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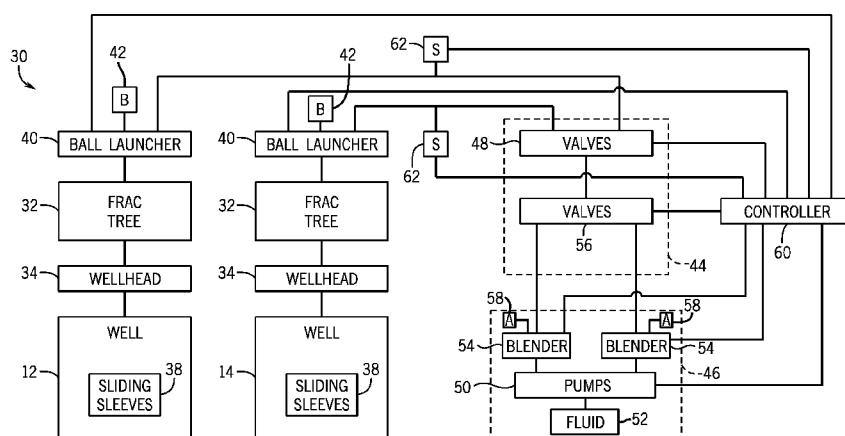


FIG. 2

(57) Abstract: A system for simultaneously fracturing multiple wells is provided. In one embodiment, the system includes fracturing trees (32) installed at multiple wells (12, 14). A fracturing manifold (44, 150, 168, 178, 190) is connected to the fracturing trees and includes output valves (48, 164, 166) to independently control flow of fracturing fluid from the manifold to each of multiple wells. The system may also include a controller (60) connected to the output valves so that the controller can remotely operate the output valves to simultaneously fracture the multiple wells and independently control the volume of fracturing fluid entering each of the wells from the fracturing manifold. Additional systems, devices, and methods are also disclosed.

MULTI-WELL SIMULTANEOUS FRACTURING SYSTEM

BACKGROUND

[0001] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the presently described embodiments. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present embodiments. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0002] In order to meet consumer and industrial demand for natural resources, companies often invest significant amounts of time and money in finding and extracting oil, natural gas, and other subterranean resources. Particularly, once a desired subterranean resource is discovered, drilling and production systems are often employed to access and extract the resource. These systems may be located onshore or offshore depending on the location of a desired resource. Further, such systems generally include a wellhead assembly through which the resource is extracted. These wellhead assemblies may include a wide variety of components, such as various casings, valves, fluid conduits, and the like, that control drilling or extraction operations.

[0003] Additionally, such wellhead assemblies may use a fracturing tree and other components to facilitate a fracturing process and stimulate production from a well. As will be appreciated, resources such as oil and natural gas are generally extracted from fissures or other cavities formed in various subterranean rock formations or strata. To facilitate extraction of such resources, a well may be subjected to a fracturing process that creates one or more man-made fractures in a rock formation. This facilitates, for example, coupling of pre-existing fissures and cavities, allowing oil, gas, or the like to flow into the wellbore. Such fracturing processes typically include injecting a fracturing fluid—often a mixture or slurry including sand and water—into the well to increase the well's pressure and form the man-made fractures.

SUMMARY

[0004] Certain aspects of some embodiments disclosed herein are set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of certain forms the invention might take and that these aspects are not intended to limit the scope of the invention. Indeed, the invention may encompass a variety of aspects that may not be set forth below.

[0005] Embodiments of the present disclosure generally relate to simultaneous fracturing of multiple wells. In at least some instances, pumping fluid into two or more wells simultaneously to fracture those wells reduces total pumping time for fracturing wells at a pad site. In one embodiment, a fracturing system includes a manifold having valves to independently control flow rates of fracturing fluid to multiple wells. Fracturing fluid can be pumped through the manifold and into the multiple wells simultaneously, and the valves can be operated to balance the volume of fluid pumped into each well. A controller can also be used with the system to remotely actuate the manifold valves and control flow rates based on measured parameters and stored data.

[0006] Various refinements of the features noted above may exist in relation to various aspects of the present embodiments. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. Again, the brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of some embodiments without limitation to the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other features, aspects, and advantages of certain embodiments will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. 1 generally depicts a fracturing system for simultaneously fracturing multiple wells in accordance with one embodiment of the present disclosure;

[0009] FIG. 2 is a block diagram of various components of the fracturing system of FIG. 1 in accordance with one embodiment;

[0010] FIGS. 3 and 4 are flow charts representative of methods for simultaneously fracturing multiple wells in accordance with certain embodiments of the present disclosure;

[0011] FIG. 5 generally depicts two horizontal wells having fracturing zones in accordance with one embodiment;

[0012] FIG. 6 is a block diagram of a programmable controller for operating the fracturing system of FIGS. 1 and 2 in accordance with one embodiment; and

[0013] FIGS. 7–10 depict various fracturing manifolds in accordance with certain embodiments of the present disclosure.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0014] One or more specific embodiments of the present disclosure will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0015] When introducing elements of various embodiments, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Moreover, any use of “top,” “bottom,” “above,” “below,” other directional terms, and variations of these terms is made for convenience, but does not require any particular orientation of the components.

[0016] Turning now to the present figures, an example of a fracturing system 10 is provided in FIG. 1 in accordance with one embodiment. The fracturing system 10 facilitates extraction of natural resources (e.g., oil or natural gas) from wells 12 and 14. Particularly, by injecting a fracturing fluid into the wells 12 and 14, the fracturing system 10 increases the number or size of fractures in a formation 16 to enhance recovery of natural resources present in the formation 16.

[0017] The fracturing fluid may, for example, include water (or another liquid) mixed with sand or some other proppants. The fracturing fluid is pumped into the formation 16 to extend fractures and fill them with the proppants, which operate to hold open the fractures after pumping has stopped to allow formation fluids to be more easily produced via the wells 12 and 14. In at least some embodiments, fracturing fluids used in the wells 12 and 14 also include other additives. For example, the fracturing fluid can include polymers or other agents to increase the viscosity of the fracturing fluid (which aids in carrying the proppants down the wells). And in some instances, the fracturing fluid includes acid (e.g., hydrochloric acid) that initiates fissures in the formation 16.

[0018] Although generally depicted as horizontal wells extending through the formation 16, the wells 12 and 14 could take other forms (e.g., vertical wells). In the presently illustrated embodiment, the wells 12 and 14 are surface wells formed at a common pad 20 and accessed through wellhead assemblies 18 installed at the wells. It will, of course, be appreciated that natural resources can be extracted from other types of wells, such as platform or subsea wells.

[0019] The fracturing system 10 also includes a fracturing supply system 22 coupled to the wellhead assemblies 18 by conduits 24 and 26 so as to provide fracturing fluid to the wells 12 and 14 via the conduits. In one embodiment, the fracturing supply system 22 includes various components depicted in block diagram 30 of FIG. 2. As here illustrated, each of the wells 12 and 14 has a fracturing tree 32 (part of the wellhead assembly 18 of FIG. 1) installed on a wellhead 34. The fracturing trees 32 include valves to control flow of fracturing fluids through the wellheads 34 and into their respective wells. The wells 12 and 14 include sliding sleeves 38, which can be run into or as part of casing strings in the wells. When actuated, the sliding sleeves 38 move to expose ports in the casing strings, allowing fracturing fluid pumped down the wells 12 and 14 to reach the formation 16 via the ports. The wells 12 and 14 can be divided into multiple fracturing zones (also referred to as fracturing stages) and sliding sleeves 38 can be used to isolate the fracturing zones to allow sequential fracturing of each zone.

[0020] In at least some embodiments, such as that depicted in FIG. 2, the sliding sleeves 38 are ball-actuated sliding sleeves and the fracturing system includes one or more ball launchers 40 to drop balls 42 (which may also be referred to as packer balls or frac balls) into the wells 12 and 14. For instance, at least some of the sliding sleeves 38 are constructed with seats or baffles for receiving packer balls 42. When the packer ball engages the seat, the ball inhibits flow through the seat and fluid pressure (e.g., from the pumping of fluid down a well behind the ball) increases and causes the ball to push the sliding sleeve 38 open. The sliding sleeve 38 can be retained in place by a shear pin or some other device so the ball does not move the sleeve 38 until the pressure on the ball exceeds a threshold amount.

[0021] The various sliding sleeves 38 of each well can be constructed for actuation by differently sized packer balls 42 and generally have seats with apertures that allow smaller balls 42 to pass through without actuating the sleeve. More specifically, the sliding sleeves 38 can be arranged in the wells in sequence by the size of the balls 42 used to actuate the sleeves, with the sleeves operated by the smallest balls provided furthest from the surface and the sleeves operated by the largest balls provided closest to the surface. In this arrangement, the smallest ball can be dropped into a well and pass

through the apertures in other sleeves before reaching (and actuating) the sleeve furthest from the surface. Balls of increasing size can then be sequentially dropped to actuate additional sleeves in the well, with the largest ball being the last dropped in order to actuate the sleeve closest to the surface. The sliding sleeves 38 can be placed between adjacent fracturing zones in the wells so that, as each ball 42 engages the seat of a corresponding sliding sleeve 38, the ball inhibits flow through the seat and isolates the fracturing zone associated with that actuated sleeve from other fracturing zones further down the well. To facilitate the sequential actuation of the sleeves 38, the conduits (e.g., conduits 24 and 26) connecting the ball launchers 40 to the wells 12 and 14 can be provided as single high-pressure lines (one to each well) having bores of sufficient size to allow the largest packer balls 42 to pass from the ball launchers 40 to the wells.

[0022] The system depicted in FIG. 2 also includes a fracturing manifold 44 for controlling the flow of fracturing fluids to both well 12 and well 14. Fluid conduits 24 and 26 (FIG. 1) generally connect the fracturing manifold 44 to the wells 12 and 14. This allows fluid to be routed from the manifold to either or both of the wells 12 and 14 via one or more manifold output valves 48. The output valves 48 can include any suitable valves (e.g., chokes or gate valves) that facilitate separate and independent control of the flow of fluid from the fracturing manifold 44 to each of the wells 12 and 14. In some embodiments the ball launchers 40 are provided separately from the fracturing manifold 44 (as depicted in FIG. 2), while in others the ball launchers 40 are integrated into the manifold 44 (see, e.g., FIGS. 7–10).

[0023] Various components, collectively denoted with reference numeral 46 in FIG. 2, cooperate to provide fracturing fluid to the manifold 44. In the depicted embodiment, such components include pumps 50, fluid tanks 52, and blenders 54. The pumps 50 can be provided by pumping trucks or in some other manner, and these pumps are used to route fluid from the fluid tanks 52 to the manifold 44 and, ultimately, to the wells. Though often water-based, any suitable fracturing fluids can be stored in the fluid tanks 52. In at least some embodiments, the fracturing fluid stored in the fluid tanks is gelled or crosslinked for increased viscosity, thereby enhancing the ability of the fluid to transport proppants to the formation.

[0024] One or more blenders 54 are used to mix additives 58 into the fracturing fluid. While some other embodiments include a single blender 54, the system depicted in FIG. 2 includes two blenders. One of the blenders 54 can be used to mix an additive 58 of sand or some other proppant into the fracturing fluid routed from the fluid tanks 52 so that the proppants can be injected into the formation 16 to maintain fissures created or extended during fracturing. The other blender 54 can be used to mix an additive 58 of acid that initiates the creation of new fissures or the extension of old fissures in the formation 16. In some instances, the fracturing fluid with acid is provided for an initial period to promote fissures and then followed with proppant-laden fracturing fluid to inhibit closing of these fissures once fracturing is completed. Given its role in initiating fissures in the formation 16, the mix of fracturing fluid and acid can be referred to as a “fracturing spear.” As noted above, a single blender 54 could instead be used for mixing additives into the fracturing fluid. For example, a single blender 54 could add acid to the fracturing fluid for a given period, after which the blender 54 could be converted to then add a proppant to the fracturing fluid for another time period. But having two blenders 54 may be more efficient in some instances by avoiding conversion of a single blender to mix different additives into the fracturing fluid at different times. And while two blenders 54 are presently depicted, it is noted that additional blenders 54 could also be provided.

[0025] In those embodiments having multiple blenders 54, and as illustrated in FIG. 2 by way of example, the manifold 44 can include input valves 56 for controlling which fracturing fluid is routed to the output valves 48 at a given time. For instance, one of the input valves 56 can be opened to allow the fracturing spear into the manifold 44 (that is, the fracturing fluid mixed with acid by one of the blenders), while another of the input valves 56 is closed to inhibit flow of proppant-laden fracturing fluid (mixed by a different blender) into the manifold 44. Once a desired amount of spear fluid is received by the manifold 44 (which can be routed to one or both wells 12 and 14), the input valves 56 can be operated to stop flow of the spear fluid into the manifold 44 and to allow the fracturing fluid with proppants to enter the manifold 44 and pass to the wells 12 and 14. Like the output valves 48, the input valves 56 can include chokes, gate valves, or any other suitable valves.

[0026] Although any or all of the ball launchers 40, the output manifold valves 48, and the input manifold valves 56 could be actuated manually, in at least some embodiments these components are operated remotely by a controller. In FIG. 2, for example, a controller 60 is connected to the ball launchers 40, the valves 48, and the valves 56 to control fracturing of the wells 12 and 14. More specifically, the controller 60 can operate the valves 48 to independently control the flow of fracturing fluid to each of the wells 12 and 14 (e.g., with a separate valve 48 for each of the wells). One or more sensors 62 (e.g., flow meters, pressure gauges, and densimeters) are connected downstream from the output valves 48 to measure operational parameters (e.g., flow rate and pressure). And as discussed in greater detail below, these measured parameters can then be provided as input to the controller 60 to facilitate operation of the fracturing system. The controller 60 can also operate the valves 56 to select a fracturing fluid to be provided to the wells (e.g., one with a high acid concentration or one carrying proppants) and operate the ball launchers 40 to drop balls into the wells 12 and 14 (e.g., to engage sliding sleeves 38 and select fracturing zones). Still further, the controller 60 of some embodiments can also control operation of other devices, such as the blenders 54 and the pumps 50.

[0027] To reduce the amount of time needed to fracture wells on a shared pad, at least some embodiments of the present technique enable multiple wells to be fractured simultaneously. That is, fracturing fluid may be pumped into two or more wells at the same time to fracture rock surrounding the wells and stimulate well productivity. This is in contrast to other techniques, such as sequential fracturing of each well or other fracturing processes (e.g., zipper fracturing) in which two wells alternate between being prepared for fracturing and actually being fractured. The simultaneous fracturing techniques disclosed herein can be used to reduce, in some instances significantly, the amount of pumping time and associated costs for injecting fluid to fracture multiple wells compared to some previous approaches.

[0028] With this in mind, two processes for fracturing multiple wells (e.g., wells 12 and 14) are generally represented by flow charts 70 and 90 in FIGS. 3 and 4 in accordance with certain embodiments. These processes are described below in the context of the fracturing system and various components described above with respect

to FIGS. 1 and 2, but it will be appreciated that the methods could be readily applied to other systems.

[0029] In the embodiment generally represented in FIG. 3, the wells 12 and 14 are connected to the fracturing manifold 44 (block 72). The wells 12 and 14 can be connected in any suitable manner, but in at least some instances each of the wells 12 and 14 are connected to the manifold 44 via a conduit with a bore diameter sufficient to pass any packer balls 42 to be dropped within the well (e.g., a conduit with a four-inch bore in one embodiment). Once the wells 12 and 14 are connected to the fracturing manifold, fracturing fluid can be pumped into the manifold (block 74) and then routed out of the manifold (block 76) into the wells 12 and 14 such that they receive fracturing fluid concurrently. Pumping of the fracturing fluid into each of the wells continues so that the wells 12 and 14 can be fractured simultaneously (block 78) to stimulate productivity of the wells. Post-fracturing production can commence (block 80) at any desired time after fracturing is complete (e.g., soon after flowback testing or after a prolonged shut-in period).

[0030] Fracturing multiple wells simultaneously reduces the amount of pumping time (and expense) needed to complete fracturing of wells at a pad. In at least some instances, operation of the fracturing system can be improved by controlling the individual flows of fracturing fluid to each well from the fracturing manifold 44. By way of example, the process generally represented in FIG. 4 includes pumping fracturing fluid into multiple wells simultaneously (block 92) and monitoring one or more fluid parameters for each well (block 94). Examples of the monitored fluid parameters include flow rate, flow volume, density, and pressure, and these parameters can be measured via any suitable devices (e.g., sensors 62) downstream from the output valves 48. The method also includes operating valves of the fracturing manifold 44 (e.g., output valves 46 and input valves 56) to control the fracturing fluid entering each of the wells connected to the manifold (block 96) based on fluid parameters monitored for each well. Additionally, in this embodiment the method includes dropping balls (block 98) in the wells 12 and 14 to actuate sliding sleeves 38 and isolate a selected fracturing stage from preceding stages deeper in the wells.

[0031] The operating of the valves and dropping of balls represented by blocks 96 and 98 may be better understood with reference to FIG. 5. As here depicted, the wells 12 and 14 have lateral (here horizontal) portions extending through the formation 16. The lateral portions of these wells can have lengths 102 and 112 of thousands of feet measured heel to toe, and these lengths may be equal to or different from one another. The lateral portions of the wells 12 and 14 can be divided into multiple fracturing zones. In FIG. 5, the well 12 includes fracturing zones or stages 104, 106, 108, and 110, and the well 14 includes fracturing zones or stages 114, 116, 118, and 120. Although only a handful of fracturing zones are depicted herein for the sake of explanation, it is noted that the wells 12 and 14 could include any number of desired fracturing zones. Further, each well could be divided into fracturing zones of equal size or of different size, and the zones of the different wells could also be sized similarly or differently compared to one another. The fracturing zones in some embodiments are divided by sliding sleeves 38 to facilitate sequential isolation and fracturing of these zones.

[0032] In at least some embodiments, including the process represented in FIG. 4, the fluid distribution between the simultaneously fractured wells is controlled to reduce total pumping time for fracturing the wells. The amount of fracturing fluid used for each well (and for each fracturing zone in the well) can vary depending on the characteristics of the well (e.g., length of well or porosity of the formation). But absent leaks in the system, fluid distribution from the fracturing manifold 44 can be described by:

$$V_{out} = \sum_{i=1}^n V_i,$$

in which V_{out} is the volume of fracturing fluid output from the fracturing manifold 44, n is the number of wells being simultaneously fractured (two in the presently described embodiment, although a different number of wells may be simultaneously fractured in other embodiments), and V_i is the volume of fracturing fluid pumped into an individual well i . Given the relationship of flow volume to flow rate, the fluid distribution from the manifold 44 is also described by:

$$V_{out} = \sum_{i=1}^n \int Q_i dt,$$

wherein Q_i is the volumetric flow rate for well i .

[0033] In a simple case in which the wells 12 and 14 are identical in length, number of fracturing zones, and wellbore length of the fracturing zones, and also in which each fracturing zone is to receive the same amount of fracturing fluid, the fracturing fluid in the manifold 44 could be divided evenly by the output valves 48 so that each well 12 and 14 receives fracturing fluid at the same rate, such as twenty-five barrels (approximately 2980 liters) per minute, for an identical amount of time. More specifically, a desired amount of fracturing spear fluid (e.g., fifty barrels) can be provided to each well 12 and 14 simultaneously, such as by opening an input valve 56 to allow the spear fluid to enter the manifold 44 and opening output valves 48 such that equal amounts of the spear fluid enters each well. The input valves 56 can then be operated to stop flow of the spear fluid into the manifold and to permit flow of a proppant-laden fracturing fluid into the wells 12 and 14 in equal amounts. Once a given zone has been fractured, the next fracturing zone can be selected by dropping balls 42 into each of the wells to activate sliding sleeves 38 and the spear fluid and the proppant-laden fluid can be routed in the same way to the next fracturing zone. This may be repeated until all of the fracturing zones have been fractured.

[0034] But in practice there will typically be variation in one or more well or fracturing parameters (e.g., wells of different lengths or differences in fracturing zones). In such instances, fluid flow to the individual wells from the fracturing manifold 44 can be controlled through operation of the output valves 48. For example, if the well 12 were longer than the well 14, pumping fracturing fluid at the same rate into each well to fracture the lowest zones in each well (i.e., zones 104 and 114) and then dropping balls 42 into each well at the same time to select the next fracturing zones (i.e., zones 106 and 116) for each well would cause a greater volume of fracturing fluid to be pumped into the fracturing zone 104 than into the fracturing zone 114 (due to the increased volume of fracturing fluid in the well 12 compared to that in well 14 when the balls 42 are dropped).

[0035] In some embodiments, however, the volumes of fracturing fluid pumped into zones 104 and 114 are balanced by operating the output valves 48 to independently control flow to the wells and change the comparative flow rates of fracturing fluid into the wells 12 and 14. As noted above, the volume of fracturing fluid pumped into each well is equal to the product of the volumetric flow rate and the amount of time the fluid flows at that rate. Thus, the volume of fracturing fluid pumped into each well can be controlled by adjusting either the flow rate or the amount of time that the fluid is pumped. The greater volume of the well 12 (due to its increased length) can be accounted for as an offset to the amount of fluid that is to be pumped into well 12 from the manifold 44 to fracture zone 104 before dropping a ball 42 to select the next fracturing zone. For instance, if a casing string of the well 12 receiving the fracturing fluid has a volume that is greater than that of a similar casing string of well 14, the manifold output valves 48 can be operated to slow the flow (and reduce the volume) to the well 12 from the manifold 44 compared to the flow (and volume) to the well 14. Further, full flow (e.g., twenty-five barrels per minute) can be provided to the well 14 and a desired fracturing time for a given zone can be calculated based on:

$$V_{frac} = Qt + V_p,$$

where V_{frac} is the volume of fracturing fluid to pump into the fracturing zone, Q is the volumetric flow rate at which fluid is pumped into the well 14 from the fracturing manifold 44, t is the desired fracturing time for the zone, and V_p is the volume of the passageway (i.e., fluid conduit) from the ball launcher 40 (of the well 14) to the far end of the zone being fractured.

[0036] Accordingly, in one embodiment a manifold valve 48 is opened to allow full flow of fracturing fluid, and the volumetric flow rate is measured via a sensor 62 (e.g., a flow meter) and input to the controller 60. The desired fracturing volume is provided to the controller 60 as initial data, and the volume of the passageway can also be provided as (or calculated from) initial data to the controller 60. Once the desired fracturing time is determined for zone 114, that time can be input into the same formula to calculate the appropriate flow rate (the only remaining variable) from the manifold 44 to the well 12 while fracturing the zone 104. (It is noted that the fracturing and passageway

volumes for zone 104 can also be determined from initial data provided to the controller 60, but may differ from those for zone 114.) The manifold valve 48 that controls flow to the well 12 can then be adjusted to set the flow rate (which can be measured by a sensor 62) to the calculated amount. Once the desired fracturing time has elapsed, the ball launchers 40 may be activated to drop balls 42 into the wells 12 and 14 to isolate the next fracturing stages for stimulation. Each fracturing stage of corresponding pairs of stages (e.g., zones 106 and 116, zones 108 and 118, and zones 110 and 120) can be fractured at the same rate and for the same duration if desired, although the rates and durations could also be varied (e.g., if it is intended that the zones are to receive different volumes of fracturing fluid).

[0037] Although the above example describes balancing fluid distribution by slowing the flow rate into one well compared to another, in other embodiments the flow rates of both wells may be kept the same while the fracturing time is varied. For example, rather than slowing the flow rate of fluid from the manifold 44 to the well 12 for fracturing zone 104, the fracturing time could be reduced. That is, a valve 48 of the manifold could be closed once a desired volume of fracturing fluid has been pumped into the well 12 while additional fracturing fluid is pumped into well 14.

[0038] Various functionality described above (including, for example, determining desired flow rates and times for multiple wells and fracturing zones, operating the valves of the manifold to supply desired fluids at desired rates, and dropping balls into the wells to isolate fracturing zones) can be implemented with the controller 60 or with any other suitable controller. In at least some embodiments, such a controller is provided in the form of a processor-based system, an example of which is provided in FIG. 6 and generally denoted by reference numeral 130. In this depicted embodiment, the system 130 includes a processor 132 connected by a bus 134 to a memory device 136. It will be appreciated that the system 130 could also include multiple processors or memory devices, and that such memory devices can include volatile memory (e.g., random-access memory) or non-volatile memory (e.g., flash memory and a read-only memory). The one or more memory devices 136 are encoded with application instructions 138 (e.g., software executable by the processor 132 to perform the control and analysis functionality described herein), as well as with data 140 (e.g.,

volumes of fracturing fluid to be provided to the fracturing zones of the wells). In one embodiment, the application instructions 138 are stored in a read-only memory and the data 140 is stored in a writeable non-volatile memory (e.g., a flash memory). The application instructions 138 and the data 140 can be copied into a faster volatile memory (such as a random-access memory or a local memory of the processor) for execution by the processor. This generally serves to reduce latency and increase operating efficiency of the system 130.

[0039] The system 130 also includes an interface 142 that enables communication between the processor 132 and various input or output devices 144. The interface 142 can include any suitable device that enables such communication, such as a modem or a serial port. The input and output devices 144 can include any number of suitable devices. For example, in one embodiment the devices 144 include the sensors 62 (FIG. 2) for providing input of measured parameters (e.g., flow volume, flow rate, density, and pressure) to the system 130, a keyboard to allow user-input to the system 130, and a display or printer to output information from the system 130 to a user. Of course, some devices may allow both input and output, such as a touchscreen display. The input and output devices 144 can be provided as part of the system 130, although in other embodiments such devices may be separately provided.

[0040] As previously noted, the fracturing manifold 44 facilitates control of fracturing fluid to multiple wells simultaneously. The fracturing manifold 44 can be provided in any suitable form, and examples of forms the manifold 44 could take are generally depicted in FIGS. 7–10. Beginning with FIG. 7, a manifold 150 is shown as installed to route fluid received from an intake conduit 152 (e.g., from pumps 50) to output conduits 154 and 156 (e.g., to wells 12 and 14). An input valve 158 is provided upstream from a ball drop device 160 (e.g., a ball launcher 40 or a connection block for receiving a ball from such a launcher) having an access port 162 for receiving a ball 42. The manifold 150 also includes output valves 164 and 166 (which may function like the output valves 48 described above) for controlling flow of fracturing fluid from the manifold to connected wells. The valves 158, 164, and 166 can be actuated in any desired manner (e.g., hydraulically or manually). Additionally, in at least some

embodiments these valves are hydraulic valves that are actuated remotely in an automated manner via the controller 60.

[0041] Activation of a ball launcher (whether provided as, or connected to, the ball drop device 160) to drop balls 42 is also controlled by the controller 60 in some embodiments. To drop balls simultaneously into multiple wells, the valves 164 and 166 can be initially closed. A first ball can be dropped into the manifold 150 and one of the valves 164 and 166 can be briefly opened to advance the first ball a short distance downstream from the opened valve. Once that valve is closed, a second ball can be dropped into the manifold 150 and the other valve can be opened to advance the second ball downstream from that valve. Both valves 164 and 166 can then be opened to flow the balls into their respective wells (via conduits 154 and 156).

[0042] The manifolds of FIGS. 8–10 also include valves 158, 164, and 166 that can be operated in the same manner as described above with respect to FIG. 7. Further, in FIG. 8 a manifold 168 includes a ball drop device 170 with two access ports 172 and 174 for receiving balls 42. The device 170 includes an internal divider 176 so that balls entering the manifold through the access port 172 are routed through valve 164 into conduit 154 and balls entering through the access port 174 are routed through valve 166 into conduit 156.

[0043] In FIG. 9, a manifold 178 includes a ball drop device 180. The device 180 includes access ports 182 and 184 for receiving balls 42, and also includes an internal divider 186 that operates like the divider 176 to guide balls in desired directions. The manifold 178 also includes a cap 188 that can be removed to provide wash-out access to the interior of the manifold. FIG. 10 depicts a manifold 190 having a connection block 192 (including a cap 194 that provides wash-out access to the manifold) for joining the valves 158, 164, and 166. But unlike the manifolds of FIGS. 7–9 (in which the ball drop devices are provided between the input valve 158 and the output valves 164 and 166), the manifold 190 is arranged so that balls can be dropped into the system downstream from the valves 164 and 166. Particularly, a ball drop device 196 with access port 198 allows balls to be routed through the conduit 154 to one well, and a ball drop device 200 with access port 202 functions similarly to allow balls to be

routed through the conduit 156 to another well. The ball drop devices 196 and 200 (like those shown in FIGS. 7–9) can be ball launchers or connection blocks constructed to receive balls from such launchers.

[0044] While the aspects of the present disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. But it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

CLAIMS

1. A system comprising:

a first fracturing tree (32) installed at a first well (12);

a second fracturing tree (32) installed at a second well (14);

a fracturing manifold (44, 150, 168, 178, 190) connected to the first fracturing tree and the second fracturing tree, the fracturing manifold including output valves (48, 164, 166) to independently control flow of fracturing fluid from the fracturing manifold to the first fracturing tree and from the fracturing manifold to the second fracturing tree; and

a controller (60) connected to the output valves of the fracturing manifold to enable the controller to remotely operate the output valves to simultaneously fracture both the first well and the second well by routing fracturing fluid into each of the first and second wells via its respective fracturing tree and to independently control the volume of fracturing fluid entering the first well and the volume of fracturing fluid entering the second well from the fracturing manifold.

2. The system of claim 1, comprising at least one ball launcher (40) connected to one or both of the first fracturing tree and the second fracturing tree.

3. The system of claim 2, wherein each of the first and second wells include sliding sleeves (38) for isolating different fracturing zones (104, 106, 108, 110, 114, 116, 118, 120) in the first and second wells.

4. The system of claim 3, wherein the sliding sleeves are ball-actuated sliding sleeves and the controller is connected to the at least one ball launcher so as to allow the controller to remotely operate the at least one ball launcher to release balls into the fracturing fluid to be conveyed to the ball-actuated sliding sleeves of the first and second wells.

5. The system of claim 1, comprising a fracturing supply system (46) connected to the fracturing manifold, the fracturing supply system including pumps (50) connected to a blender (54).
6. The system of claim 5, wherein the fracturing supply system includes an additional blender (54) and the fracturing manifold includes input valves (56, 158) connected to the blender and to the additional blender to control flow of fracturing fluid from the blender and from the additional blender into the fracturing manifold.
7. The system of claim 6, wherein the controller is connected to the input valves to enable remote operation of the input valves by the controller.
8. The system of claim 1, comprising sensors (62) coupled between the output valves of the fracturing manifold and the first and second wells, wherein the controller is configured to receive input from the sensors and use the received input to vary operation of the output valves of the fracturing manifold.
9. The system of claim 1, comprising one or more ball launchers (40, 160, 170, 180, 196, 200) integrated as part of the fracturing manifold.
10. A method comprising:
 - receiving fracturing fluid into a manifold (44, 150, 168, 178, 190);
 - routing the fracturing fluid from the manifold into multiple wells (12, 14) simultaneously;
 - measuring flow characteristics of the fracturing fluid output from the manifold with sensors (62) downstream from the manifold;
 - providing input based on the measured flow characteristics to a controller (60);
 - and

actuating valves (48, 164, 166) connected to the multiple wells with the controller to control the amount of fracturing fluid routed into each of the multiple wells.

11. The method of claim 10, wherein measuring flow characteristics of the fracturing fluid output from the manifold includes measuring volumetric flow rate from the manifold to each of the multiple wells.

12. The method of claim 11, comprising:

calculating a duration for pumping fracturing fluid from the manifold into a first well of the multiple wells to stimulate a fracturing zone (104, 106, 108, 110) of the first well (12); and

determining, based on the calculated duration for the first well, a desired volumetric flow rate for fracturing fluid into a second well (14) via the manifold.

13. The method of claim 10, wherein actuating valves connected to the multiple wells includes operating at least one of the valves to balance volumes of fracturing fluids routed into each of the multiple wells.

14. The method of claim 10, comprising selecting between different fracturing fluids for pumping into the manifold by actuating one or more input valves (56, 158) of the manifold.

15. The method of claim 10, wherein routing the fracturing fluid from the manifold into the multiple wells causes simultaneous fracturing of the multiple wells, the method further comprising subsequently producing formation fluids from the simultaneously fractured multiple wells.

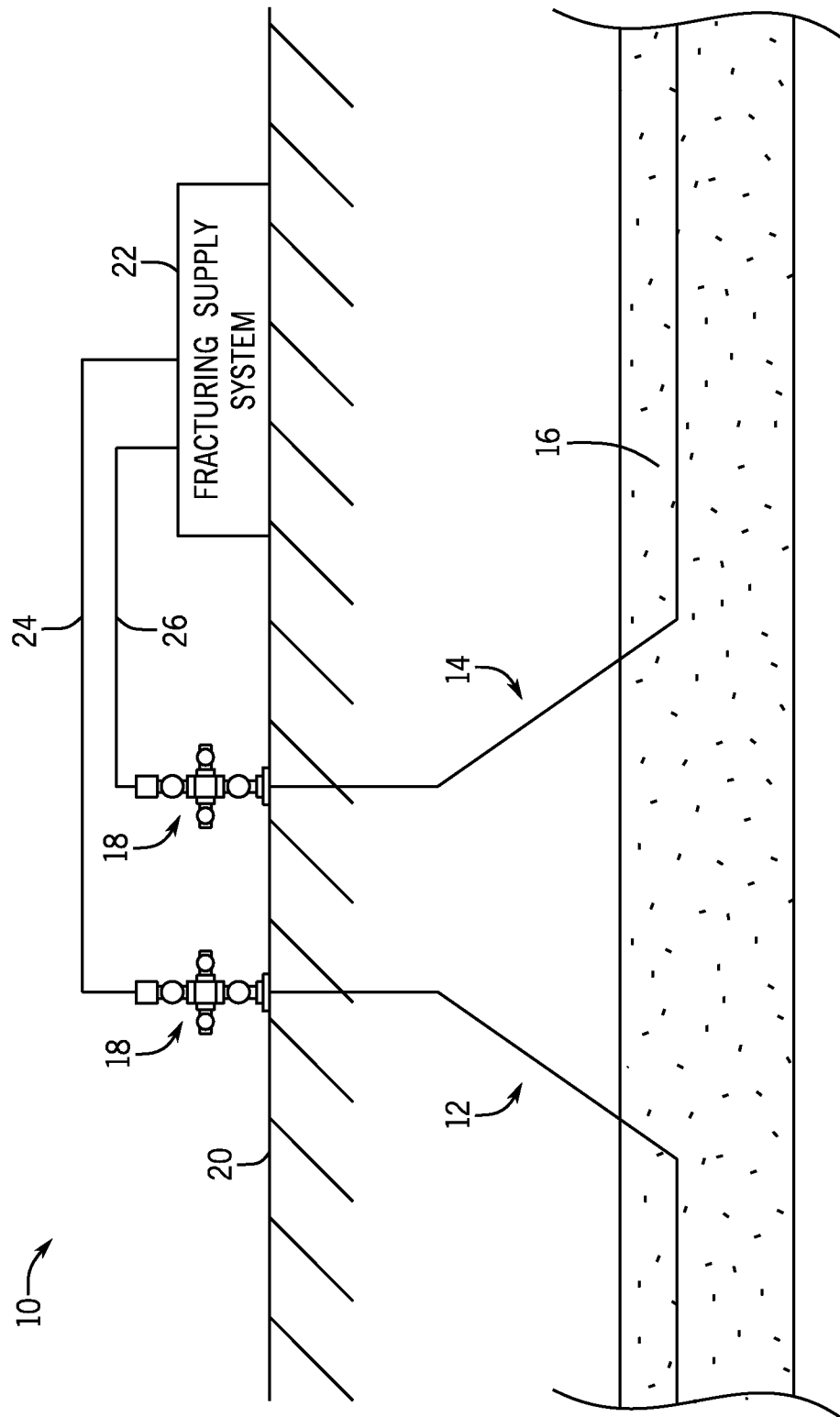
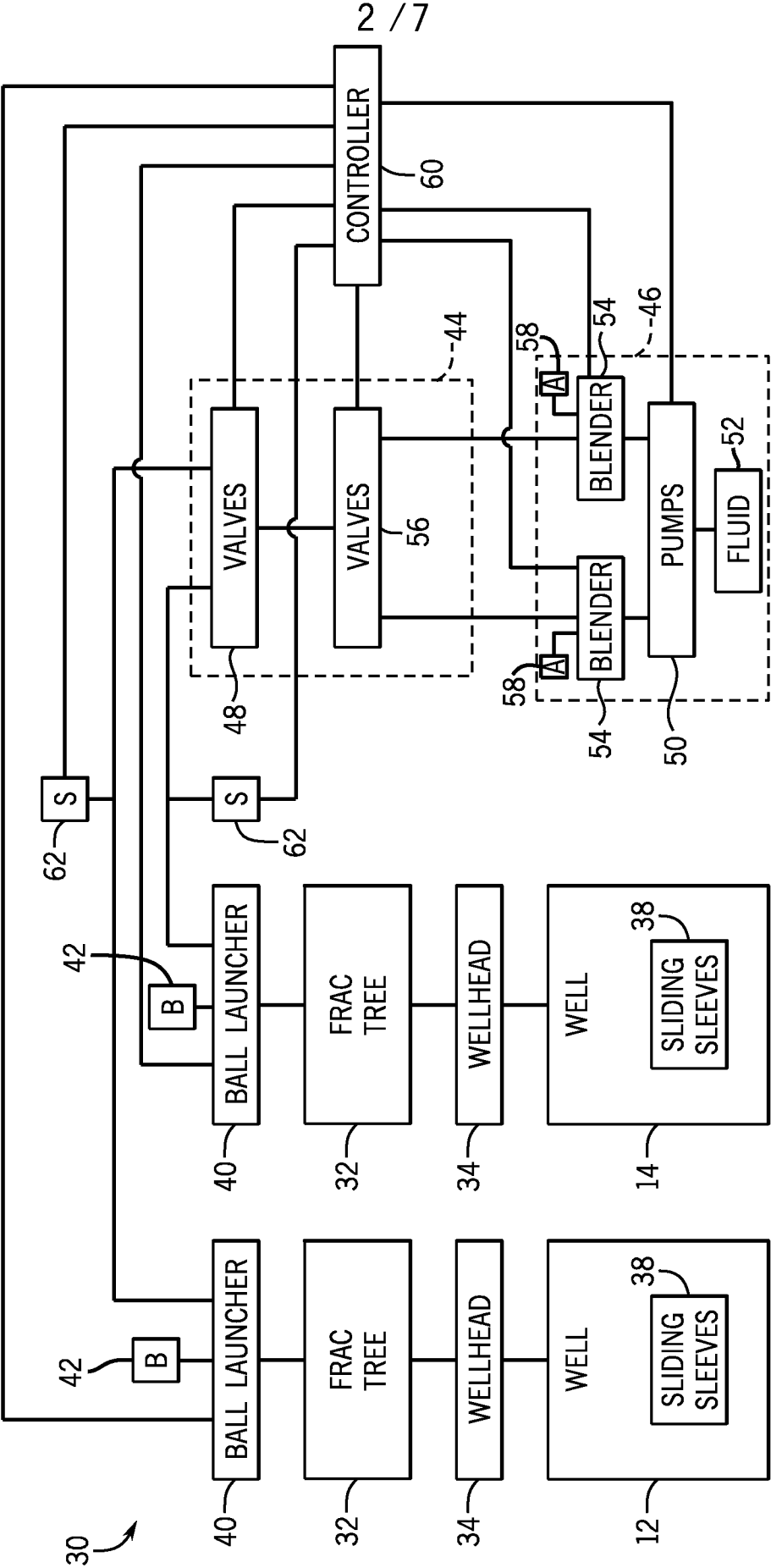


FIG. 1



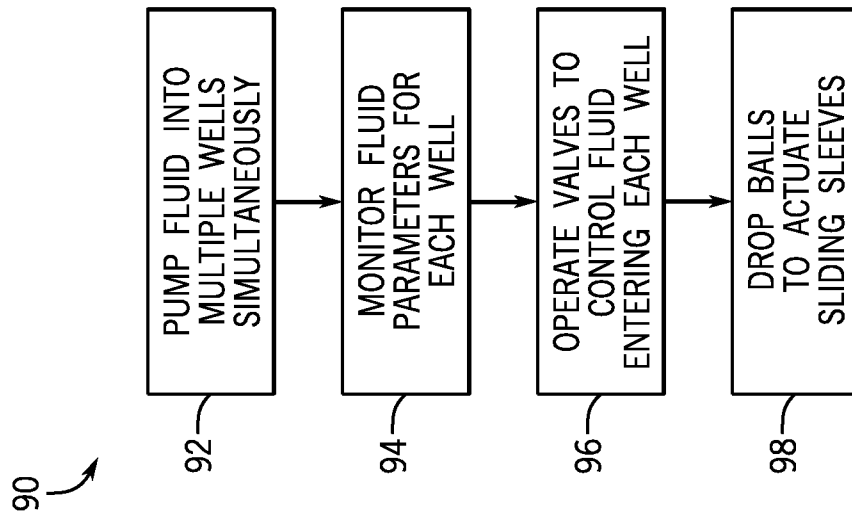


FIG. 4

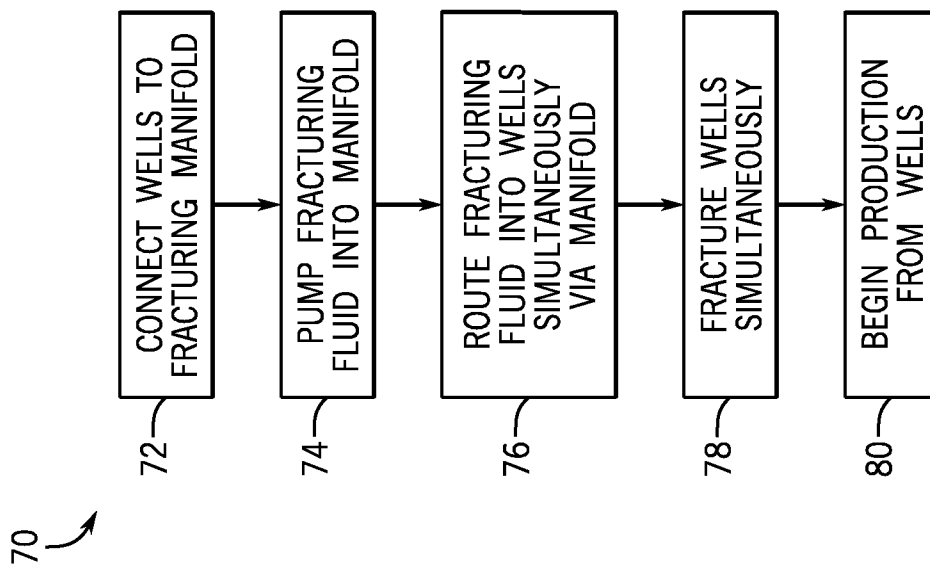


FIG. 3

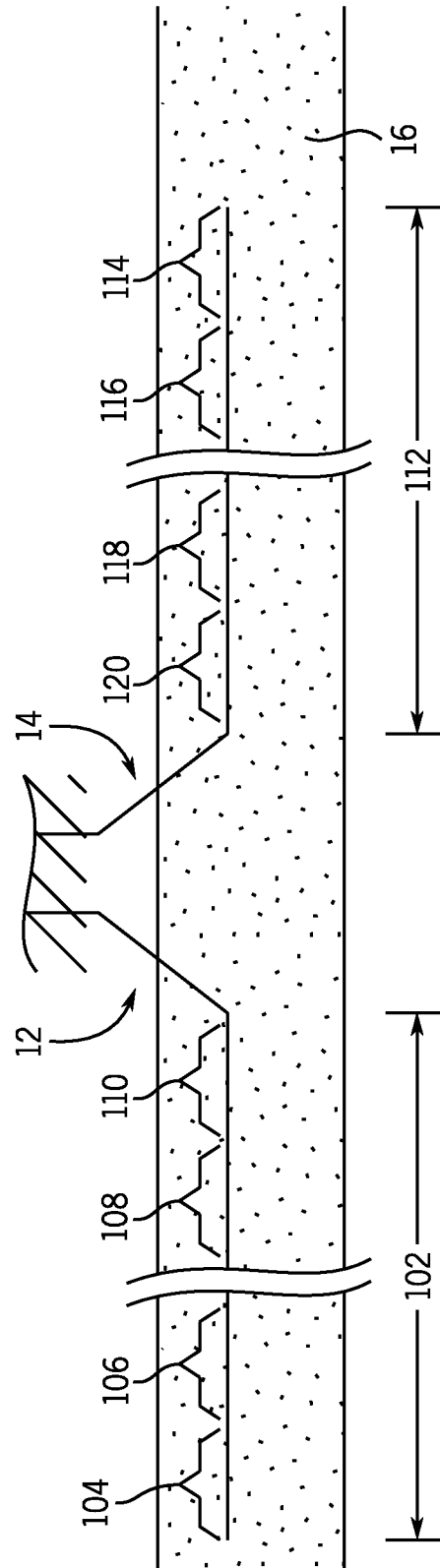


FIG. 5

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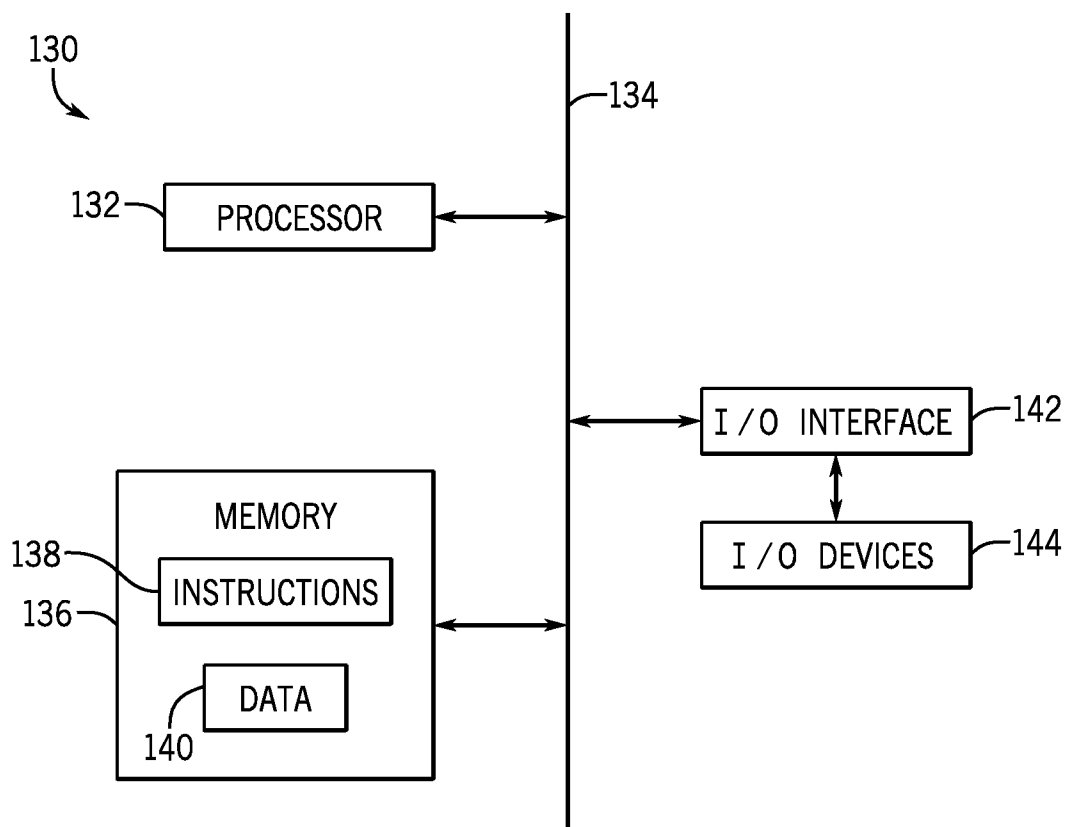
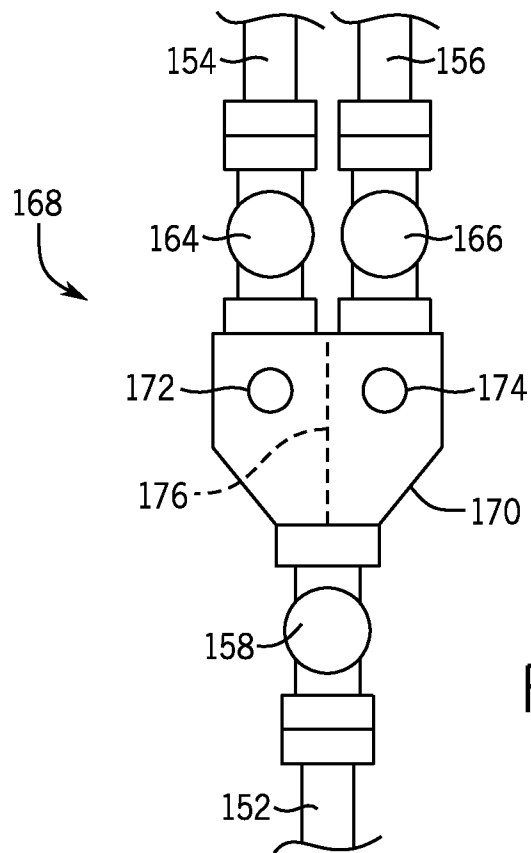
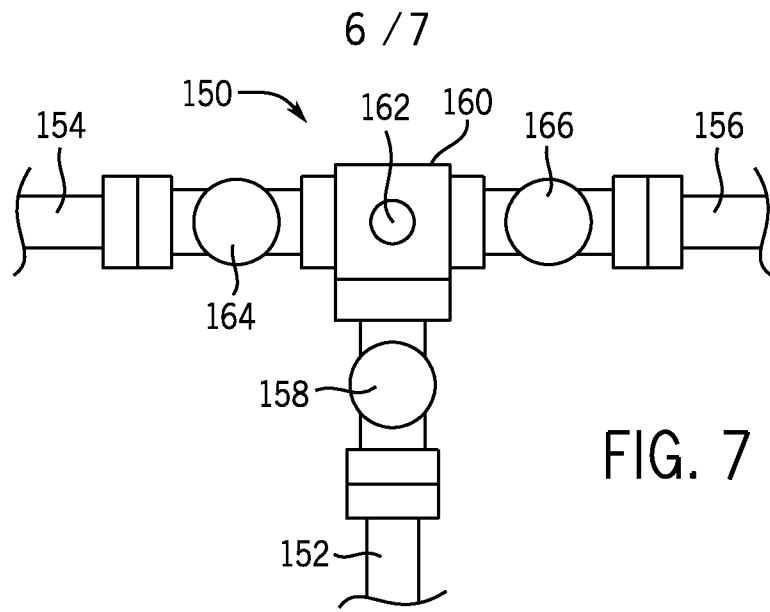


FIG. 6



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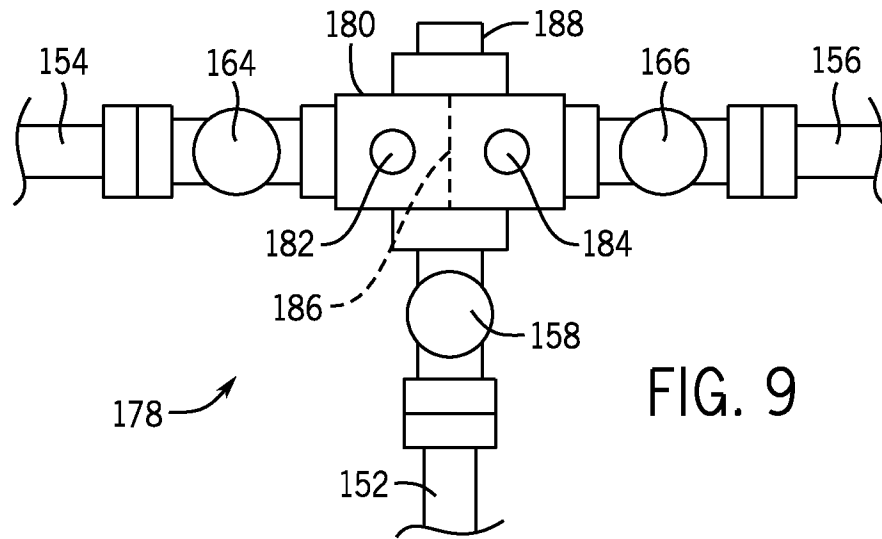


FIG. 9

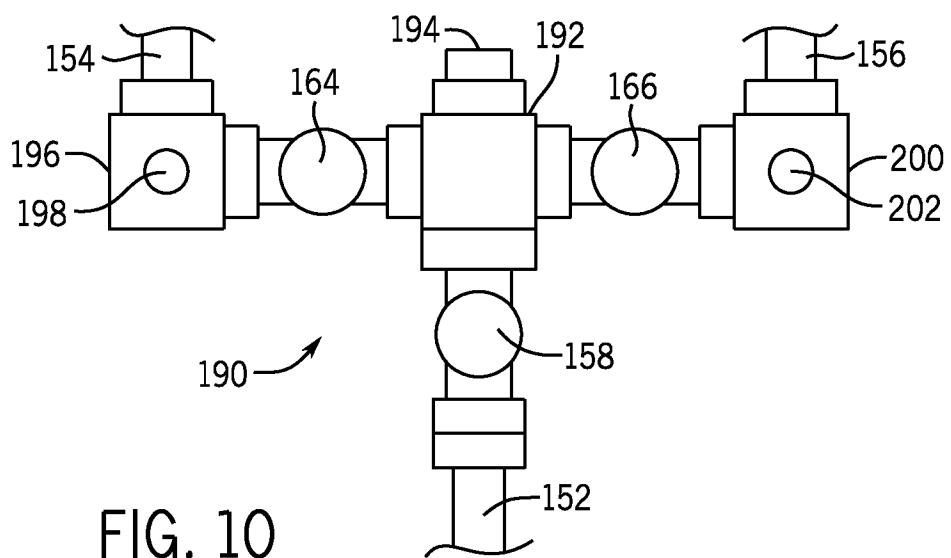


FIG. 10

INTERNATIONAL SEARCH REPORT

14/0449 18.09.2014

International application No.

PCT/US 14/40449

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 34/16, 43/17, 43/26 (2014.01)

CPC - E21B 34/16

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)

IPC(8) - E21B 34/16, 43/17, 43/26 (2014.01)

USPC - 166/305.1, 308.1

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

USPC - 166/307, 373, 53, 90.1, 177.5, 316; 175/24

CPC - E21B 34/16, 43/17, 43/26

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

Patbase; Google Patents; Google Scholar; Google Web; Espacenet; Search Terms: additional*, amount*, automat*, ball*, blend*, bore*, calculat*, comput*, control*, determin*, direct*, distribut*, flow*, fluid*, frac*, isolat*, launch*, manifold*, multi*, plural*, processor*, quantit*, rate*, rout*, same time, second*, simultaneous*, sleeve*, slid*,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2010/0038077 A1 (Heilman et al.) 18 February 2010 (18.02.2010), entire document, especially Fig. 1, Fig. 5, para [0023], [0032], [0036]	1, 5, 8, 10-11, 13-15 ----- 2-4, 6-7, 9 and 12
Y	US 2012/0234534 A1 (Hughes et al.) 20 September 2012 (20.09.2012), para [0004], [0025], [0028], [0033]	2-4
Y	US 2001/0000996 A1 (Grimland et al.) 10 May 2001 (10.05.2001), Fig. 6, para [0028]	6-7
Y	US 2013/0032327 A1 (He et al.) 07 February 2013 (07.02.2013), Fig. 1, para [0004], [0016]	9
Y	US 2009/0194273 A1 (Surjaatmadja et al.) 06 August 2009 (06.08.2009), para [0163]	12
A	US 3,233,668 A (Hamilton et al.) 08 February 1966 (08.02.1966), Figs. 1-2, col. 4, ln. 50-54	1-15
A	US 2011/0259584 A1 (Broussard II) 27 October 2011 (27.10.2011), para [0013], [0015], [0037]	1-15
A	US 2010/0300672 A1 (Childress et al.) 02 December 2010 (02.12.2010), Fig. 1, para [0013]-[0016]	1-15

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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

26 August 2014 (26.08.2014)

Date of mailing of the international search report

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