(51) International Patent Classification:  
COM 8/68 (2006.01)  

(21) International Application Number:  
PCT/GB201 1/001 112  

(22) International Filing Date:  
22 July 201 1 (22.07.201 1)  

(25) Filing Language:  
English  

(26) Publication Language:  
English  

(30) Priority Data:  
12/841,543 22 July 2010 (22.07.2010) US  

(71) Applicant (for all designated States except US):  
HALiburton Energy Services, Inc. [US/US]; P.O. Box 143 I Duncan, OK 73536 (US).  

(71) Applicant (for MW only):  
COTTRILL, Emily, Elizabeth, Helen [GB/GB]; A A Thornton & Co, 235 High Holborn, London WC1V 7LE (GB).  

(72) Inventors; and  

(75) Inventors/ Applicants (for US only):  
BRYANT, Jason, E. [US/US]; 2026 Stone Ridge Lane, Duncan, OK 73533 (US).  
HAGGSTROM, Johanna. A. [US/US]; 3207 Paloma Drive, Duncan, OK 73533 (US).  

(74) Agent:  
COTTRILL, Emily, Elizabeth, Helen; A A Thornton & Co, 235 High Holborn, London WC1V 7LE (GB).  

(54) Title:  
Real-Time Field Friction Reduction Meter and Method of Use  

(57) Abstract:  
A method of servicing a subterranean formation comprising communicating a servicing fluid comprising a hydratable friction reducer and a base fluid to the subterranean formation via a route of fluid communication, determining an actual percent by which the friction reducer reduces a pipe friction pressure, comparing the actual percent by which the friction reducer reduces the pipe friction pressure to an ideal percent by which the friction reducer should reduce pipe friction pressure to determine an effectiveness of the friction reducer, and determining if the effectiveness of the friction reducer is within an acceptable range. A method of servicing a subterranean formation comprising communicating a servicing fluid comprising a hydratable friction reducer and a base fluid to the subterranean formation via a route of fluid communication, measuring a wellhead pressure, determining a pipe friction pressure independent from the wellhead pressure, calculating a formation response pressure, and monitoring the formation response pressure.
REAL-TIME FIELD FRICTION REDUCTION METER AND METHOD OF USE

BACKGROUND

[0001] Hydrocarbon-producing wells often are serviced by a variety of operations involving introducing a servicing fluid into a portion of a subterranean formation penetrated by a wellbore. Examples of such servicing operations include a fracturing operation, a hydrafjetting operation, an acidizing operation, or the like. In providing such a servicing fluid to the subterranean formation, it is often desirable to employ a friction reducer to lessen the friction between the servicing fluid and the conduit through which the servicing fluid is communicated to the formation.

[0002] Servicing fluids and the components comprising those servicing fluids are diverse. As such, a given friction reducer may not be compatible with a given servicing fluid and, therefore, may be ineffective to reduce the friction between the servicing fluid and the conduit through which the servicing fluid is communicated to the subterranean formation. Further, because the constituents and the relative amounts of those constituents of a servicing fluid may be changed or varied over the course of a servicing operation, the effectiveness of a given friction reducer may vary over the course of a servicing operation. As the effectiveness of the friction reducer changes, the friction between the servicing fluid and the conduit through which the servicing fluid is flowing will also likely change. As such, because the friction between the flowing servicing fluid and the conduit through which the servicing fluid flows changes, the pressure due to friction between the flowing servicing fluid and the innermost surface of the conduit, referred to herein as "pipe friction pressure," may vary.

[0003] During a servicing operation, various factors contribute to the total pressure experienced within the conduit through which the servicing fluid is communicated; the pipe friction pressure is one such component. Therefore, changes in the pipe friction pressure may yield a change in the total pressure. Conventionally, there has been no means by which to assess whether a change in the total pressure is due to a change in the effectiveness of the friction reducer employed (resulting in a change in the pipe friction pressure) or to some other component of the total pressure. In many situations, it is desirable to know whether changes in the total pressure are the result of a change in the effectiveness of the friction reducer or some
other factor. As such, there exists a need for methods, systems, and apparatuses for determining the effectiveness of a friction reducer in subterranean formation servicing operations.

SUMMARY

[0004] According to one aspect of the invention there is provided a method of servicing a subterranean formation comprising communicating a servicing fluid comprising a hydratable friction reducer and a base fluid to the subterranean formation via a route of fluid communication, determining an actual percent by which the friction reducer reduces a pipe friction pressure, comparing the actual percent by which the friction reducer reduces the pipe friction pressure to an ideal percent by which the friction reducer should reduce pipe friction pressure to determine an effectiveness of the friction reducer, and determining if the effectiveness of the friction reducer is within an acceptable range.

[0005] In an embodiment, the method further comprises determining the ideal percent by which the friction reducer should reduce pipe friction pressure.

[0006] In an embodiment, the ideal percent by which the friction reducer should reduce pipe friction comprises a previously determined value.

[0007] In an embodiment, determining the actual percent by which the friction reducer reduces the pipe friction comprises: diverting at least a portion of the servicing fluid from the route of fluid communication through a friction reducer meter; measuring a pressure at a first point within the friction reducer meter and a pressure at a second point within the friction reducer meter; and calculating the difference between the pressure at the first point and the pressure at the second point. The flow of the portion of the servicing fluid diverted through the friction reducer meter may comprise a turbulent fluid flow.

[0008] In an embodiment, the determination of the effectiveness of the friction reducer is determined at the instant of measuring the pressure at the first point within the friction reducer meter and the pressure at the second point within the friction reducer.

[0009] In an embodiment, the method further comprises adjusting the composition of the servicing fluid, the route of fluid communication, or both in response to the effectiveness of the friction reducer where the effectiveness of the friction reducer is not within the desirable range. Adjusting the composition of the servicing fluid may comprise altering the amount of friction reducer, altering the type of friction reducer, adding second friction reducer, adding a
component to the base fluid, subtracting a component from the base fluid, altering the composition of the base fluid, or combinations thereof. Adjusting the route of fluid communication may comprise altering the amount of time for hydration of the friction reducer, altering the amount of time prior to communicating the servicing fluid to the subterranean formation, altering the amount of time the servicing fluid is mixed, altering the pressure at which the servicing fluid is communicated to the subterranean formation, altering the volume of servicing fluid communicated to the subterranean formation, or combinations thereof.

[0010] In an embodiment, adjusting the servicing fluid increases the hydration of the friction reducer.

[0011] In an embodiment, adjusting the servicing fluid increases the effectiveness of the friction reducer.

[0012] In an embodiment, the route of fluid communication comprises one or more storage vessels, one or more supply lines, a blending pump, a low-pressure-side conduit, one or more pressurizing pumps, a manifold, a high-pressure-side conduit, a wellhead, the pipe string, one or more pathways between the pipe string and the subterranean formation, or combinations thereof.

[0013] In an embodiment, the base fluid comprises an aqueous base fluid.

[0014] In an embodiment, the aqueous base fluid comprises water produced from the subterranean formation.

[0015] In an embodiment, the servicing fluid comprises a fracturing fluid. The fracturing fluid may comprise a proppant.

[0016] In an embodiment, the servicing fluid comprises a perforating fluid, a hydrajetting fluid, or combinations thereof.

[0017] In an embodiment, the friction reducer comprises a polyacrylamide, a copolymer of polyacrylamide and acrylic acid, a copolymer of polyacrylamide and 2-acrylamido-2-methylpropane sulfonic acid (AMPS), or combinations thereof.

[0018] In an embodiment, the servicing fluid further comprises a proppant, an acid, an abrasive, a scale inhibitor, a rheology modifying agent, a resin, a viscosifying agent, a suspending agent, a dispersing agent, a salt, an accelerant, a surfactant, a retardant, a defoamer, a settling prevention agent, a weighting material, a vitrified shale, a formation conditioning agent, a pH-adjusting agent, or combinations thereof.
According to another aspect of the invention there is provided a method of servicing a subterranean formation comprising communicating a servicing fluid comprising a hydratable friction reducer and a base fluid to the subterranean formation via a route of fluid communication, measuring a wellhead pressure, determining a pipe friction pressure independent from the wellhead pressure, calculating a formation response pressure, and monitoring the formation response pressure.

In an embodiment, determining the pipe friction pressure comprises: diverting at least a portion of the servicing fluid from the route of fluid communication through a friction reducer meter; measuring a pressure at a first point within the friction reducer meter and a pressure at a second point within the friction reducer meter; and calculating the difference between the pressure at the first point and the pressure at the second point. The flow of the portion of the servicing fluid diverted through the friction reducer meter may comprise a turbulent fluid flow.

In an embodiment, the method further comprises adjusting the composition of the servicing fluid, adjusting the route of fluid communication, or both in response to the formation response pressure. Adjusting the composition of the servicing fluid may comprise altering the amount of friction reducer, altering the type of friction reducer, adding second friction reducer, adding a component to the base fluid, subtracting a component from the base fluid, altering the composition of the base fluid, altering the type of servicing fluid communicated, or combinations thereof. Adjusting the route of fluid communication may comprise altering the amount of time prior for hydration of the friction reducer, altering the amount of time prior to communicating the servicing fluid to the subterranean formation, altering the amount of time the servicing fluid is mixed, altering the pressure at which the servicing fluid is communicated to the subterranean formation, altering the volume of servicing fluid communicated to the subterranean formation, or combinations thereof.

In an embodiment, adjusting the communication of the servicing fluid comprises altering the pressure at which fluid is communicated, altering the rate at which fluid is communicated, or combinations thereof.

In an embodiment, the servicing fluid comprises a fracturing fluid, a perforating fluid, a hydrajetting fluid, or combinations thereof.
[0024] In an embodiment, the servicing fluid further comprises a proppant, an acid, an abrasive, a scale inhibitor, a rheology modifying agent, a resin, a viscosifying agent, a suspending agent, a dispersing agent, a salt, an accelerant, a surfactant, a retardant, a defoamer, a settling prevention agent, a weighting material, a vitrified shale, a formation conditioning agent, a pH-adjusting agent, or combinations thereof.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0025] Figure 1 is a partial cutaway view of the operating environment of the invention depicting a wellbore penetrating a subterranean formation.

[0026] Figure 2 is a partial cutaway view of an embodiment of friction reducer effectiveness meter.

[0027] Figure 3 is a schematic overview of a method of servicing a subterranean formation.

[0028] Figure 4 is a graph depicting the percent friction reduction over time for various servicing fluids.

**DETAILED DESCRIPTION**

[0029] Unless otherwise specified, use of the terms "connect," "engage," "couple," "attach," or any other like term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described.

[0030] Unless otherwise specified, use of the terms "up," "upper," "upward," "uphole," "upstream," or other like terms shall be construed as generally from the formation toward the surface or toward the surface of a body of water; likewise, use of "down," "lower," "downward," "downhole," "downstream," or other like terms shall be construed as generally into the formation away from the surface or away from the surface of a body of water, regardless of the wellbore orientation. Use of any one or more of the foregoing terms shall not be construed as denoting positions along a perfectly vertical axis.

[0031] Unless otherwise specified, use of the term "subterranean formation" shall be construed as encompassing both areas below exposed earth and areas below earth covered by water such as ocean or fresh water.

[0032] Referring to Figure 1, an embodiment of an operating environment for a Friction Reducer Effectiveness (FRE) meter and a method of using the same is illustrated. It is noted that although some of the figures may exemplify horizontal or vertical wellbores, the principles of the devices, systems, and methods disclosed may be similarly applicable to horizontal
wellbore configurations, conventional vertical wellbore configurations, and combinations thereof. Therefore, the horizontal or vertical nature of any figure is not to be construed as limiting the wellbore to any particular configuration.

[0033] As depicted in Figure 1, the operating environment generally comprises a wellbore 114 that penetrates a subterranean formation 102 for the purpose of recovering hydrocarbons, storing hydrocarbons, disposing of carbon dioxide, or the like. The wellbore 114 may be drilled into the subterranean formation 102 using any suitable drilling technique. In an embodiment, a drilling or servicing rig comprises a derrick with a rig floor through which a pipe string 150 (e.g., a drill string, segmented tubing, coiled tubing, etc.) may be positioned within or partially within the wellbore 114. A wellbore servicing apparatus 140 configured for one or more wellbore servicing operations may be integrated within the pipe string 150. Additional downhole tools may be included with or integrated within the wellbore servicing apparatus and/or the pipe string 150 for example, one or more isolation devices, for example, packers such as swellable packers or mechanical packers.

[0034] The drilling or servicing rig may be conventional and may comprise a motor driven winch and other associated equipment for lowering the pipe string 150 into the wellbore 114. Alternatively, a mobile workover rig, a wellbore servicing unit (e.g., coiled tubing units), or the like may be used to lower the pipe string 150 into the wellbore 114.

[0035] The wellbore 114 may extend substantially vertically away from the earth's surface over a vertical wellbore portion, or may deviate at any angle from the earth's surface 104 over a deviated or horizontal wellbore portion. In alternative operating environments, portions or substantially all of the wellbore 114 may be vertical, deviated, horizontal, and/or curved. In some instances, a portion of the pipe string 150 may be secured into position within the wellbore 114 in a conventional manner using cement 116; alternatively, the pipe string 150 may be may be partially cemented in wellbore 114; alternatively, the pipe string 150 may be un cemented in the wellbore 114. In an embodiment, the pipe string 150 may comprise two or more concentrically positioned strings of pipe (e.g., a first pipe string may be positioned within a second pipe string). It is noted that although some of the figures may exemplify a given operating environment, the principles of the devices, systems, and methods disclosed may be similarly applicable in other operational environments, such as offshore and/or subsea wellbore applications.
The devices, methods, and systems disclosed herein generally relate to an FRE meter. In an embodiment, the FRE meter may be employed to independently determine one or more components of the total pressure during a subterranean formation servicing operation. In an embodiment, independently determining one or more components of the servicing fluid may allow adjustment of the servicing operation to achieve a desired result.

Referring again to Figure 1, an embodiment of a route of fluid communication to the subterranean formation 102, illustrated by flow arrows 10, is shown in the context of a wellbore servicing equipment spread or layout (e.g., a fracturing spread) assembled at a well site. In the embodiment of Figure 1, the route of fluid communication 10 may generally comprise one or more storage vessels 230, one or more supply lines 220, a blending pump 210, a low-pressure-side conduit 200, one or more pressurizing pumps 190, a high-pressure manifold 180, a high-pressure-side conduit 170, a wellhead 160, the pipe string 150, and, optionally, one or more pathways between the pipe string 150 and the formation 102. Although Figure 1 illustrates a general route of fluid communication to the subterranean formation 102, the FRE meter disclosed herein may be applicable to other suitable routes of fluid communication. For example, a route of fluid communication, like the route of fluid communication illustrated in Figure 1, may further comprise various other fluid conduits, such as, one or more conduits leading to the manifold.

In an embodiment, the one or more storage vessels 230 may comprise any suitable storage device, for example a tank, reservoir, hopper, container, or the like. The storage vessels 230 may be portable or movable, alternatively, permanent or semi-permanent. The storage vessels 230 may be configured to store a given material or substance as will be necessary for a given servicing operation. In a non-limiting example, the storage vessels may be individually configured for the storage of a liquid, a solid, a semi-solid, a suspension, a powder, a slurry, a gas, or combinations thereof. In an embodiment, one or more components of the servicing fluid may be stored in the one or more storage vessels. For example, a first storage vessel 230 may store a first servicing fluid component (e.g., a base fluid, as will be discussed herein below), a second storage vessel 230 may store a second servicing fluid component (e.g., a friction reducer, as will be discussed herein below), and a third, fourth, fifth, etcetera, storage vessel 230 may store one or more additional servicing fluid components.

In an embodiment, the one or more storage vessels 230 may be connected to one or more supply lines. The supply lines 220 may comprise any suitable conduit, nonlimiting
examples of which include a pipe, a line, a tubing member, or the like. The supply lines may comprise flowbore extending therethrough. In an embodiment, the one or more supply lines 220 may comprise a route of fluid communication between the storage vessels 230 and the blending pump 210. In an alternative embodiment, one or more of the storage vessels 230 may be directly connected to the blending pump 210.

[0040] In an embodiment, the one or more supply lines 220 may be connected to the blending pump 210. The blending pump 210 may comprise any suitable configuration. The blending pump 210 may be configured to blend servicing fluid components introduced therein and to discharge the resulting composition therefrom. The blending pump 210 may comprise a route of fluid communication between the one or more supply lines 220 and the low-pressure-side conduit 200.

[0041] In an embodiment, the blending pump 210 may be connected to a low-pressure-side conduit 200. The low-pressure-side conduit 210 may comprise any suitable conduit, nonlimiting examples of which include a pipe, a line, a tubing member, or the like. The low-pressure-side conduit 200 may comprise a flowbore extending therethrough. The low-pressure-side conduit may comprise a route of fluid communication between the blending pump 210 and the one or more pressurizing pumps 190.

[0042] In an embodiment, the low-pressure-side conduit 200 may be connected with the one or more pressurizing pumps 190. The pressurizing pumps 190 may be configured to increase the pressure of a fluid moving therethrough. Although Figure 1 illustrates three independent pressurizing pumps, any suitable number of pumps may be employed. The pressurizing pumps may comprise any suitable type or configuration of pump. Nonlimiting examples of a suitable pump include a centrifugal pump, a gear pump, a screw pump, a roller pump, a scroll pump, a piston pump, a progressive cavity pump, or combinations thereof. The one or more pressurizing pumps 190 may comprise a route of fluid communication between the low-pressure-side conduit 200 and the manifold 180.

[0043] In an embodiment, the one or more pressurizing pumps 190 may be connected with the manifold 180. The manifold 180 may suitably comprise one or more pipes, lines, valves, connections, the like, or combinations thereof. In an embodiment, the manifold 180 may be configured to merge two or more fluid streams (e.g., from the one or more pressurizing pumps 190) into a single fluid stream. The manifold 180 may comprise a flowbore comprising a route
of fluid communication between the pressurizing pumps 190 and the high-pressure-side conduit 170.

[0044] In an embodiment, the manifold 180 may be connected with the high-pressure-side conduit 170. The high-pressure-side conduit 170 may comprise any suitable conduit, nonlimiting examples of which include a pipe, a line, a tubing member, or the like. The high-pressure-side conduit 170 may comprise an axial flowbore extending therethrough. The high-pressure-side conduit 170 may comprise a route of fluid communication between the manifold 180 and the wellhead 160.

[0045] In an embodiment, the high-pressure-side conduit 170 may be connected with the wellhead 160. The wellhead may suitably comprise one or more pipes, lines, valves, connections, the like, or combinations thereof. The wellhead 160 may comprise one or more flowbores for the communication of a fluid therethrough. The wellhead 160 may comprise a route of fluid communication between the high-pressure-side conduit 170 and the pipe string 150.

[0046] In an embodiment, the wellhead 160 may be connected to the pipe string 150. The pipe string 150 may comprise a flowbore for the communication of fluid therethrough. In various embodiments, the pipe string 150 may comprise a casing string, a liner, a production tubing, coiled tubing, a drilling string, the like, or combinations thereof. The pipe string 150 may extend from the earth’s surface 104 downward within the wellbore 114 to a predetermined or desirable depth.

[0047] In an embodiment where the route of fluid communication 10 comprises a wellbore servicing apparatus 140, the wellbore servicing apparatus 140 or some part thereof may be incorporated or integrated within the pipe string 150. The wellbore servicing apparatus 140 may be configured to perform a given servicing operation, for example, fracturing the formation 102, expanding or extending a fluid path through or into the subterranean formation 102, producing hydrocarbons from the formation 102, or other servicing operation. In an embodiment, the wellbore servicing apparatus 140 may comprise one or more ports, apertures, nozzles, jets, windows, or combinations thereof for the communication of fluid from the flowbore of the pipe string 150 to the subterranean formation 102. In an embodiment, the wellbore servicing apparatus comprises a housing comprising a plurality of housing ports, a sleeve being movable with respect to the housing, the sleeve comprising a plurality of sleeve ports, the plurality of housing ports being selectively alignable with the plurality of sleeve ports
to provide a fluid flow path from the wellbore servicing apparatus to the wellbore, the
subterranean formation, or combinations thereof. Such a wellbore servicing apparatus is
described in greater detail in U.S. Application No. 12/274,193, which is incorporated in its
totality herein by reference.

Persons of ordinary skill in the art with the aid of this disclosure will appreciate that
the components of route of fluid communication 10 described herein may be connected and/or
coupled via any suitable connection. Nonlimiting examples of suitable connections may
include flanges, collars, welds, or combinations thereof. One of more of the components of
route of fluid communication 10 may include various configurations of pipe tees, elbows, the
like, or combinations thereof.

In an embodiment the FRE meter generally comprises a route of fluid
communication of a servicing fluid, a side-stream from the route of fluid communication, a flow
meter disposed in the side-stream, two or more pressure gauges, optionally, a flow regulator,
and, optionally, a side-stream valve. The side-stream may be configured such that a portion of
the servicing fluid flows may be diverted from the route of fluid communication through the
side-stream.

Referring to Figure 2, an embodiment of an FRE meter 300 is illustrated. In the
embodiment of Figure 2, the FRE meter comprises a side-stream 310, a first pressure gauge
320a, a second pressure gauge 320b, a flow-rate meter 330, one or more optional side-stream
valves 350, and an optional flow regulator 340.

In an embodiment, the FRE meter 300 may be connected to one or more suitable
components of a route of fluid communication such as route of fluid communication 10. In the
embodiment of Figure 2, the FRE meter 300 is connected to and in fluid communication with
the low-pressure-side conduit 200. In alternative embodiments, one of skill in the art viewing
the instant disclosure will recognize that the FRE meter 300 might be connected to the storage
vessels 230, to the supply lines 220, the blending pump 210, the low-pressure-side conduit 200,
the one or more pressurizing pumps 190, the manifold 180, the high-pressure-side conduit 170,
the wellhead 160, the pipe sting 150, or combinations thereof.

In an embodiment, the side-stream 310 comprises any suitable conduit through
which at least a portion of the servicing fluid may be routed. Nonlimiting examples of such a
conduit include a pipe, tube, the like, or combinations thereof. The side-stream 310 may
comprise a flowbore extending therethrough and may be in fluid communication with the route
of fluid communication. In the embodiment of Figures 1 and 2, the side-stream 310 is connected to the low-pressure-side conduit 200 and is in fluid communication therewith such that a portion of the fluid flowing via route of fluid communication 10 may be selectively diverted through the side-stream 310.

[0053] The side-stream 310 may be of any suitable length and any suitable diameter. In an embodiment, the side-stream 310 comprises a conduit of a suitable, known diameter. In an embodiment, the diameter may be within the range of from about 0.25 inches to about 12 inches, alternatively, from about 0.5 inches to about 4 inches, alternatively, about 0.5 inches. In an embodiment, the length of the side-stream 310 may be within the range of from about 1 foot to about 25 feet, alternatively, from about 1.5 feet to about 20 feet, alternatively, from about 2 feet to about 10 feet. The side-stream 310 may be characterized as straight, curved, looped, or combinations thereof and may comprise one or more elbows, bends, joints, the like, or combinations thereof.

[0054] In an embodiment, the side-stream 310 conduit comprises a suitable inner surface. In an embodiment, the inner surface of the side-stream 310 may comprise a suitable roughness, as will be appreciated by one of skill in the art. For example, in an embodiment the relative roughness with respect to the pipe diameter may be in the range of from about 0 to about 0.05, alternatively, from about 0 to about 0.001.

[0055] In the embodiment of Figure 2, the FRE meter 300 comprises a flow-rate meter 330. In an embodiment, the flow-rate meter 330 is configured to determine the rate at which a fluid is moving through the flowbore of the side-stream 310. The flow-rate meter 330 may comprise any type or configuration of device or apparatus suitable for measuring or determining a rate fluid of flow. Non-limiting examples of a suitable types or configurations of a flow-rate meters include Coriolis mass flow meters, differential pressure flow meters, electromagnetic flow meters, positive displacement flow meters, ultrasonic flow meters, turbine or paddlewheel flow meters, variable area flowmeters, the like, or combinations thereof.

[0056] In the embodiment of Figure 2, the FRE meter 300 comprises a first pressure gauge 320a and a second pressure gauge 320b. In an embodiment, the first pressure gauge 320a, the second pressure gauge 320b, or both is configured to measure the pressure of the fluid at a point within the side-stream 310. The first and second pressure gauges, 320a and 320b, may comprise any suitable type or configuration of pressure gauge for determining or monitoring the pressure of fluid. Non-limiting examples of a suitable pressure gauge include a hydrostatic
gauge, a piston-type gauge, a liquid column gauge, a mechanical gauge, a diaphragm gauge, a piezoresistive strain gauge, a capacitive gauge, a magnetic gauge, a piezoelectric gauge, an optical fiber gauge, a potentiometric gauge, a resonant gauge, or combinations thereof. The first pressure gauge 320a, the second pressure gauge 320b, or both may comprise a suitable output, for example, a display, an electric signal, a dial, etcetera.

[0057] In an embodiment, the first pressure gauge 320a and the second pressure gauge 320b may be separated by a known distance. In the embodiment of Figure 2, the first pressure gauge 320a and the second pressure gauge 320b are illustrated as being separated by distance \( d \). In an embodiment, distance \( d \) may be within the range of from about 1 foot to about 25 feet, alternatively, from about 1.5 feet to about 20 feet, alternatively, from about 2 feet to about 10 feet.

[0058] In an embodiment where the FRE meter 300 comprises one or more side-stream valves 350, the side-stream valve 350 may comprise any suitable device or apparatus configured to selectively alter, adjust, allow, disallow, or combinations thereof, flow of a fluid therethrough. The side-stream valves 350 may be manually manipulatable, automatically manipulatable, or combinations thereof. Suitable valves are generally known to one of skill in the art.

[0059] In an embodiment where the FRE meter 300 comprises a flow regulator 340, the flow regulator 340 may comprise any suitable device or apparatus configured to impede, resist, or prohibit fluid flow therethrough in a given direction, for example, a check-valve. In an embodiment, the flow regulator may additionally be configured to selectively alter, adjust, allow, disallow, or combinations thereof, flow of a fluid therethrough, for example, a valve. Suitable devices or apparatuses operable as the flow regulator 340 are generally known to one of skill in the art.

[0060] In an embodiment, the FRE meter 300 disclosed herein may be employed to independently determine the pipe friction pressure, the formation response pressure, or other components of the wellhead pressure.

[0061] In an embodiment, during a wellbore servicing operation several pressure components may contribute to the total pressure which may be measured at the wellhead, referred to as the "wellhead pressure." For example, the wellhead pressure may comprise a formation response pressure component, a pipe friction pressure component, a hydrostatic fluid pressure component, and one or more additional pressure components such as perforation
friction. As used herein, "formation response pressure" refers to the component of the wellhead pressure attributable to the response of the subterranean formation into which the servicing fluid is introduced during a servicing operation. A near-wellbore pressure component and a formation friction pressure component may contribute to the formation response pressure. As used herein, "near-wellbore pressure" generally refers to pressure due to flow restrictions from the perforations to the fracture such as, for example, tortuosity. As used herein "formation friction pressure" generally refers to the pressure due to friction between a servicing fluid and a fracture as the servicing fluid moves through the fracture. As used herein, "pipe friction pressure" refers to the pressure due to pipe friction and "pipe friction" refers to the friction between the servicing fluid and the inner surface of the pipe string as the servicing fluid flows through the pipe string. As used herein, hydrostatic fluid pressure generally refers to the pressure at a given point within a fluid generally due to the weight of the fluid above it.

[0062] In an embodiment, determining the pipe friction pressure independent from one or more other components of the wellhead pressure may allow the efficiency of the friction reducer included within the servicing fluid flowing via the route of fluid communication 10 to be ascertained or calculated. In an embodiment, knowledge of the efficiency of the friction reducer may allow an operator to adjust the servicing fluid to achieve a desired level of friction reducer efficiency.

[0063] In another embodiment, determining the formation response pressure independent from one or more other components of the wellhead pressure may provide an operator with valuable information regarding downhole conditions during the performance of the servicing operation. In an embodiment, knowledge of downhole conditions during the servicing operation may allow an operator to adjust the servicing operation parameters to achieve one or more desired results.

[0064] In an embodiment, the servicing fluid may comprise any suitable servicing fluid. Nonlimiting examples of suitable servicing fluids include a fracturing fluid, a perforating fluid, an acidizing fluid, a debris removal fluid, the like, or combinations thereof. In an embodiment, the servicing fluid may generally comprise a base fluid, a friction reducer, and, optionally, one or more additional components which may include but are not limited to proppants, scale inhibitors, biocides, surfactants, breakers, relative permeability modifiers, or the like.

[0065] In an embodiment, the base fluid may comprise an aqueous base fluid, alternatively, a substantially aqueous base fluid. In an embodiment, a substantially aqueous base fluid
comprises less than about 50% of a nonaqueous component, alternatively less than about 45%, 40%, 35%, 30%, 25%, 20%, 15%, 10%, 5%, 4%, 3%, 2% or 1% of a nonaqueous component by weight of the base fluid. In an embodiment, the base fluid may further comprise an inorganic monovalent salt, multivalent salt, or combinations thereof. Nonlimiting examples of salts suitable for use in such a base fluid include water soluble chloride, bromide and carbonate, hydroxide and formate salts of alkali and alkaline earth metals, zinc bromide, and combinations thereof. The salt or salts in the base fluid may be present in an amount ranging from greater than about 0% by weight of the base fluid to a saturated salt solution. The water may be fresh water or salt water. Examples of the base fluid include for are not limited to water produced from the subterranean formation, flowback water, water transported to the site of the servicing operation, or both.

[0066] In an embodiment, the base fluid may comprise a nonaqueous base fluid. In an embodiment, a nonaqueous base fluid may comprise an oleaginous fluid. Nonlimiting examples of such an oleaginous olefins, kerosene, diesel oil, fuel oil, synthetic oils, linear or branched paraffins, olefins, esters, acetalts, mixtures comprising crude oil, derivatives thereof, or combinations thereof.

[0067] In an embodiment, the base fluid may comprise an emulsion of an aqueous fluid and a nonaqueous fluid. Nonlimiting examples of an emulsion include an invert emulsion (a water-in-oil emulsion), an oil-in-water emulsion, a reversible emulsion, or combinations thereof.

[0068] In an embodiment, the friction reducer may comprise any suitable friction reducer. In an embodiment the friction reducer comprises a hydratable friction reducer. The hydratable friction reducer may be effective to reduce friction between a servicing fluid comprising the friction reducer and a conduit through which the servicing fluid is communicated. In an embodiment, the hydratable friction reducer comprises a polymer. Nonlimiting examples of a suitable polymer include a polyacrylamide, polyacrylate, a copolymer of polyacrylamide and polyacrylate, a copolymer of polyacrylamide and 2-acrylamido-2-methylpropane sulfonic acid (AMPS), polyethylene oxide, polypropylene oxide, a copolymer of polyethylene and polypropylene oxide, polysaccharides, and combinations thereof. Other suitable friction reducers will be known to those of skill in the art. Examples of suitable friction reducers that are commercially available are FR-46, FR-56, FR-58, FR-66, FDP-S944-09, SGA-2, SGA-5, and SGA-18 from Halliburton Energy Services, Inc.
In an embodiment, the one or additional components comprise any suitable servicing fluid components. Suitable servicing fluid components will be known to those of skill in the art with the aid of this disclosure. Nonlimiting examples of such components include a proppant, an acid, an abrasive, a scale inhibitor, a rheology modifying agent, a resin, a viscousifying agent, a suspending agent, a breaker, a dispersing agent, a salt, an accelerant, a surfactant, a relative permeability modifier, a retardant, a defoamer, a settling prevention agent, a weighting material, a vitrified shale, a formation conditioning agent, a pH-adjusting agent, or combinations thereof. These additional components may be included singularly or in combination.

In an embodiment, the base fluid, the friction reducer, and any additional component are blended together in any suitable order to form the wellbore servicing fluid. In an embodiment, the attributes of one or more of the components of the servicing fluid may vary from one servicing operation to another. Further, the components of a servicing fluid or the relative amounts thereof may vary throughout the course of a given servicing operation. Not intending to be bound by theory, the friction reducer employed in a servicing fluid may vary in compatibility with the other servicing fluid components between servicing operations or throughout a servicing operation, thereby causing the friction reducer to vary as to its effectiveness. For example, the base fluid may comprise water produced from the subterranean formation; because the attributes and/or relative amount of the produced water may vary over the course of the servicing operation, the friction reducer may vary in compatibility with the base fluid and, as such, the effectiveness of the friction reducer may vary. Not intending to be bound by theory, poor dispersion, inversion, hydration, or combinations thereof of a friction reducer may cause a friction reducer to exhibit less than a desired level of effectiveness.

In an embodiment, it may be desirable for a friction reducer to be about 100, alternatively, 95, 90, 85, 80, 75, or 70% effective. In an embodiment, where a friction reducer exhibits less than the desired level of effectiveness, it may be desirable to adjust the servicing fluid, the route of fluid communication of the servicing fluid; or combinations thereof to improve dispersion, inversion, hydration, or combinations thereof and thereby increase friction reducer effectiveness.

Disclosed herein is an embodiment of a method of servicing a subterranean formation. In various embodiments, the servicing operation may comprise a fracturing operating, a perforating and/or hydrajetting operation, an acidizing operation, or combinations
thereof. In the embodiment of Figure 3, the servicing method 50 generally comprises the steps of determining an ideal percent friction reduction for a given friction reducer 500, communicating a subterranean formation servicing fluid to the subterranean formation 510, and determining an actual percent friction reduction 520. In an embodiment, the subterranean formation servicing method optionally comprises calculating a percent effectiveness of the friction reducer 530. In an embodiment, a servicing method optionally comprises adjusting at least one parameter of the servicing operation in response to the effectiveness of the friction reducer 540.

[0073] In an embodiment, determining the ideal percent friction reduction 500, $\%FR_{ideal}$ may comprise any suitable method. As used herein, the term "ideal percent friction reduction" refers to the ideal percentage by which the pipe friction is reduced by a friction reducer. The $\%FR_{ideal}$ may be determined analytically, experimentally, or combinations thereof.

[0074] In an embodiment, determining the $\%FR_{ideal}$ 500 may comprise an experimental determination. For a fluid flowing from a first point, Point A, to a second point, Point B, in a pipe, assuming that the diameter of the pipe remains constant, that the elevation of the pipe between Point A and Point B is unchanged, and that the velocity of the fluid is constant along the pipe, the pressure at Points A and B may be generally described in that the pressure at Point B, $P_B$, is equal to the pressure at Point A, $P_A$, minus the pipe friction pressure, $P_{pipe}$. Therefore, assuming the foregoing, the pipe friction pressure will be equal to the difference in the pressure at Point A and the pressure at Point B as shown in equation (I):

$$P_{pipe} = P_A - P_B$$  \hspace{1cm} \text{Equation (I)}.

[0075] In an embodiment, determining the $\%FR_{ideal}$ 500 may generally comprise determining the pipe friction pressure for a fluid (e.g., fresh water) that does not comprise a friction reducer, $P_{\text{frid}}$, and determining the pipe friction pressure for fresh water comprising a friction reducer at its ideal effectiveness, $P_{\text{ideal}}$. In an embodiment, an experimental determination of the $\%FR_{ideal}$ may also generally comprise comparing the $P_{\text{frid}}$ with the $P_{\text{ideal}}$.

[0076] In an embodiment, determining the $P_{\text{initid}}$ comprises observing the difference in $P_A$ and $P_B$ for fresh water from which a friction reducer is absent while flowing through a conduit (e.g., a pipe, a test loop, a pressure loop, or the like). In an embodiment, determining the $P_{\text{frid}}$ comprises observing the difference in $P_A$ and $P_B$ for the same fresh water or a substantially similar fresh water with a friction reducer while flowing through the same or a similar conduit.
[0077] In an alternative embodiment, determining the $P_{\text{initial}}$ comprises calculating the change in pressure for a fluid (e.g., fresh water) from which a friction reducer is absent at about ambient conditions (e.g., about 25 °C and about 1 atm. [101.325 kilopascal]) over a given portion of a flow conduit of length $L$ according to equation (II-A):

$$P_{\text{initial}} = \frac{\rho V^2 L f}{2 g_c D} \quad \text{Equation (II-A)}$$

where $\rho$ is the density of the fluid at about 25 °C and about 1 atm. [101.325 kilopascal], $V$ is the velocity of the fluid, $g_c$ is the gravitational constant, $D$ is the diameter of the flow conduit, and where $f$ is the friction factor. The friction factor, may be calculated according to equation (III) for a fully turbulent fluid flow:

$$f = \left(-2 \log \left[ \frac{\varepsilon / D}{3.7} - \frac{5.02}{Re} \log \left( \frac{\varepsilon / D}{3.7} + \frac{14.5}{Re} \right) \right] \right)^2 \quad \text{Equation (III)}$$

where $\varepsilon$ is the pipe roughness, $D$ is the diameter of the flow conduit, and $Re$ is the Reynolds number as calculated for the fluid at about 25 °C and about 1 atm. [101.325 kilopascal] (Shacham, M., Isr. Chem. Eng., 8, 7E (1976)).

[0078] As will be appreciated by one of skill in the art, one or more of the time that the friction reducer is in contact with an aqueous fluid, temperature of the fluid, the solute (e.g., a salt) concentration of the fluid, the combinations of solutes of the fluid, the soluble and insoluble organic materials of the fluid, the particulates of the fluid, the pressure of the fluid, or combinations thereof may vary the effectiveness of the friction reducer utilized in such a fluid. In an embodiment, the fluid for which the pipe friction will be determined comprises freshwater. Not intending to be bound by theory, utilizing freshwater to determine the pipe friction pressure may minimize the opportunity for incompatibility of the friction reducer; as such, the friction reducer may be fully or substantially hydrated (and thereby, not intending to be bound by theory, maximally effective). In an embodiment, the friction reducer may be contacted with the fluid for 20 seconds under appreciable flow or shear to ensure the friction reducer may be fully or substantially hydrated (and thereby, not intending to be bound by theory, maximally effective). In an embodiment, the maximum effectiveness of a given hydratable friction reducer may be determined where, for example, the friction reducer has been in contact with a fluid for a given amount of time, the fluid is at a given temperature, the fluid is at a given solute (e.g., a salt) concentration, the fluid is at a given pressure, or combinations thereof.
In an embodiment, the presence of the friction reducer in the fluid may reduce the amount of pipe friction. Therefore, the $P_{\text{ideai}}$ may be less than the $P_{\text{initial}}$. By comparing the $P_{\text{ideai}}$ and the PMM, the percent by which the pipe friction is reduced, the $\% FR_{\text{ideai}}$, may be calculated according to equation (IV):

$$\% FR_{\text{ideai}} = \left(1 - \frac{P_{\text{ideai}}}{P_{\text{initial}}}\right) \times 100\%$$  \hspace{1cm} \text{Equation (IV).}

In an alternative embodiment, determining the $\% FR_{\text{ideai}}$ 500 may comprise an analytical determination. Such an analytical determination of the $\% FR_{\text{ideai}}$ may generally comprise calculating, deriving, or extrapolating $\% FR_{\text{ideai}}$, $P_{\text{ideai}}$, $P_{\text{initial}}$, or combinations thereof according to a suitable mathematical relationship.

In an embodiment, $\% FR_{\text{ideai}}$ may be determined prior to the servicing operation, at a site removed from the servicing operation, or both. For example, $\% FR_{\text{ideai}}$ may be determined in a laboratory setting prior to a given servicing operation. In an embodiment, where a $\% FR_{\text{ideai}}$ has been determined for a given friction reducer, the previously determined $\% FR_{\text{ideai}}$ may be employed. For example, a $\% FR_{\text{ideai}}$ utilized in a prior or separate servicing operation may be employed as the $\% FR_{\text{ideai}}$ for another servicing operation. It is specifically contemplated that the $\% FR_{\text{ideai}}$ associated with a friction reducer may be known or may be derived from other known data and, as such, need not be determined for each and every servicing operation.

In an embodiment, the servicing method 50 comprises communicating a servicing fluid comprising the friction reducer the subterranean formation 510. In an embodiment, the servicing fluid may be communicated to the subterranean formation 102 via a suitable route of fluid communication, for example, referring to Figure 1, route of fluid communication 10.

In an embodiment, the components of the servicing fluid may be provided from the one or more storage vessels 230 to the blending pump 210 via the one or more supply lines 220. Alternatively, one or more of the components may be introduced directly into the blending pump 210. The servicing fluid components may be introduced at any suitable rate, in any suitable order, in any suitable ratio, as will be appreciated by one of skill in the art. When mixed, the servicing fluid may be routed from the blending pump 210 to the one or more pressurizing pumps 190 via the low-pressure-side conduit 200. A portion of the servicing fluid may be routed through each of the one or more pressurizing pumps 190, thereby increasing the pressure of the servicing fluid moving within the route of fluid communication 10. As will be appreciated by one of skill in the art, the servicing fluid may be pressurized to a suitable
pressure, dependent upon the servicing operation being performed. The pressurized servicing fluid may be routed from the one or more pressurizing pumps 190 through the manifold 180, high-pressure-side conduit, wellhead 160, pipe string 150, and wellbore servicing apparatus 140 to the subterranean formation 102. A portion of the servicing fluid may flow into and/or through the subterranean formation 102. Additionally, a portion of the servicing fluid may be circulated through the wellbore 114.

[0084] In an embodiment, the servicing method 50 may comprise determining the actual percent friction reduction, \( \% FR_{\text{Act \text{u}}} \) 520. In an embodiment, \( \% FR_{\text{Act \text{m}}} \) may be determined by any suitable method. As used herein, the term “actual percent friction reduction” refers to the actual percentage by which the pipe friction of a servicing fluid is reduced by a given friction reducer.

[0085] In an embodiment, determining the \( \% FR_{\text{Act \text{u}}} \) 520 may comprise diverting at least a portion of the servicing fluid through the side-stream 310, measuring the velocity of the diverted servicing fluid, measuring a change in pressure of the diverted servicing fluid over a given distance, or combinations thereof.

[0086] In an embodiment, at least a portion of the servicing fluid flowing via the route of fluid communication may be diverted into the side-stream 310 of the FRE meter 300. In an embodiment, the portion of the servicing fluid that is diverted may be in the range of from about less than 1% to about 99% of the total volume of servicing fluid, alternatively, from about 1% to about 20% of the total volume of servicing fluid, alternatively, from about 5% to about 15% of the total volume of servicing fluid, alternatively, about 10% of the total volume of servicing fluid. In an embodiment, the percentage of the total volume of the servicing fluid diverted into the side-stream 310 may be adjusted by opening or closing the side-stream valves 350.

[0087] In an embodiment, the average fluid velocity of the portion of the servicing fluid diverted into the side-stream 310 may be determined from the flow-rate meter 330. In an embodiment, the average fluid velocity of the fluid flowing through the side-stream may be any suitable velocity. In an embodiment, the average fluid velocity of the fluid flowing through the side-stream may be in the range of from about 1 to about 200 feet per second (fps), alternatively, about 10 to about 100 fps, alternatively, about 20 to about 60 fps. In an embodiment, the average fluid velocity of the fluid flowing through the side-stream 310 may be adjusted, for example, as by manipulation of one or more of the side-stream valves 350. In an embodiment, adjustment of one or more of the side-stream valves 350 may be manual,
automatic, or combinations thereof. For example, an operator viewing the average fluid velocity of the fluid within the side-stream 310 may manually adjust the side-stream valve to achieve a desirable average fluid velocity. Alternatively, the side-stream valves 350 may be automatically adjusted in response to the velocity of the fluid in the side-stream 310 as measured by the flow-rate meter (e.g., via a suitable connection between the flow-rate meter 330 and the side-stream valves 350). In an embodiment, the velocity of the fluid flowing via the side-stream may be employed in comparing the ideal percent friction reduction for the friction reducer, \( \% \text{FR_{ideal}} \), to the actual friction reduction for that friction reducer, \( \% \text{FR_{Actual}} \).

For example, because \( \% \text{FR_{ideal}} \) may depend largely on fluid velocity and shear rate, it may be advantageous, alternatively, necessary, to know the fluid velocity at which \( \% \text{FR_{ideal}} \) occurs to ensure that \( \% \text{FR_{Actual}} \) is compared to the appropriate \( \% \text{FR_{ideal}} \), which is discussed in greater detail below.

In an embodiment, the flow of the servicing fluid through the side-stream 310 may be characterized as a turbulent flow. As will be appreciated by one of skill in the art, turbulent flow is a flow regime that may be characterized by secondary flows appreciable in magnitude compared to the primary flow direction, eddies, and apparent randomness. Conversely, non-turbulent flow may be referred to as laminar flow. The Reynolds number, a dimensionless number that relates the ratio of inertial forces to viscous forces, often indicates whether a flow regime will be characterized as turbulent or laminar for a given flow geometry. Generally Newtonian fluids flowing in pipes with circular cross-sections, flow regimes where the Reynolds number is greater than about 2000 may be characterized as turbulent flow while flow regimes where the Reynolds number is less than about 2000 may be characterized as laminar flow.

In an embodiment, the change in the pressure of the portion of the servicing fluid flowing over distance \( d \) within the FRE meter 300 is determined using the first pressure gauge 320a and the second pressure gauge 320b. Not intending to be bound by theory, as discussed above, for a fluid flowing from a first point, Point A, to a second point, Point B, in a pipe, assuming that the diameter of the pipe remains constant, that the elevation of the pipe between Point A and Point B is unchanged, and that the velocity of the fluid is constant along the pipe, the pressure at Point A (e.g., as measured by the first pressure gauge 320a) and the pressure at Point B (e.g., as measured by the second pressure gauge 320b) may be generally described in that the pressure at Point B, \( P_B \), is equal to the pressure at Point A, \( P_A \), minus the pipe friction...
Pressure, $P_{pipe}$. Therefore, assuming the foregoing, the pipe friction pressure may be calculated according to equation (I):

$$ P_{pipe} = P_A - P_B $$

Equation (I).

[0090] In an embodiment, determining $%FRA_{cw}$ may comprise determining the pipe friction pressure for the servicing fluid from which the friction reducer is absent, $P_0$; determining the pipe friction pressure for the servicing fluid comprising a friction reducer, $P_{Actual}$; and comparing the $P_0$ with the $P_{Actual}$.

[0091] In an embodiment, determining the $P_0$ may comprise observing the difference in $P_A$ and $P_B$ for a servicing fluid from which a friction reducer is absent. In an embodiment, determining the $P_{Actual}$ may comprise observing the difference in $P_A$ and $P_B$ for a servicing fluid comprising a friction reducer. By comparing the $P_0$ and the $P_{Actual}$, the $%FRA_{Actual}$ may be calculated according to equation (V):

$$ %FRA_{Actual} = \left(1 - \frac{P_{Actual}}{P_0}\right) \times 100\% $$

Equation (V).

[0092] In an alternative embodiment, the $P_0$ may be estimated, calculated, or otherwise determined based upon a prior known value, for example, based upon the value of $P_{initial}$ used in determining $%FR_{ideal}$ as described above.

[0093] In another embodiment, $P_0$ may be calculated (similar to the calculation of $P_{initial}$ given above) by equation (II-B):

$$ P_0 = \frac{\rho V^2 Lf}{2g_c D} $$

Equation (II-B)

where $L$ is the length of the flow conduit, $\rho$ is the density of the fluid at 25 °C and about 1 atm. [101.325 kilopascal], $V$ is the velocity of the fluid, $g_c$ is the gravitational constant, $D$ is the diameter of the flow conduit, and where $f$ is the friction factor. The friction factor, $f$, may be calculated according to equation (III) for a fully turbulent fluid flow:

$$ f = \left[ -2 \log \left( \frac{\varepsilon D}{3.7} \frac{5.02}{Re} \log \left( \frac{\varepsilon / D}{3.7} + \frac{14.5}{Re} \right) \right) \right]^{-2} $$

Equation (III)

where $\varepsilon$ is the pipe roughness, $D$ is the diameter of the flow conduit, and $Re$ is the Reynolds number as calculated for the fluid at about 25 °C and about 1 atm. [101.325 kilopascal] (Shacham, M., *Isr. Chem. Eng.*, 8, 7E (1976)).
In an embodiment, the servicing method 50 comprises calculating the effectiveness of the friction reducer 530. In an embodiment, calculating the effectiveness of the friction reducer 530 comprises comparing the ideal percent friction reduction for the friction reducer, $\%FR_{Ideal}$, to the actual friction reduction for that friction reducer, $\%FR_{Actual}$. By comparing $\%FR_{Actual}$ and $\%FR_{Ideal}$, the effectiveness, expressed as a percent, may be calculated according to equation (VI):

$$\text{Effectiveness} = \frac{\%FR_{Actual}}{\%FR_{Ideal}} \times 100\%$$

Equation (VI).

In an embodiment, the FRE meter 300 and the methods disclosed herein may yield a measure of friction reduction and/or friction reducer effectiveness at a time from about 10 to about 60 seconds after the friction reducer has been injected into the servicing fluid (e.g., the FRE meter measures the pipe friction pressure at a point downstream from where the components of the servicing fluid are first mixed, as shown in Fig. 1). The FRE meter 300 and the methods disclosed herein may yield a measure of friction reduction and/or friction reducer effectiveness that is instantaneous and/or in real-time.

In an embodiment, the FRE Meter 300 allows for the determination of the pipe friction pressure independent from one or more other components of the wellhead pressure. In an embodiment where the pipe friction pressure is known, it may be possible to calculate or monitor changes in one or more other components of the wellhead pressure. For example, it may be possible to calculate the formation response pressure component, the hydrostatic fluid pressure component, or one or more additional pressure components independent from the wellhead pressure.

In an embodiment, the servicing method 50 further comprises adjusting at least one parameter of the servicing operation 540. In an embodiment, adjusting at least one parameter of a servicing operation 540 may increase the efficiency of a friction reducer, effect a change in the servicing operation, or combinations thereof.

As discussed above, a given friction reducer may vary as to its effectiveness dependent upon the servicing fluid in which it is used, and/or other components present within the servicing fluid. As such, it may be desirable to adjust one or more parameters of the servicing operation to achieve a desirable friction reducer effectiveness. In an embodiment where the effectiveness of a friction reducer is less than desired, an operator may adjust one or more parameters of the servicing operation to increase the effectiveness of the friction reducer.
[0099] As discussed above, the formation response pressure may indicate the presence or absence of a condition within a downhole portion of the wellbore and/or the subterranean formation. As such, it may be desirable to adjust one or more parameter of the servicing operation where the formation response pressure so-indicates.

[00100] In an embodiment adjusting one or more parameters of the servicing operation may comprise altering, changing, adjusting the composition of the servicing fluid, for example, by altering, changing, adjusting the base fluid of the servicing fluid, one or more components of the servicing fluid, the friction reducer used therein, or combinations thereof in order to achieve a desired effectiveness. For example, the operator might adjust or alter the servicing fluid by changing the amount or proportion of some component, adding a component, altering a pH, changing the amount, type, or proportion of friction reducer used, using a different friction reducer, using a combination of friction reducers, or combinations thereof.

[00101] In an embodiment, adjusting at least one parameter of the servicing operation may comprise altering, changing, or adjusting the route of fluid communication of the servicing fluid in response to the effectiveness of the friction reducer. For example, the operator might alter the amount of time for hydration of the friction reducer, alter the amount of time prior to communicating the servicing fluid to the subterranean formation, alter the amount of time the servicing fluid is mixed, alter the pressure at which the servicing fluid is communicated to the subterranean formation, alter the volume of servicing fluid communicated to the subterranean formation, or combinations thereof.

[00102] In an embodiment, one or more of the steps of the servicing method disclosed herein may be implemented in software on one or more computers or other computerized components having a processor, user interface, microprocessor, memory, and other associated hardware and operating software. Software may be stored in tangible media and/or may be resident in memory on the computer. Likewise, input and/or output from the software, for example ratios, percentages, comparisons, and results may be stored in a tangible media, computer memory, hardcopy such a paper printout, or other storage device.

[00103] In an embodiment, data (e.g., pressures, pressure differentials, etc.) obtained from the performance of the foregoing methods may be input into a computer automatically via a suitable interface; alternatively, data may be input by a user or operator. Calculations and comparisons (e.g., percent effectiveness, ideal percent friction reduction, actual percent friction reduction) may be performed by a suitable computer or computerized component; alternatively,
calculations and comparisons may be performed by a user or operation. A suitable computer or computerized component may effect changes to the servicing operation (e.g., changes to the servicing fluid, the route of fluid communication, or both) responsive to a calculation, comparison, or both (e.g., a comparison of the actual effectiveness of a friction reducer with the desired effectiveness of the friction reducer) via a suitable interface (e.g., electric, electronic, mechanical, or combinations thereof); alternatively, the results of a calculation or comparison may be provided to a user or operator via a suitable display (e.g., a print-out, a screen, etc) and the user or operator may decide whether changes to the servicing operation are desirable and, if so effect one or more changes to the servicing operation via one or more suitable control means (a dial, switch, level, etc).

In an embodiment, the devices, systems, and/or methods of the instant disclosure may be employed to introduce a fracture into a subterranean formation (e.g., a fracturing operation). Hydrocarbon-producing wells often may be stimulated by hydraulic fracturing operations. In an embodiment of a fracturing operation, a fracturing fluid, such as a particle laden fluid, is pumped at relatively high-pressure into a wellbore. The fracturing fluid may be introduced into a portion of a subterranean formation at a sufficient pressure and/or velocity and/or initiate, create, extend, or enhance at least one fracture therein. Proppants, such as grains of sand, may be mixed with the fracturing fluid to keep the fractures open so that hydrocarbons may be produced from the subterranean formation and flow into the wellbore. Hydraulic fracturing may desirably create high-conductivity fluid communication between the wellbore and the subterranean formation.

In an embodiment, the method of introducing a fracture into a subterranean formation comprises preparing a fracturing fluid. In such an embodiment, the servicing fluid comprises a fracturing fluid comprising a base fluid, a proppant, a hydratable friction reducer, and, optionally, additives.

In an embodiment, the base fluid may comprise water. The water may be potable, non-potable, untreated, partially treated, treated water, or combinations thereof. In an embodiment, the water may be produced water that has been extracted from the wellbore while producing hydrocarbons form the wellbore. The produced water may comprise dissolved and/or entrained organic materials, salts, minerals, paraffins, aromatics, resins, asphaltenes, and/or other natural or synthetic constituents that are displaced from a hydrocarbon formation during the production of the hydrocarbons. In an embodiment, the water may be flowback
water that has previously been introduced into the wellbore during wellbore servicing operation. The flowback water may comprise some hydrocarbons, gelling agents, friction reducers, surfactants and/or remnants of wellbore servicing fluids previously introduced into the wellbore during wellbore servicing operations. The water may further comprise local surface water contained in natural and/or manmade water features (such as ditches, ponds, rivers, lakes, oceans, etc.). Still further, the water may comprise water stored in local or remote containers. The water may be water that originated from near the wellbore and/or may be water that has been transported to an area near the wellbore from any distance. In some embodiments, the water may comprise any combination of produced water, flowback water, local surface water, and/or container stored water.

[00107] In an embodiment, proppant, the base fluid, the hydratable friction reducer, and, optionally, the additives are fed into the blending pump 210 via supply lines 220. The blending pump 210 mixes solid and fluid components to achieve a well-blended fracturing fluid. The mixing conditions of the blending pump 210, including time period, agitation method, pressure, and temperature, may be chosen by one of ordinary skill in the art with the aid of this disclosure to produce a homogeneous blend having a desirable composition, density, and viscosity. In alternative embodiments, however, sand or proppant, water, friction reducer, and/or additives may be premixed and/or stored in a storage tank.

[00108] In an embodiment, the method of introducing a fracture into a subterranean formation comprises determining the ideal percent friction reduction, $\%FR_{\text{ideal}}$, for a given friction reducer. As disclosed above, the $\%FR_{\text{ideal}}$ may be determined by experimental means. For example, it may be determined that a given friction reducer ideally may reduce pipe friction by about up to 80% ($\%FR_{\text{ideal}} = 80\%$) at about 15-25 seconds after injection of the friction reducer into the base fluid.

[00109] In an embodiment, the method of introducing a fracture into a subterranean formation comprises communicating the fracturing fluid to a subterranean formation via a suitable route of fluid communication, for example, route of fluid communication 10 disclosed herein. In an embodiment, the pressurizing pumps 190 may pressurize the fracturing fluid to a pressure suitable for delivery into the wellhead 160. For example, the pressurizing pumps 190 may increase the pressure of the fracturing fluid to a pressure of up to about 20,000 psi or higher. In an embodiment, the fracturing fluid may be combined to achieve a total fluid flow
rate that enters the wellhead 160 at a total flow of between about 1 BPM to about 200 BPM, alternatively from between about 50 BPM to about 150 BPM, alternatively about 100 BPM.

[00110] During the communication of the fracturing fluid, a portion of the fracturing fluid may be diverted from the route of fluid communication through an FRE meter so as to determine the actual percent friction reduction, %FR Actual. In an embodiment, to determine %FR Actual, the pipe friction pressure for the servicing fluid from which the friction reducer is absent, $p_0$, may be calculated by equation (II-B):

$$p_0 = \frac{\rho V^2 lf}{2g_c D}$$  

Equation (II-B)

where $L$ is the length of the flow conduit, $p$ is the density of the fluid at 25 $^\circ$C and about 1 atm. [101.325 kilopascal], $V$ is the velocity of the fluid, $g_c$ is the gravitational constant, $D$ is the diameter of the flow conduit, and where $l$ is the friction factor. The friction factor, $f$, may be calculated according to equation (III) for a fully turbulent fluid flow:

$$f = \left( -2 \log \left[ \frac{\varepsilon / D}{3.7} - 5.02 \log \left( \frac{\varepsilon / D}{3.7} + 14.5 \frac{Re}{D} \right) \right] \right)^{-2}$$  

Equation (III)

where $\varepsilon$ is the pipe roughness, $D$ is the diameter of the flow conduit, and $Re$ is the Reynolds number as calculated for the fluid at about 25 $^\circ$C and about 1 atm. [101.325 kilopascal] (Shacham, M., Isr. Chem. Eng., 8, 7E (1976)). $P_{Actual}$ may be determined by measuring the pipe pressure of the servicing fluid having the friction reducer present as the servicing fluid flows via the FRE meter. Therefore, as disclosed above, comparing $p_0$ with $P_{Actual}$ yields the actual percent by which the friction reducer reduces pipe friction. For example, it may be determined that a given friction reducer actually reduces pipe friction by 60% ($%FR_{Actual} = 60\%$) at about 15-25 seconds after injection into the fracturing fluid. As disclosed above, comparing the %FR Ideal with the %FR Actual yields the percent effectiveness. For example, a friction reducer that ideally reduces pipe friction by 80% and actually reduces pipe friction by 60% would be 75% effective.

[00111] In an embodiment where the percent effectiveness of the friction reducer is less than a desired percent effectiveness, an operator may choose to adjust the composition of the servicing fluid, the route of fluid communication or both. For example, if an operator desired 90% effectiveness, where a friction reducer performed at 75% effectiveness, the operator might choose to adjust the composition of the servicing fluid, the route of fluid communication, or combinations thereof. In an embodiment, adjusting the composition of the servicing fluid, the
route of fluid communication, or combinations thereof may increase the effectiveness of the
friction reducer by, not intending to be bound by theory, increasing the hydration, inversion,
dispersion, or combinations thereof of the friction reducer.

[00112] In an embodiment, the operator may adjust the composition of the servicing fluid by
altering the amount of friction reducer, altering the type of friction reducer, adding second
friction reducer, adding a component to the base fluid, subtracting a component from the base
fluid, altering the composition of the base fluid, or combinations thereof. In an embodiment,
the operator may adjust the route of fluid communication by altering the amount of time for
hydration of the friction reducer, altering the amount of time prior to communicating the
servicing fluid to the subterranean formation, altering the amount of time the servicing fluid is
mixed, altering the pressure at which the servicing fluid is communicated to the subterranean
formation, altering the volume of servicing fluid communicated to the subterranean formation,
or combinations thereof.

EXAMPLES

[00113] The embodiments having been generally described, the following examples are
given as embodiments of the disclosure and to demonstrate the practice and advantages thereof.
It is to be understood that the examples are presented herein as a means of illustration and are
not intended to limit the specification or the claims.

[00114] In each of the following examples, an FRE meter, for example, similar to FRE meter
300 disclosed herein, was used, for example, as by the methods disclosed herein, to measure
friction reduction and/or the effectiveness of a friction reducer. The results of these examples
are shown in Figure 4.

Example 1

[00115] 1 gpt (gallons per thousand gallons) [3.785 litres per 3785 litres] of FR-56 was
injected into Duncan tap water flowing at a nominal rate of 28 gallons [106 litres] per minute
through a 0.56-inch [1.42 cm], smooth pipe. Approximately 20 seconds after the friction
reducer was injected, the instantaneous friction reduction was measured at about 72%, and the
friction reduction effectiveness was 100%. In an embodiment, this may represent %FRu,rt.

Example 2

[00116] 1 gpt [3.785 litres per 3785 litres] of FR-56 was injected into Duncan tap water
containing 16 wt% CaCl (calcium chloride) flowing at a nominal rate of 28 gallons [106 litres]
per minute through a 0.56-inch [1.42 cm], smooth pipe. Approximately 20 seconds after the
friction reducer was injected, the instantaneous friction reduction was measured at about 30%, and the friction reduction effectiveness was 42%.

Example 3

1 gpt [3.785 litres per 3785 litres] of FR-46 was injected into untreated Velma field water flowing at a nominal rate of 10 gallons [37.85 litres] per minute through a 0.56-inch [1.42 cm], smooth pipe. Approximately 20 seconds after the friction reducer was injected, the instantaneous friction reduction was measured at about 48%, and the friction reduction effectiveness was 67%.

At least one embodiment is disclosed and variations, combinations, and/or modifications of the embodiment(s) and/or features of the embodiment(s) made by a person having ordinary skill in the art are within the scope of the disclosure. Alternative embodiments that result from combining, integrating, and/or omitting features of the embodiment(s) are also within the scope of the disclosure. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes 2, 3, 4, etc.; greater than 0.10 includes 0.11, 0.12, 0.13, etc.). For example, whenever a numerical range with a lower limit, R_l, and an upper limit, R_u, is disclosed, any number falling within the range is specifically disclosed. In particular, the following numbers within the range are specifically disclosed: R = R_l + k*(R_u - R_l), wherein k is a variable ranging from 1 percent to 100 percent with a 1 percent increment, i.e., k is 1 percent, 2 percent, 3 percent, 4 percent, 5 percent, ..., 50 percent, 51 percent, 52 percent, ..., 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, or 100 percent. Moreover, any numerical range defined by two R numbers as defined in the above is also specifically disclosed. Use of the term "optionally" with respect to any element of a claim means that the element is required, or alternatively, the element is not required, both alternatives being within the scope of the claim. Use of broader terms such as comprises, includes, and having should be understood to provide support for narrower terms such as consisting of, consisting essentially of, and comprised substantially of. Accordingly, the scope of protection is not limited by the description set out above but is defined by the claims that follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated as further disclosure into the specification and the claims are embodiment(s) of the present invention. The discussion of a reference in the disclosure is not an admission that it is prior art, especially any reference that
has a publication date after the priority date of this application. The disclosure of all patents, patent applications, and publications cited in the disclosure are hereby incorporated by reference, to the extent that they provide exemplary, procedural or other details supplementary to the disclosure.
CLAIMS

1. A method of servicing a subterranean formation comprising:
   communicating a servicing fluid comprising a hydratable friction reducer and a base fluid to the subterranean formation via a route of fluid communication;
   determining an actual percent by which the friction reducer reduces a pipe friction pressure;
   comparing the actual percent by which the friction reducer reduces the pipe friction pressure to an ideal percent by which the friction reducer should reduce pipe friction pressure to determine an effectiveness of the friction reducer; and
   determining if the effectiveness of the friction reducer is within an acceptable range.

2. A method according to claim 1, further comprising determining the ideal percent by which the friction reducer should reduce pipe friction pressure.

3. A method according to claim 1 or claim 2, wherein the ideal percent by which the friction reducer should reduce pipe friction comprises a previously determined value.

4. A method according to any one of the preceding claims, wherein determining the actual percent by which the friction reducer reduces the pipe friction comprises:
   diverting at least a portion of the servicing fluid from the route of fluid communication through a friction reducer meter;
   measuring a pressure at a first point within the friction reducer meter and a pressure at a second point within the friction reducer meter; and
   calculating the difference between the pressure at the first point and the pressure at the second point.

5. A method according to any one of the preceding claims, wherein the determination of the effectiveness of the friction reducer is determined at the instant of measuring the pressure at the first point within the friction reducer meter and the pressure at the second point within the friction reducer.
6. A method according to any one of the preceding claims, further comprising adjusting the composition of the servicing fluid, the route of fluid communication, or both in response to the effectiveness of the friction reducer where the effectiveness of the friction reducer is not within the desirable range.

7. A method according to any one of the preceding claims, wherein adjusting the servicing fluid increases the hydration of the friction reducer.

8. A method according to any one of the preceding claims, wherein adjusting the servicing fluid increases the effectiveness of the friction reducer.

9. A method according to any one of the preceding claims, wherein the base fluid comprises an aqueous base fluid.

10. A method according to claim 9, wherein the aqueous base fluid comprises water produced from the subterranean formation.

11. A method according to any one of the preceding claims, wherein the friction reducer comprises a polyacrylamide, a copolymer of polyacrylamide and acrylic acid, a copolymer of polyacrylamide and 2-acrylamido-2-methylpropane sulfonic acid (AMPS), or combinations thereof.

12. A method of servicing a subterranean formation comprising:
   communicating a servicing fluid comprising a hydratable friction reducer and a base fluid to the subterranean formation via a route of fluid communication;
   measuring a wellhead pressure;
   determining a pipe friction pressure independent from the wellhead pressure;
   calculating a formation response pressure; and
   monitoring the formation response pressure.
13. A method according to claim 12, wherein determining the pipe friction pressure comprises:
   diverting at least a portion of the servicing fluid from the route of fluid communication through a friction reducer meter;
   measuring a pressure at a first point within the friction reducer meter and a pressure at a second point within the friction reducer meter; and
   calculating the difference between the pressure at the first point and the pressure at the second point.

14. A method according to claim 4 or 13, wherein the flow of the portion of the servicing fluid diverted through the friction reducer meter comprises a turbulent fluid flow.

15. A method according to any one of claims 12 to 14, further comprising adjusting the composition of the servicing fluid, adjusting the route of fluid communication, or both in response to the formation response pressure.

16. A method according to claim 6 or claim 15, wherein adjusting the composition of the servicing fluid comprises altering the amount of friction reducer, altering the type of friction reducer, adding second friction reducer, adding a component to the base fluid, subtracting a component from the base fluid, altering the composition of the base fluid, altering the type of servicing fluid communicated, or combinations thereof.

17. A method according to claim 6, claim 15 or claim 16, wherein adjusting the route of fluid communication comprises altering the amount of time for hydration of the friction reducer, altering the amount of time prior to communicating the servicing fluid to the subterranean formation, altering the amount of time the servicing fluid is mixed, altering the pressure at which the servicing fluid is communicated to the subterranean formation, altering the volume of servicing fluid communicated to the subterranean formation, or combinations thereof.
18. A method according to any one of claims 12 to 17, further comprising adjusting the communication of the servicing fluid, wherein adjusting the communication of the servicing fluid comprises altering the pressure at which fluid is communicated, altering the rate at which fluid is communicated, or combinations thereof.

19. A method according to any one of the preceding claims, wherein the servicing fluid comprises a fracturing fluid, a perforating fluid, a hydrajetting fluid, or combinations thereof.

20. A method according to claim 19, wherein the fracturing fluid comprises a proppant.

21. A method according to any one of the preceding claims, wherein the servicing fluid further comprises a proppant, an acid, an abrasive, a scale inhibitor, a rheology modifying agent, a resin, a viscosifying agent, a suspending agent, a dispersing agent, a salt, an accelerant, a surfactant, a retardant, a defoamer, a settling prevention agent, a weighting material, a vitrified shale, a formation conditioning agent, a pH-adjusting agent, or combinations thereof.

22. A method according to any one of the preceding claims, wherein the route of fluid communication comprises one or more storage vessels, one or more supply lines, a blending pump, a low-pressure-side conduit, one or more pressurizing pumps, a manifold, a high-pressure-side conduit, a wellhead, the pipe string, one or more pathways between the pipe string and the subterranean formation, or combinations thereof.
FIG. 3

1. Determine % FR\textsubscript{ideal} (500)
2. Communicate servicing fluid to a subterranean formation (510)
3. Determine % FR\textsubscript{actual} (520)
4. Calculate friction reducer effectiveness (530)
5. Adjust at least one parameter of servicing operation (540)