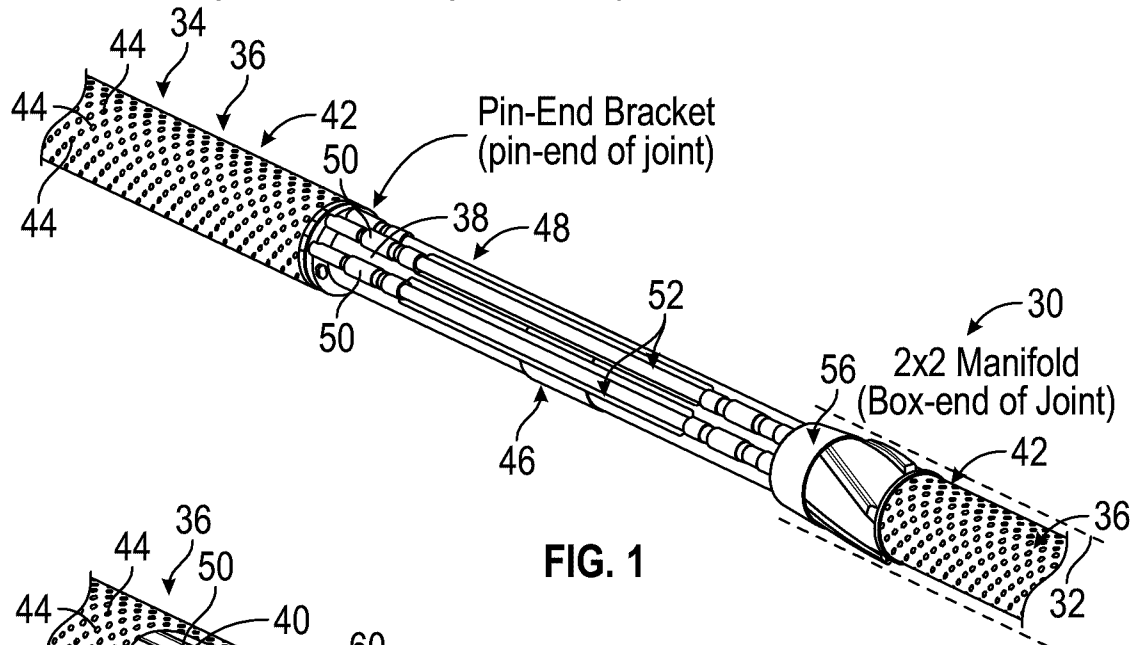
positioning a shunt system along a sand screen system;
deploying the shunt system and the sand screen system into a borehole;
depositing a gravel slurry along the sand screen system via a plurality of
packing tubes coupled with a plurality of gravel slurry transport tubes via a
manifold; and

commingling gravel slurry, flowing through the plurality of gravel slurry transport tubes, within a commingler located along the sand screen system at a position separated from the manifold.

12. The method as recited in claim 11, wherein commingling comprises commingling gravel slurry received from two gravel slurry transport tubes.
13. The method as recited in claim 11, further comprising providing the sand screen system with a plurality of sand screen joints connected sequentially.
14. The method as recited in claim 13, wherein positioning comprises positioning at least one manifold along each sand screen joint, and at least one commingler along at least one sand screen joint.
15. The method as recited in claim 14, further comprising: providing the shunt system with additional transport tubes at each sand screen joint; and passing the additional transport tubes through the manifold at each sand screen joint without placing the additional transport tubes in fluid communication with the packing tubes.
16. The method as recited in claim 15, wherein positioning comprises positioning two comminglers at each sand screen joint and connecting at least one gravel slurry transport tube and at least one additional transport tube to each commingler of the two comminglers.
17. The method as recited in claim 11, further comprising arranging the shunt system as a 2x2 shunt system.
18. The method as recited in claim 11, further comprising arranging the shunt system as a 3x2 shunt system.

19. The method as recited in claim 11, further comprising arranging the shunt system as a 4x2 shunt system.
20. The method as recited in claim 11, further comprising: providing the sand screen system with a plurality of sand screen joints connected sequentially; and providing the sand screen system with a plurality of jumper tubes, which fluidly couple the transport tubes of sequential sand screen joints together, wherein positioning comprises positioning at least one commingler along the plurality of jumper tubes in a conjoined commingled jumper.
21. A system, comprising:
 - a shunt system for use in facilitating gravel packing of a wellbore, the shunt system comprising:
 - a plurality of transport tubes;
 - a plurality of packing tubes;
 - a manifold coupled to the plurality of transport tubes and to the plurality of packing tubes to provide an interface for separating a portion of a gravel slurry flowing through the plurality of transport tubes into the plurality of packing tubes; and
 - a commingler separated from the manifold and coupled with the plurality of transport tubes to provide commingling of gravel slurry, flowing along the plurality of transport tubes, independently of the interface for separating the portion of gravel slurry into the plurality of packing tubes.

Showing connection region of two joints of 2x2 shunted screens



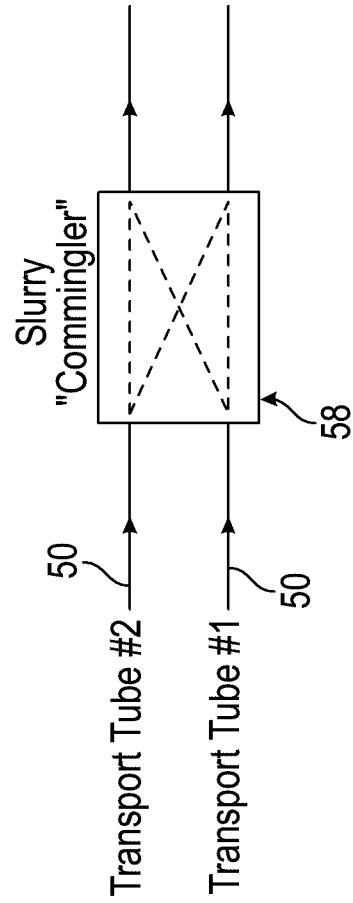
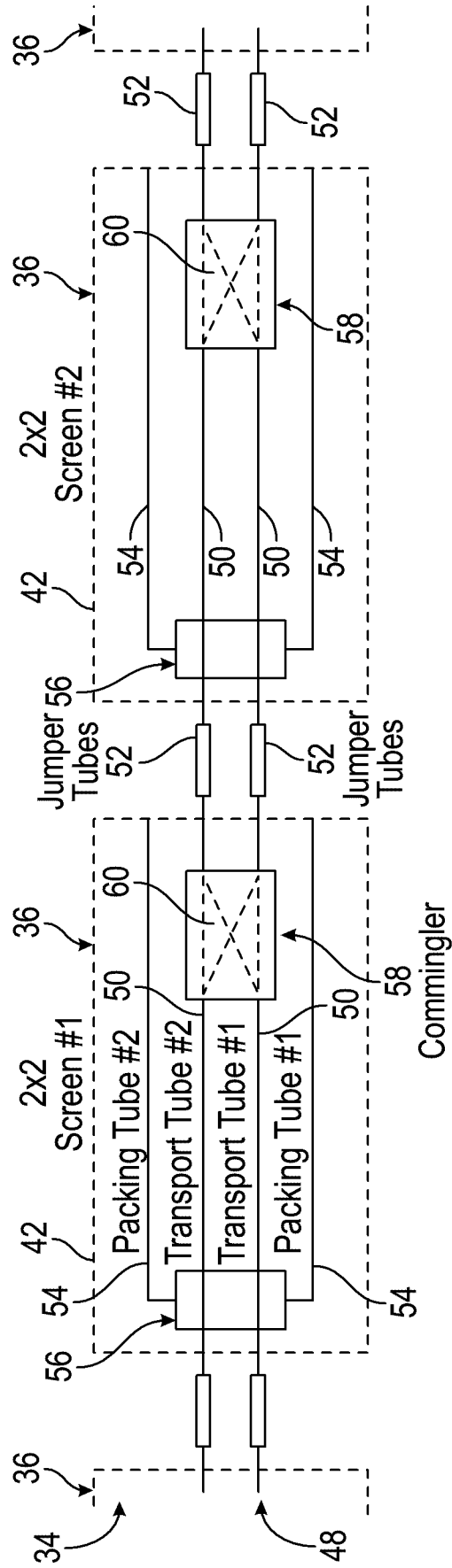


FIG. 4

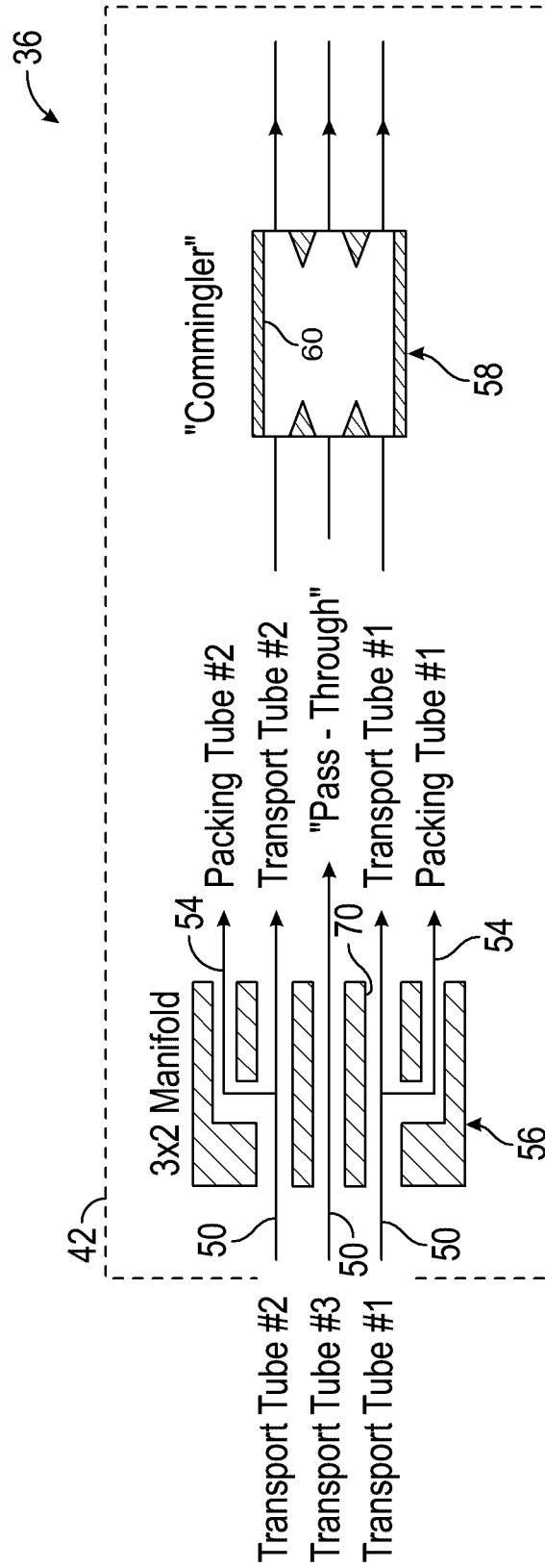


FIG. 5

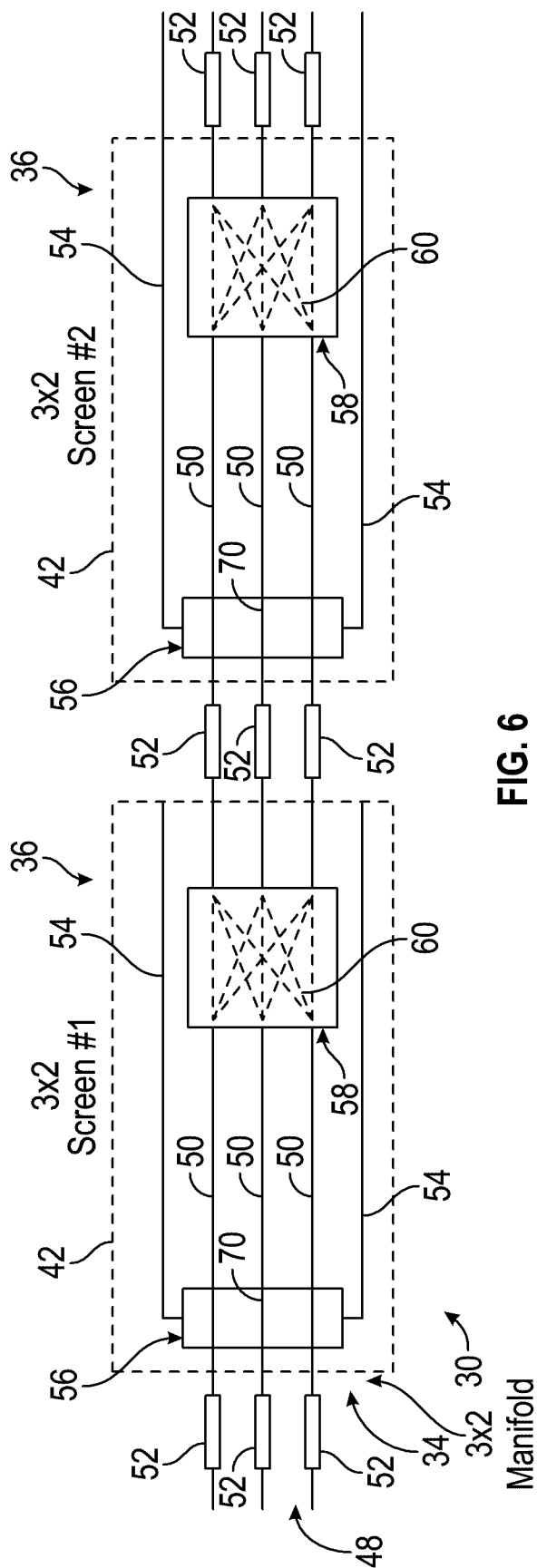


FIG. 6

Scenario: Commingler Above Manifold

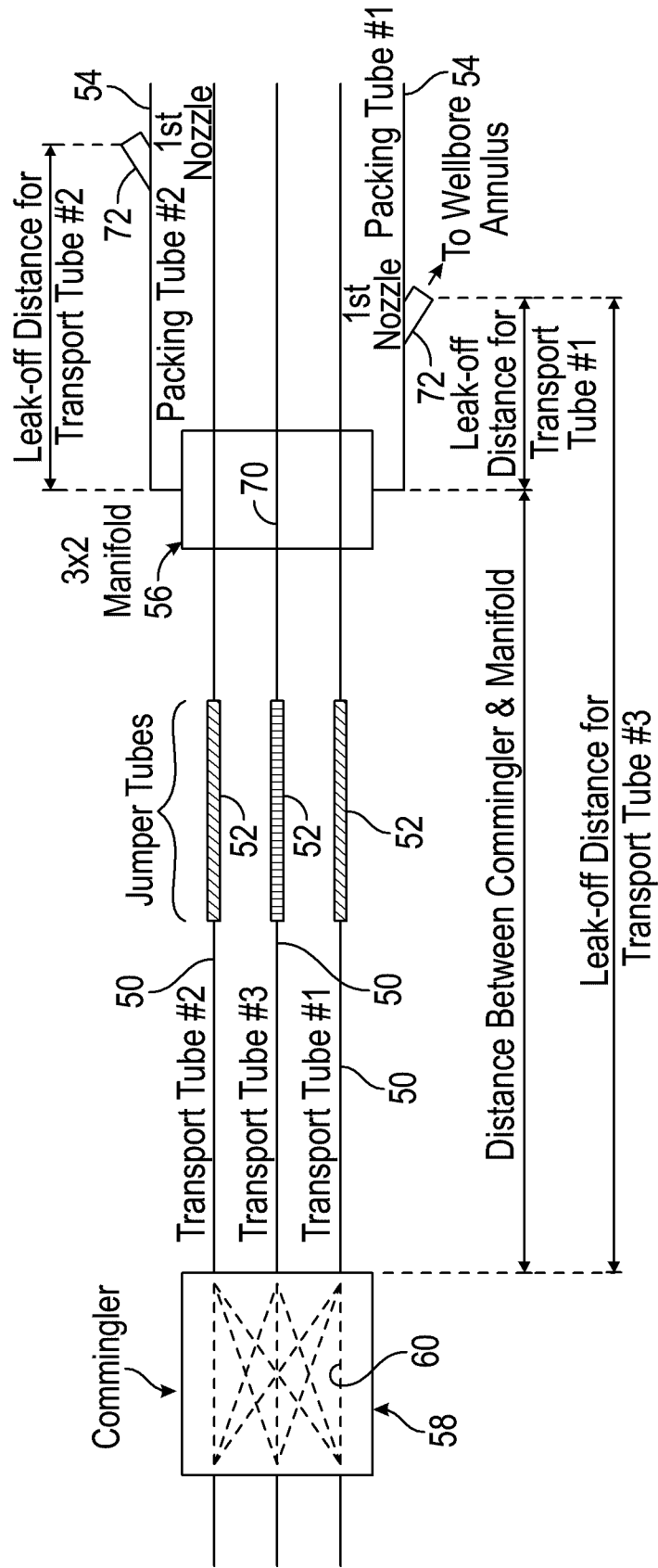


FIG. 7

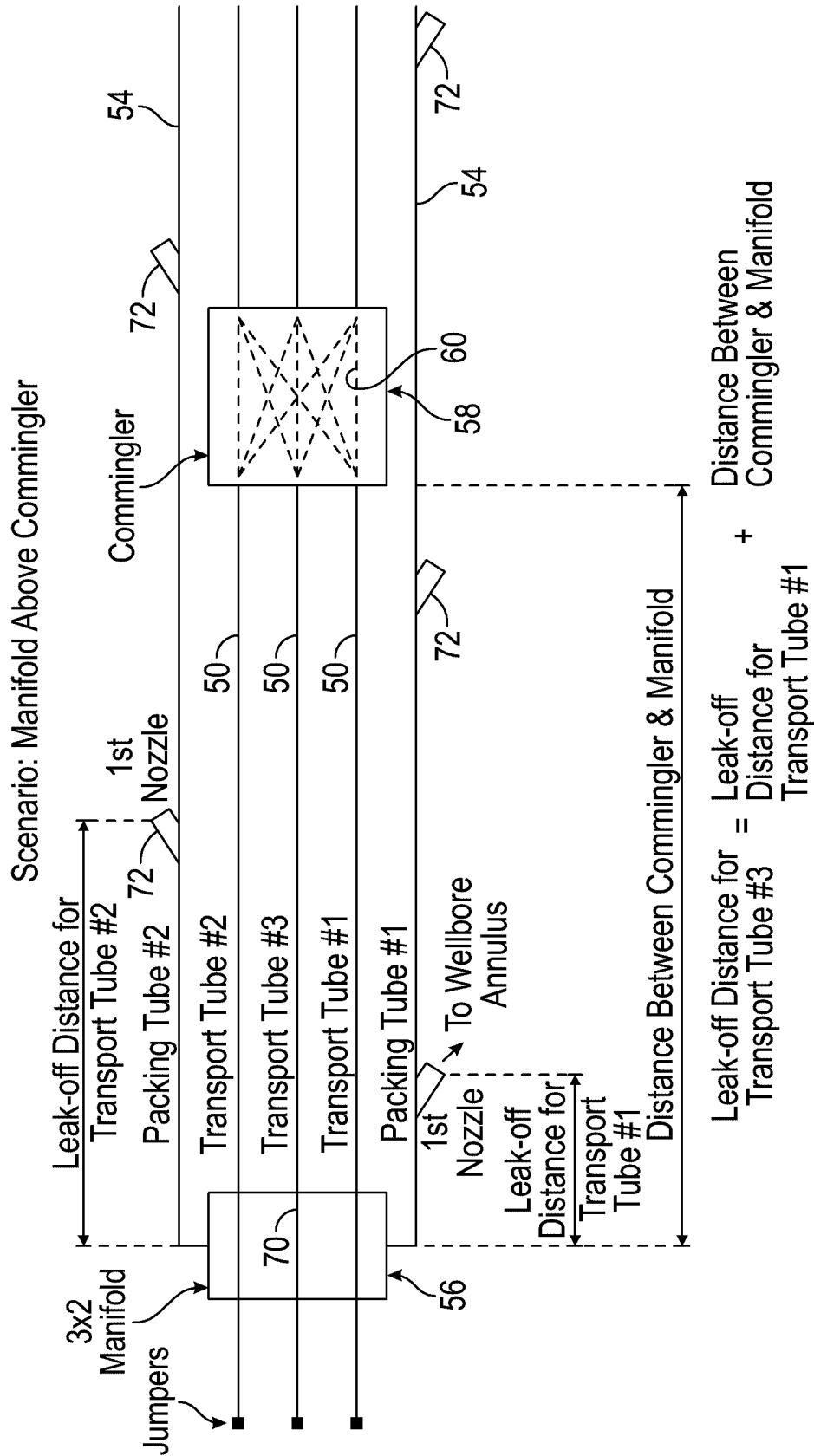


FIG. 8

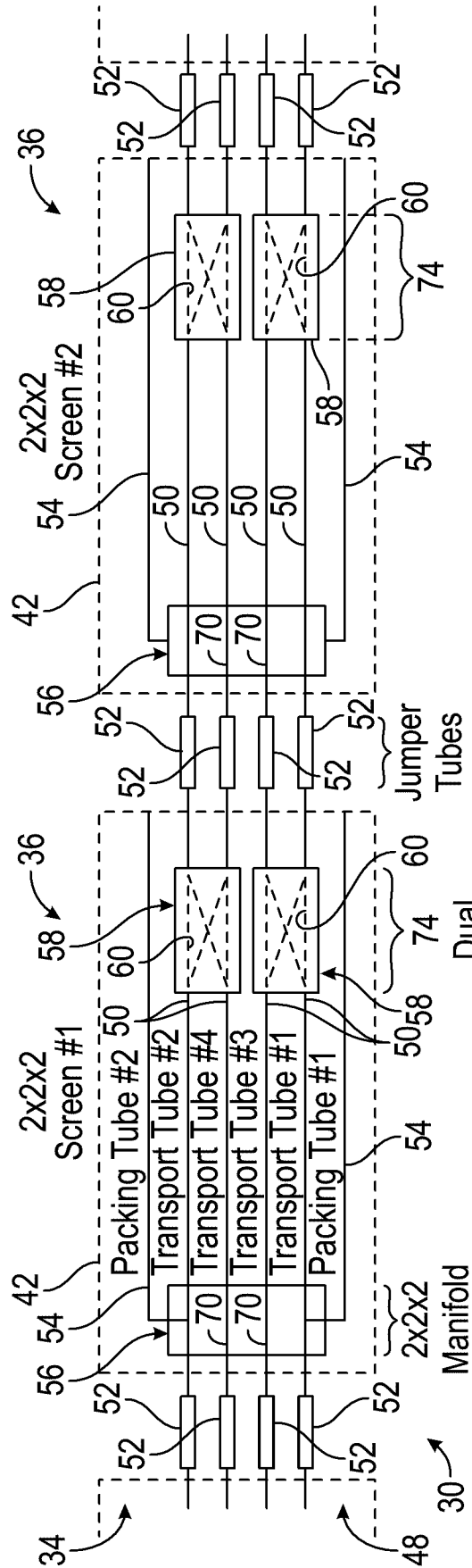
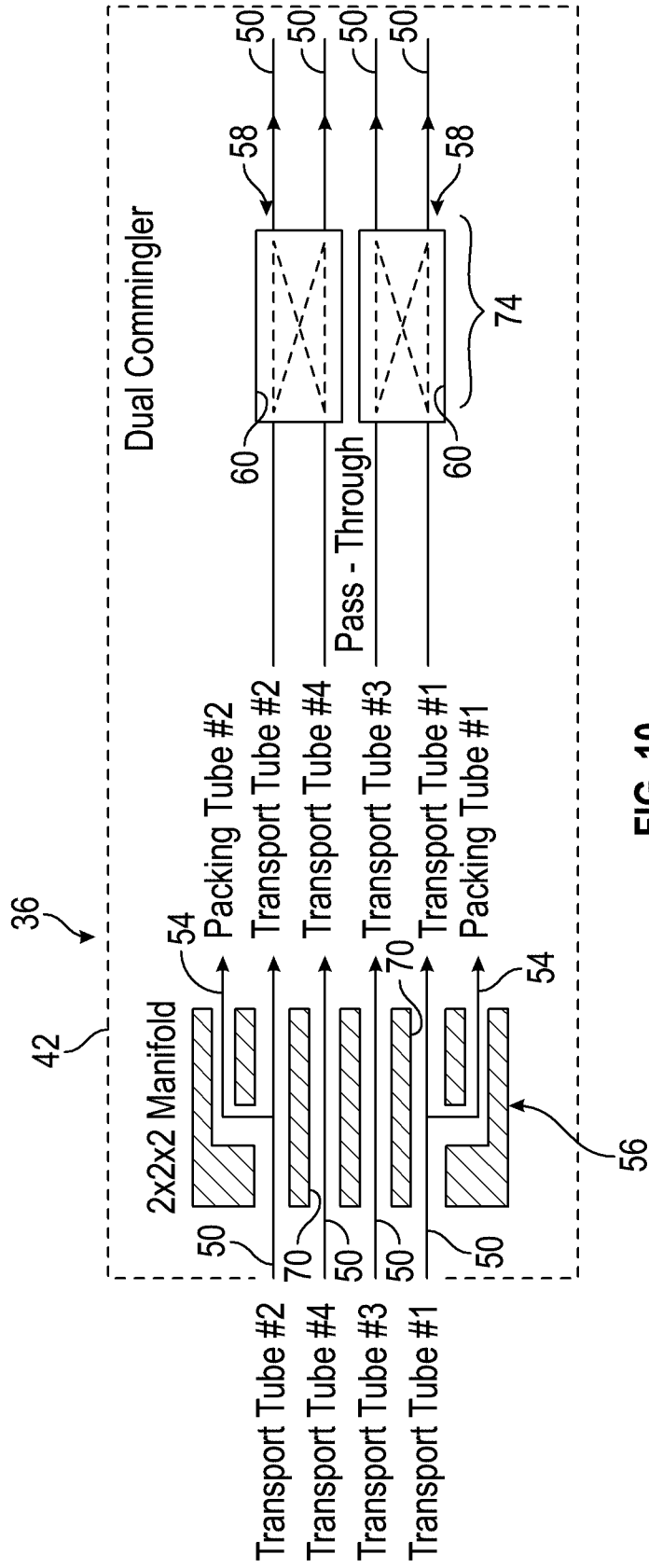


FIG. 9

Dual
Commingler



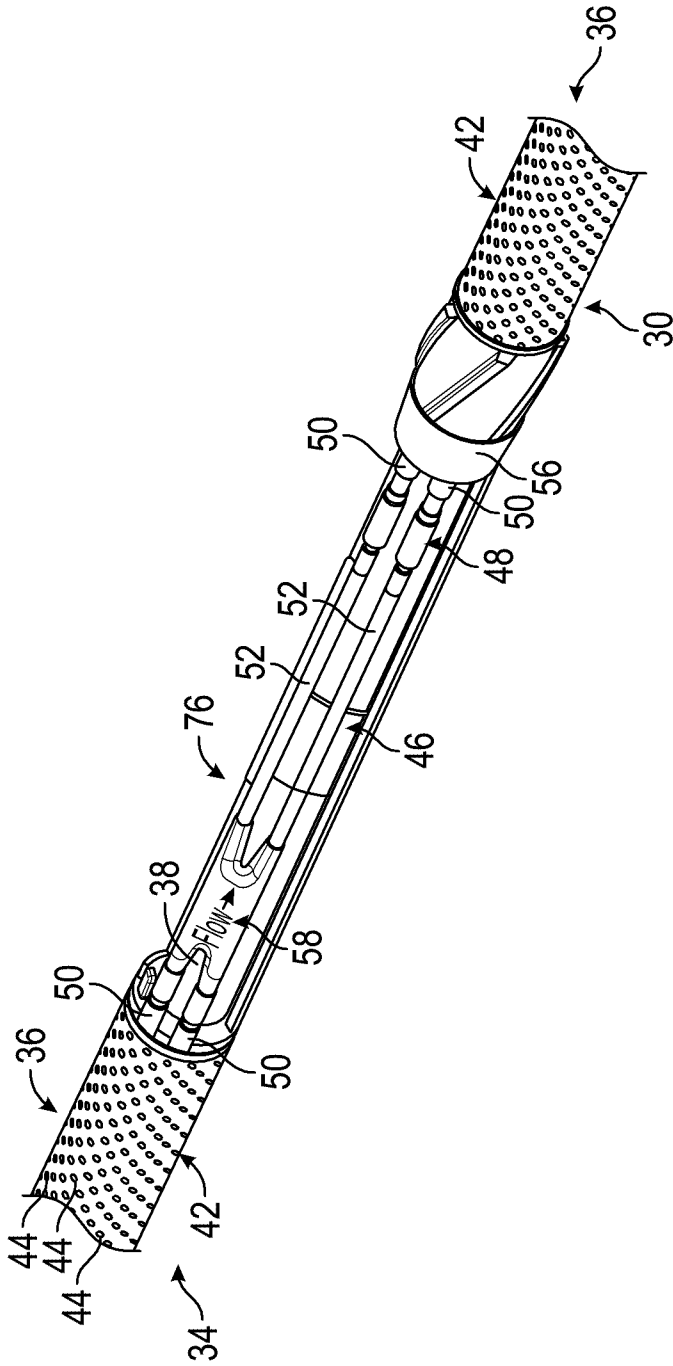


FIG. 11A

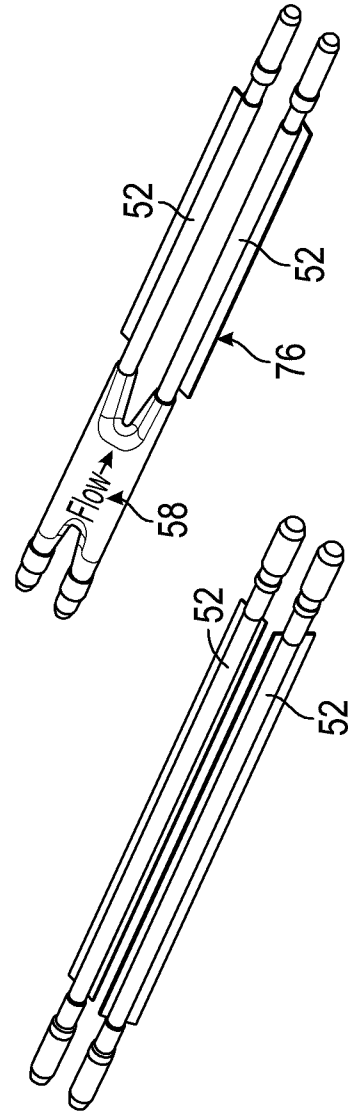


FIG. 11B

