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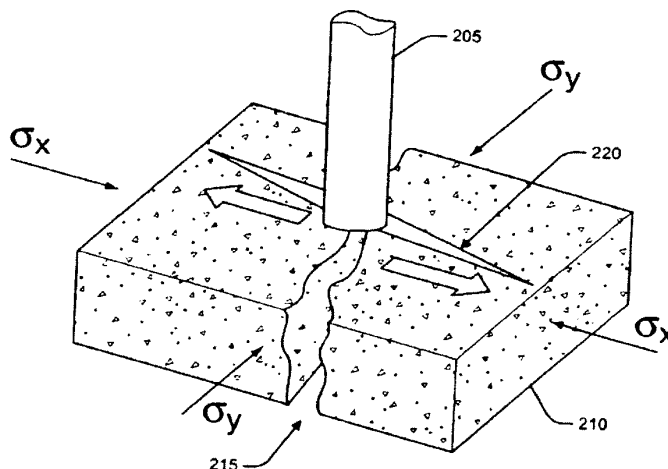
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(54) Title: METHODS AND SYSTEMS FOR WELL STIMULATION USING MULTIPLE ANGLED FRACTURING



(57) Abstract: Methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the formation are disclosed. The first and second fractures are initiated at about a fracturing location. The initiation of the first fracture is characterized by a first orientation line. The first fracture temporarily alters a stress field in the subterranean formation. The initiation of the second fracture is characterized by a second orientation line. The first orientation line and the second orientation line have an angular disposition to each other.

METHODS AND SYSTEMS FOR WELL STIMULATION USING MULTIPLE ANGLED FRACTURING

[0001] The present invention relates generally to methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly to methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the formation.

[0002] Oil and gas wells often produce hydrocarbons from subterranean formations. Occasionally, it is desired to add additional fractures to an already-fractured subterranean formation. For example, additional fracturing may be desired for a previously producing well that has been damaged due factors such as fine migration. Although the existing fracture may still exist, it is no longer effective, or less effective. In such a situation, stress caused by the first fracture continues to exist, but it would not significantly contribute to production. In another example, multiple fractures may be desired to increase reservoir production. This scenario may be also used to improve sweep efficiency for enhanced recovery wells such water flooding steam injection, etc. In yet another example, additional fractures may be created to inject with drill cuttings.

[0003] Conventional methods for initiating additional fractures typically induce the additional fractures with near-identical angular orientation to previous fractures. While such methods increase the number of locations for drainage into the wellbore, they may not introduce new directions for hydrocarbons to flow into the wellbore. Conventional method may also not account for, or even more so, utilize, stress alterations around existing fractures when inducing new fractures.

[0004] Thus, a need exists for an improved method for initiating multiple fractures in a wellbore, where the method accounts for tangential forces around a wellbore.

SUMMARY

[0005] The present invention relates generally to methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly to methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the formation.

[0006] An example method of the present invention is for fracturing a subterranean formation. The subterranean formation includes a wellbore having an axis. A first fracture is induced in the subterranean formation. The first fracture is initiated at about a fracturing location. The initiation of the first fracture is characterized by a first orientation line. The first fracture temporarily alters a stress field in the subterranean formation. A second fracture is induced in the subterranean formation. The second fracture is initiated at about the fracturing location. The initiation of the second fracture is characterized by a second

orientation line. The first orientation line and the second orientation line have an angular disposition to each other.

[0007] An example fracturing tool according to present invention includes a tool body to receive a fluid, the tool body comprising a plurality of fracturing sections, wherein each fracturing section includes at least one opening to deliver the fluid into the subterranean formation at an angular orientation; and a sleeve disposed in the tool body to divert the fluid to at least one of the fracturing sections while blocking the fluid from exiting another at least one of the fracturing sections.

[0008] An example system for fracturing a subterranean formation according to the present invention includes a downhole conveyance selected from a group consisting of a drill string and coiled tubing, wherein the downhole conveyance is at least partially disposed in the wellbore; a drive mechanism configured to move the downhole conveyance in the wellbore; a pump coupled to the downhole conveyance to flow a fluid through the downhole conveyance; and a computer configured to control the operation of the drive mechanism and the pump.

[0009] The fracturing tool includes tool body to receive the fluid, the tool body comprising a plurality of fracturing sections, wherein each fracturing section includes at least one opening to deliver the fluid into the subterranean formation at an angular orientation and a sleeve disposed in the tool body to divert the fluid to at least one of the fracturing sections while blocking the fluid from exiting another at least one of the fracturing sections.

[0010] The features and advantages of the present invention will be apparent to those skilled in the art. While numerous changes may be made by those skilled in the art, such changes are within the spirit of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] These drawings illustrate certain aspects of some of the embodiments of the present invention, and should not be used to limit or define the invention.

[0012] Figure 1 is a schematic block diagram of a wellbore and a system for fracturing.

[0013] Figure 2A is a graphical representation of a wellbore in a subterranean formation and the principal stresses on the formation.

Figure 2B is a graphical representation of a wellbore in a subterranean formation that has been fractured and the principal stresses on the formation.

[0014] Figure 3 is a flow chart illustrating an example method for fracturing a formation according to the present invention.

[0015] Figure 4 is a graphical representation of a wellbore and multiple fractures at different angles and fracturing locations in the wellbore.

[0016] Figure 5 is a graphical representation of a formation with a high-permeability region with two fractures.

[0017] Figure 6 is a graphical representation of drainage into a horizontal wellbore fractured at different angular orientations.

[0018] Figures 7A, 7B, and 7C illustrate a cross-sectional view of a fracturing tool showing certain optional features in accordance with one example implementation.

[0019] Figure 8 is a graphical representation of the drainage of a vertical wellbore fractured at different angular orientations.

[0020] Figure 9 is a graphical representation of a fracturing tool rotating in a horizontal wellbore and fractures induced by the fracturing tool.

DETAILED DESCRIPTION

[0021] The present invention relates generally to methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly to methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the formation. Furthermore, the present invention may be used on cased well bores or open holes.

[0022] The methods and apparatus of the present invention may allow for increased well productivity by the introduction of multiple fractures introduced at different angles relative to one another in the a wellbore.

[0023] Figure 1 depicts a schematic representation of a subterranean well bore 100 through which a fluid may be injected into a region of the subterranean formation surrounding well bore 100. The fluid may be of any composition suitable for the particular injection operation to be performed. For example, where the methods of the present invention are used in accordance with a fracture stimulation treatment, a fracturing fluid may be injected into a subterranean formation such that a fracture is created or extended in a region of the formation surrounding well bore 12 and generates pressure signals. The fluid may be injected by injection device 105 (e.g., a pump). At wellhead 115, a downhole conveyance device 120 is used to deliver and position a fracturing tool 125 to a location in the wellbore 100. In some example implementations, the downhole conveyance device 120 may include coiled tubing. In other example implementations, downhole conveyance device 120 may include a drill string that is capable of both moving the fracturing tool 125 along the wellbore 100 and rotating the fracturing tool 125. The downhole conveyance device 120 may be driven by a drive mechanism 130. One or more sensors may be affixed to the downhole conveyance device 120 and configured to send signals to a control unit 135. The control unit 135 is coupled to drive unit 130 to control the operation of the drive unit. The control unit

135 is coupled to the injection device 105 to control the injection of fluid into the wellbore 100. The control unit 135 includes one or more processors and associated data storage.

[0024] Figure 2 is an illustration of a wellbore 205 passing through a formation 210 and the stresses on the formation. In general, formation rock is subjected by the weight of anything above it, *i.e.* σ_z overburden stresses. By Poisson's rule, these stresses and formation pressure effects translate into horizontal stresses σ_x and σ_y . In general, however, Poisson's ratio is not consistent due to the randomness of the rock. Also, geological features, such as formation dipping and tectonic stresses may cause other stresses. Therefore, in most cases, σ_x and σ_y are different.

[0025] Figure 2B is an illustration the wellbore 205 passing through the formation 210 after a fracture 215 is induced in the formation 210. Assuming for this example that σ_x is smaller than σ_y , the fracture 215 will extend into the y direction. The orientation of the fracture is, however, in the x direction. As used herein, the orientation of a fracture is defined to be a vector perpendicular to the fracture plane.

[0026] As fracture 215 opens fracture faces to be pushed in the x direction. Because formation boundaries cannot move, the rock becomes more compressed, increasing both σ_x and σ_y however to different degrees. Over time, the fracture will tend to close as the rock moves back to its original shape due to the increased σ_x . The change in the two horizontal stresses will change the hoop stress (tangential stress around the wellbore) While the fracture is closing however, the stresses in the formation will cause a subsequent fracture to propagate in a new direction shown by projected fracture 220. The method, system, and apparatus according to the present invention are directed to initiating fractures, such as projected fracture 220, while the stress field in the formation 210 is temporarily altered by an earlier fracture, such as fracture 215.

[0027] If the existing fracture is prevented from taking any more fluid (by chemical or mechanical means) the new hoop stress will favor the initiation of a fracture at angle to the first fracture. The minimum tangential stress will be between 0 and 90 degrees. This value will depend on the magnitude of the minimum and maximum horizontal stresses, the fracture width, and net stress reached during creation of the first fracture. The tangential stress will not be 90 degrees even if the initial horizontal stresses are equal.

[0028] The foregoing is illustrated by the following example. The general equation for the distribution of the tangential (hoop) stress is given below:

$$\sigma_{\theta} = \frac{1}{2}(\sigma_y + \sigma_x) \left(1 + \left(\frac{r}{r_w} \right)^2 \right) - \frac{1}{2}(\sigma_y - \sigma_x) \left(1 + 3 \left(\frac{r}{r_w} \right)^4 \right) \cos(2\theta)$$

[0029] The tangential stress forms a profile around the wellbore. The minimum value occurs at angle, θ , of zero. The value of the tangential stress is at maximum at the wellbore surface. It declines quickly to a value equal to perpendicular principal stress within a few radii from the wellbore. The axial stress on the other hand is equal to zero at the wellbore.

[0030] The hoop stress before and after the creation of the first fracture given the reservoir data set forth in the Table I below is illustrated in Figure 10.

Table 1 – Input parameters for example

parameter	value	Parameter	value
$\sigma_{\min}$, psi	6000	Pore pressure, psi	5000
$\sigma_{\max}$, psi	6500	Net pressure, psi	500
σ_v , psi	7000	Wellbore radius, ft	0.25

From Figure 10, it is clear that the following has happened:

- The magnitude of the tangential stress all around the well bore has increased. The largest increase occurred right near where the first fracture was created.
- The location of the minimum tangential stress has moved from angle Theta of zero to angle Theta of $+38^\circ$ and -38° .
- There are two preferred orientations for the second fracture. Presence of perforation / jetting will determine which orientation would be the actual orientation of the fracture.

[0031] Lithological heterogeneity may also play a part in the determining the fracture orientation. It is highly desirable to orient the second fracture in the preferred orientation to minimize tortiousity. The technique used in creating the first fracture will apply when creating the second fracture.

[0032] After the creation of a second fracture, it would be expected that the tangential stress changes would be even more significant in the orientation of a third or subsequent fracture. In addition the symmetry of the system would be lost. Figure 11 illustrates the tangential stress profile in the first quadroon for the condition give in Figure 10 after creating two fractures. The minimum tangential stress would occur at about 52 degrees and at a value slightly more than 4700 psi.

[0033] The tangential stress after creating the first fracture was calculated first by calculating the increase in stress due to the presence of the fracture. Assuming that the width of the fracture is too small to affect the circular shape of the well, the tangential pressure may

be calculated using conventional methods. A more accurate method is to do this calculation using a numerical simulator. However the potential change in angle will most probably too small to be of significant effect under real operational conditions.

[0034] This invention may also be used to create multiple longitudinal fractures intersecting a horizontal well. If the horizontal well is drilled in the direction of maximum stress a longitudinal fracture is usually expected. This longitudinal fracture may be created in situations involving open hole fracturing, cased hole with perforations and slotted casing. The preferred way is to create the perforation or slot or other means of communication along the top and bottom of the well. One method to create the means of communication is by hydrojetting.

[0035] Figure 3 is a flow chart illustration of an example implementation of one method of the present invention, shown generally at 300. The method includes determining one or more geomechanical stresses at a fracturing location in step 305. In some implementations, step 305 may be omitted. In some implementations, this step includes determining a current minimum stress direction at the fracturing location. In one example implementation, information from tilt meters or micro-seismic tests performed on neighboring wells is used to determine geomechanical stresses at the fracturing location. In some implementations, geomechanical stresses at a plurality of possible fracturing locations are determined to find one or more locations for fracturing. Step 305 may be performed by the control unit 305 by computer with one or more processors and associated data storage.

[0036] The method 300 further includes initiating a first fracture at about the fracturing location in step 310. The first fracture's initiation is characterized by a first orientation line. In general, the orientation of a fracture is defined to be a vector normal to the fracture plane. In this case, the characteristic first orientation line is defined by the fracture's initiation rather than its propagation. In certain example implementations, the first fracture is substantially perpendicular to a direction of minimum stress at the fracturing location in the wellbore.

[0037] The initiation of the first fracture temporarily alters the stress field in the subterranean formation, as discussed above with respect to figures 2A and 2B. The duration of the alteration of the stress field may be based on factors such as the size of the first fracture, rock mechanics of the formation, the fracturing fluid, and subsequently injected proppants, if any. Due to the temporary nature of the alteration of the stress field in the

formation, there is a limited amount of time for the system to initiate a second fracture at about the fracturing location before the temporary stresses alteration has dissipated below a level that will result in a subsequent fracture at the fracturing being usefully reoriented. Therefore, in step 315 a second fracture is initiated at about the fracturing location before the temporary stresses from the first fracture have dissipated. In some implementations, the first and second fractures are initiated within 24 hours of each other. In other example implementations, the first and second fractures are initiated within four hours of each other. In still other implementations, the first and second fractures are initiated within an hour of each other.

[0038] The initiation of the second fracture is characterized by a second orientation line. The first orientation line and second orientation lines have an angular disposition to each other. The plane that the angular disposition is measured in may vary based on the fracturing tool and techniques. In some example implementations, the angular disposition is measured on a plane substantially normal to the wellbore axis at the fracturing location. In some example implementations, the angular disposition is measured on a plane substantially parallel to the wellbore axis at the fracturing location.

[0039] In some example implementations, step 315 is performed using a fracturing tool 125 that is capable of fracturing at different orientations without being turned by the drive unit 130. Such a tool may be used when the downhole conveyance 120 is coiled tubing. In other implementations, the angular disposition between the fracture initiations is caused by the drive unit 130 turning a drillstring or otherwise reorienting the fracturing tool 125. In general there may be an arbitrary angular disposition between the orientation lines. In some example implementations, the angular orientation is between 45° and 135°. More specifically, in some example implementations, the angular orientation is about 90°. In still other implementations, the angular orientation is oblique.

[0040] In step 320, the method includes initiating one or more additional fractures at about the fracturing location. Each of the additional fracture initiations are characterized by an orientation line that has an angular disposition to each of the existing orientation lines of fractures induced at about the fracturing location. In some example implementations, step 320 is omitted. Step 320 may be particularly useful when fracturing coal seams or diatomite formations.

[0041] The fracturing tool may be repositioned in the wellbore to initiate one or more other fractures at one or more other fracturing locations in step 325. For example, steps 310, 315, and optionally 320 may be performed for one or more additional fracturing locations in the wellbore. An example implementation is shown in Figure 4. Fractures 410 and 415 are initiated at about a first fracturing location in the wellbore 405. Fractures 420 and 425 are initiated at about a second fracturing location in the wellbore 405. In some implementations, such as that shown in figure 4, the fractures at two or more fracturing locations, such as fractures 410-425, and each have initiation orientations that angularly differ from each other. In other implementations, fractures at two or more fracturing locations have initiation orientations that are substantially angularly equal. In certain implementations, the angular orientation may be determined based on geomechanical stresses about the fracturing location.

[0042] Figure 5 is an illustration of a formation 505 that includes a region 510 with increased permeability, relative to the other portions of formation 505 shown in the figure. When fracturing to increase the production of hydrocarbons, it is generally desirable to fracture into a region of higher permeability, such as region 510. The region of high permeability 510, however, reduces stress in the direction toward the region 510 so that a fracture will tend to extend in parallel to the region 510. In the fracturing implementation shown in figure 5, a first fracture 515 is induced substantially perpendicular to the direction of minimum stress. The first fracture 515 alters the stress field in the formation 505 so that a second fracture 520 can be initiated in the direction of the region 510. Once the fracture 520 reaches the region 510 it may tend to follow the region 510 due to the stress field inside the region 510. In this implementation, the first fracture 515 may be referred to as a sacrificial fracture because its main purpose was simply to temporarily alter the stress field in the formation 505, allowing the second fracture 520 to propagate into the region 510.

[0043] Figure 6 illustrates fluid drainage from a formation into a horizontal wellbore 605 that has been fractured according to method 100. In this situation, the effective surface area for drainage into the wellbore 605 is increased, relative to fracturing with only one angular orientation. In the example shown in figure 6, fluid flow along planes 610 and 615 are able to enter the wellbore 605. In addition, flow in fracture 615 does not have to enter the wellbore radially, which causes a constriction to the fluid. Fig. 6 also shows flow entering the fracture 615 in a parallel manner; which then flows through the fracture 615 in a parallel

fashion into fracture 610. This scenario causes very effective flow channeling into the wellbore.

[0044] In general, additional fractures, regardless of their orientation, provide more drainage into a wellbore. Each fracture will drain a portion of the formation. Multiple fractures having different angular orientations, however, provide more coverage volume of the formation, as shown by the example drainage areas illustrated in figure 8. The increased volume of the formation drained by the multiple fractures with different orientations may cause the well to produce more fluid per unit of time.

[0045] A cut-away view of an example fracturing tool 125, shown generally at 700, that may be used with method 300 is shown in figures 7A-7C. The fracturing tool 700 includes at least two fracturing sections, such as fracturing sections 705 and 710. Each of sections 705 and 710 are configured to fracture at an angular orientation, based on the design of the section. In one example implementation, fluid flowing from section 710 may be oriented obliquely, such as between 45° to 90°, with respect to fluid flowing from section 705. In another implementation fluid flow from sections 705 and 710 are substantially perpendicular.

[0046] The fracturing tool includes a selection member 715, such as sleeve, to activate or arrest fluid flow from one or more of sections 705 and 710. In the illustrated implementation selection member 715 is a sliding sleeve, which is held in place by, for example, a detent. While the selection member 715 is in the position shown in Fig. 7A, fluid entering the tool body 700 exits through section 705.

[0047] A valve, such as ball valve 725 is at least partially disposed in the tool body 700. The ball valve 725 includes an actuating arm allowing the ball valve 725 to slide along the interior of tool body 700, but not exit the tool body 700. In this way, the ball valve 725 prevents the fluid from exiting from the end of the fracturing tool 125. The end of the ball valve 725 with actuating arm may be prevented from exiting the tool body 700 by, for example, a ball seat (not shown).

[0048] The fracturing tool further comprises a releasable member, such as dart 720, secured behind the sliding sleeve. In one example implementation, the dart is secured in place using, for example, a J-slot.

[0049] In one example implementation, once the fracture is induced by sections 705, the dart 720 is released. In one example implementations, the dart is released by quickly and

briefly flowing the well to release a j-hook attached to the dart 725 from a slot. In other example implementations, the release of the dart 720 may be controlled by the control unit 135 activating an actuator to release the dart 720. As shown in figure 7B, the dart 720 causes the selection member 715 to move forward causing fluid to exit through section 710.

[0050] As shown in Figure 7C, the ball valve 725 with actuating arm may reset the tool by forcing the dart 720 back into a locked state in the tool body 700. The ball valve 725 also may force the selection member 715 back to its original position, before fracturing was initiated. The ball valve 725 may be forced back into the tool body 700 by, for example, flowing the well.

[0051] Another example fracturing tool 125 is shown in figure 9. Tool body 910 receives fracturing fluid through a drill string 905. The tool body has an interior and an exterior. Fracturing passages pass from the interior to the exterior at an angle, causing fluid to exit from the tool body 910 at an angle, relative to the axis of the wellbore. Because of the angular orientation of the fracturing passages, multiple fractures with different angular orientations may be induced in the formation by reorienting the tool body 810. In one example implementation, the tool body is rotated to reorient the tool body 810 to fracture at different orientations and create fractures 915 and 920. For example, the tool body may be rotated about 180°. In the example implementation shown in figure 9 where the fractures 915 and 920 are induced in a horizontal or deviated portion of a wellbore, the drill string 805 may be rotated more than the desired rotation of the tool body 910 to account for friction.

[0052] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

What is claimed is:

1. A method for fracturing a subterranean formation, wherein the subterranean formation comprises a wellbore having an axis, the method comprising:
 - inducing a first fracture in the subterranean formation, wherein:
 - the first fracture is initiated at about a fracturing location,
 - the initiation of the first fracture is characterized by a first orientation line, and
 - the first fracture temporarily alters a stress field in the subterranean formation; and
 - inducing a second fracture in the subterranean formation, wherein:
 - the second fracture is initiated at about the fracturing location,
 - the initiation of the second fracture is characterized by a second orientation line, and
 - the first orientation line and the second orientation line have an angular disposition to each other.
2. The method of claim 1, wherein the second fracture is initiated before the temporary alteration of the set of geomechanical stresses at the fracturing location due to the first fracture has dissipated.
3. The method of claim 1, wherein the second fracture is initiated no later than twenty-four hours after the first fracture is initiated.
4. The method of claim 1, wherein the second fracture is initiated no later than four hours after the first fracture is initiated.
5. The method of claim 1, wherein the angular disposition is between 45°-135°.
6. The method of claim 1, wherein the angular disposition is about 90°.
7. The method of claim 1, further comprising:
 - determining a set of geomechanical stresses at the fracturing location in the wellbore and wherein the first orientation line and second orientation line are chosen based, at least in part, on the set of geomechanical stresses.
8. The method of claim 1, wherein the first fracture is substantially perpendicular to a direction of minimum stress at the fracturing location in the wellbore.
9. The method of claim 1, further comprising:
 - inducing a third fracture in the subterranean formation, wherein:
 - the third fracture is initiated at about a second fracturing location,
 - the initiation of the third fracture is characterized by a third orientation line, and
 - the third fracture temporarily alters a stress field in the subterranean formation; and

inducing a fourth fracture in the subterranean formation, wherein:
the fourth fracture is initiated at about the second fracturing location,
the initiation of the fourth fracture is characterized by a fourth
orientation line, and
the third orientation line and the fourth orientation line have an angular
disposition to each other.

10. The method of claim 1, further comprising:

inducing at least one additional fracture, wherein:

the at least one additional fracture is initiated at about the fracturing
location;

the initiation of the at least one additional fracture is characterized by
an additional orientation line, and

the additional orientation line differs from both the first orientation line
and the second orientation line.

11. The method of claim 1, further comprising:

providing a fracturing tool that is configured to receiving a fluid and deliver a
fluid into the subterranean formation, the fracturing tool comprising a plurality of
sections, each comprising at least one opening to deliver the fluid into the
formation at an orientation and a sleeve divert the fluid to at least one of the
plurality of sections.

12. A system for fracturing a subterranean formation, wherein the subterranean
formation comprises a wellbore, the system comprising:

a downhole conveyance selected from a group consisting of a drill string and
coiled tubing, wherein the downhole conveyance is at least partially disposed in
the wellbore;

a drive mechanism configured to move the downhole conveyance in the
wellbore;

a pump coupled to the downhole conveyance to flow a fluid through the
downhole conveyance;

a fracturing tool coupled to the downhole conveyance, the fracturing tool
comprising:

a tool body to receive the fluid, the tool body comprising a plurality of
fracturing sections, wherein each fracturing section includes at least one opening
to deliver the fluid into the subterranean formation at an angular orientation; and

a computer configured to control the operation of the drive mechanism and the
pump.

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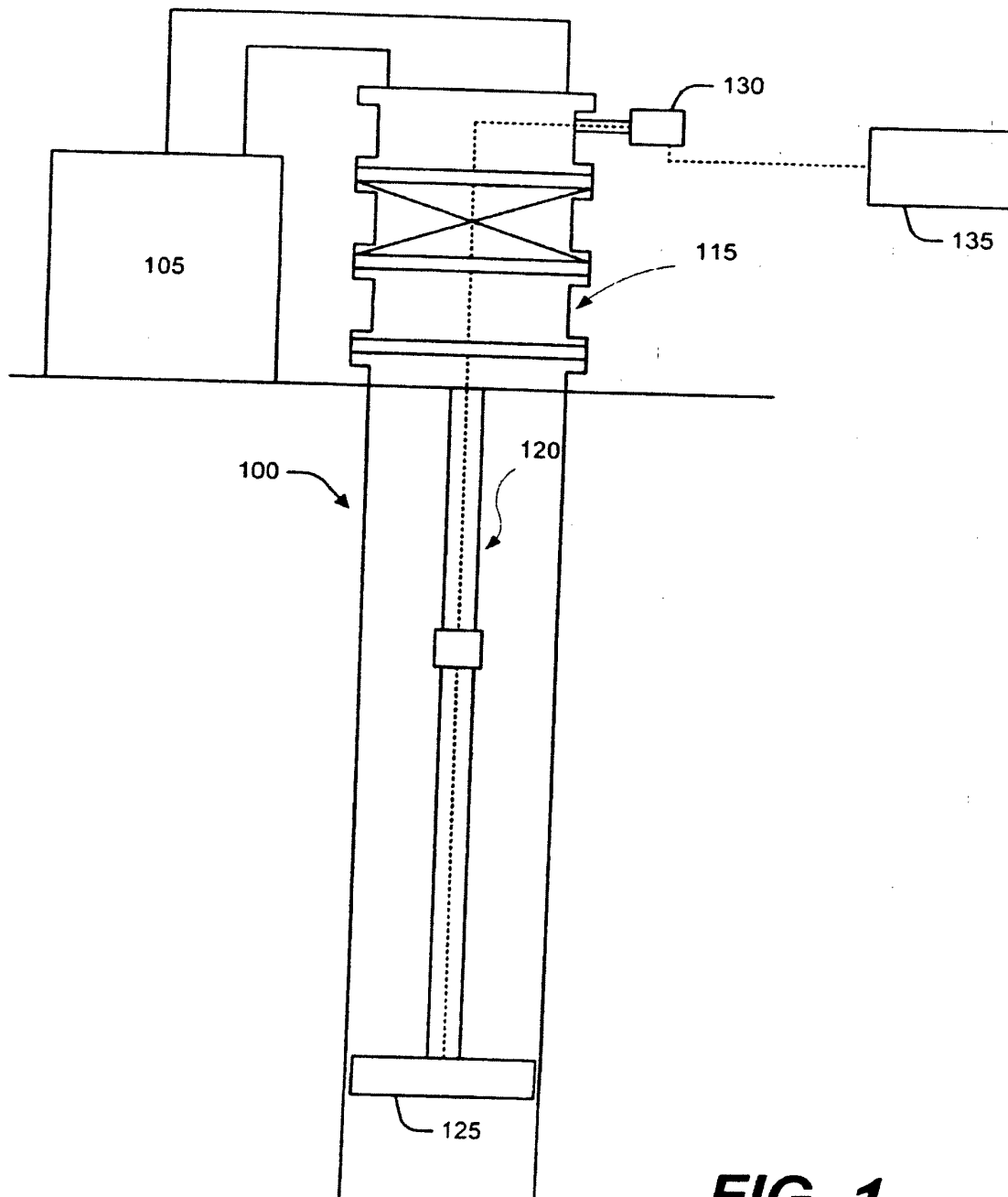
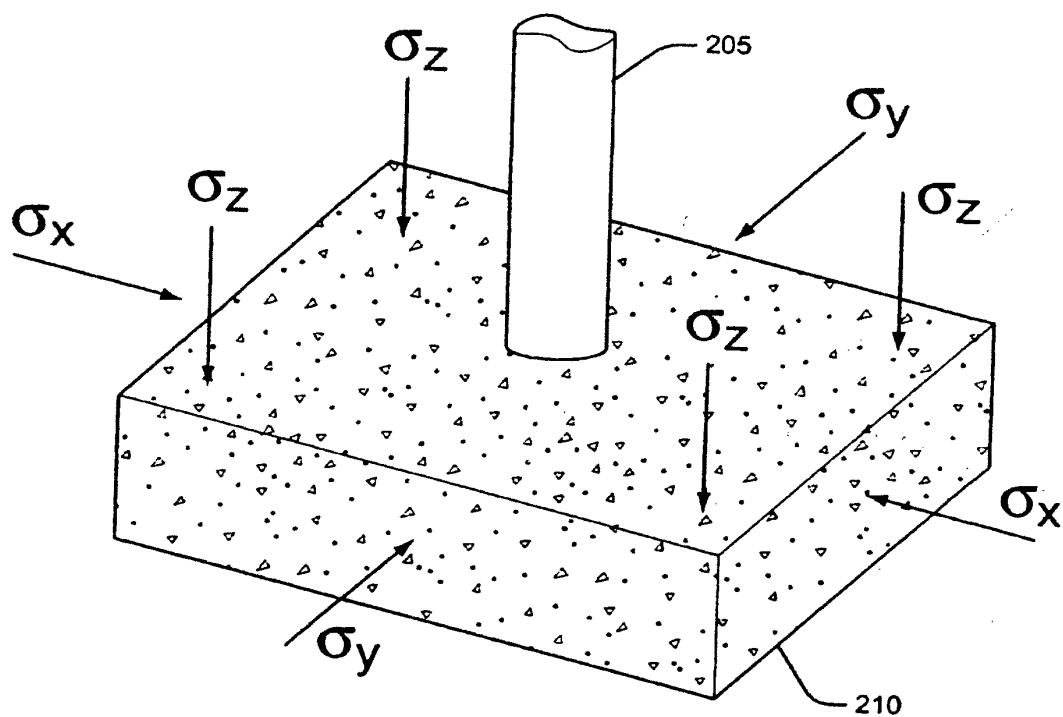
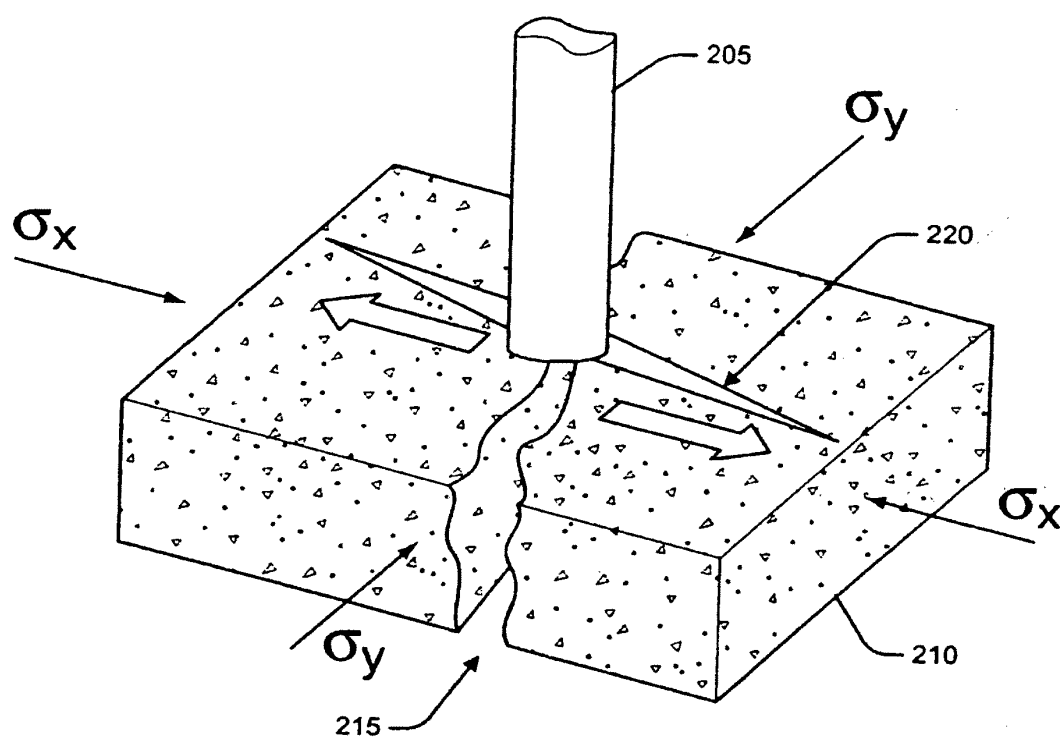


FIG. 1

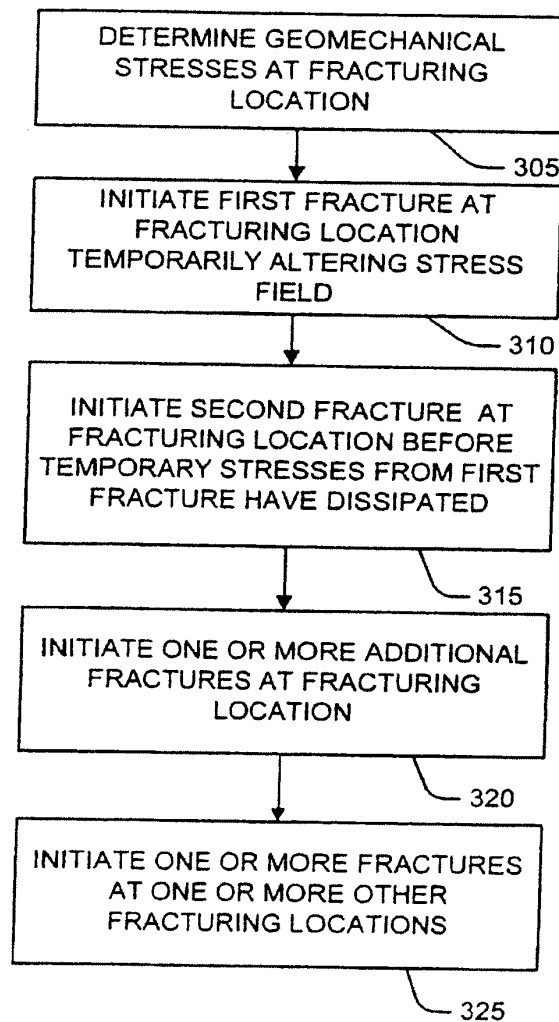
**FIG. 2A**

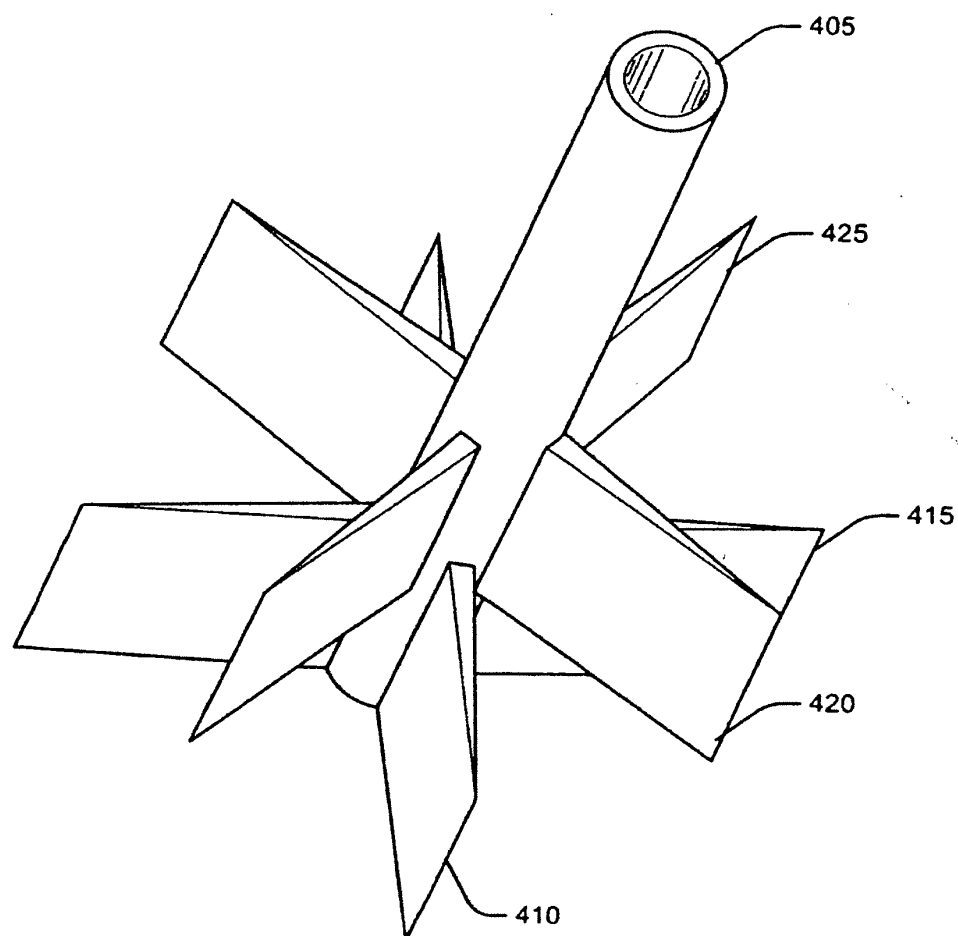
**FIG. 2B**

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FIG. 3

300



**FIG. 4**

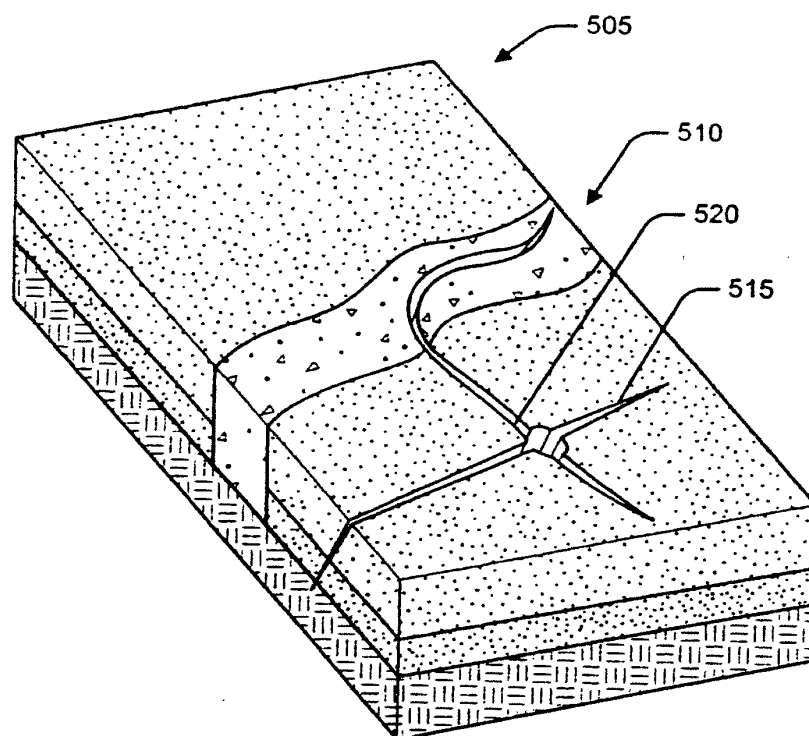


FIG. 5

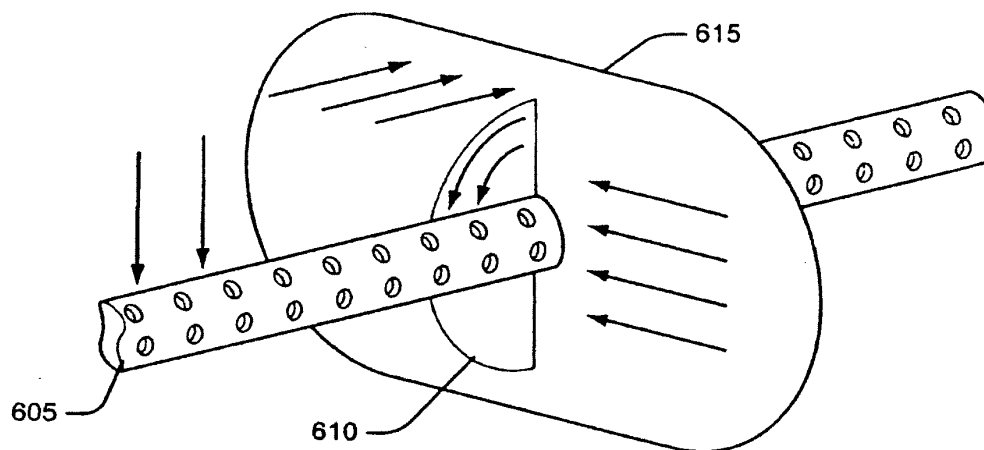


FIG. 6

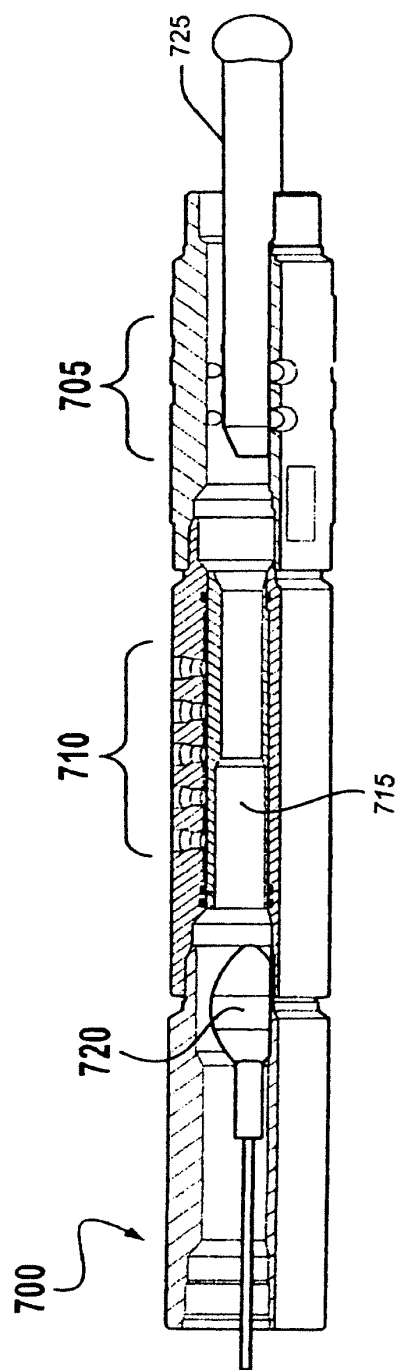


FIG. 7A

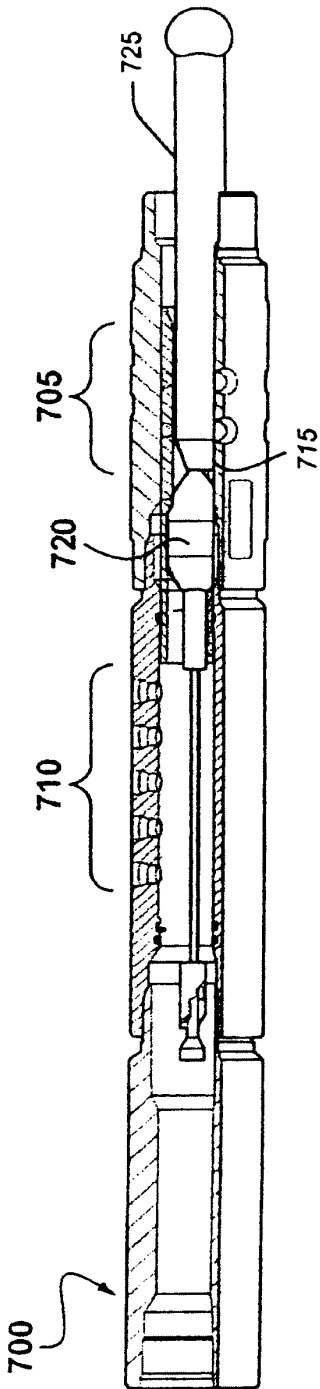


FIG. 7B

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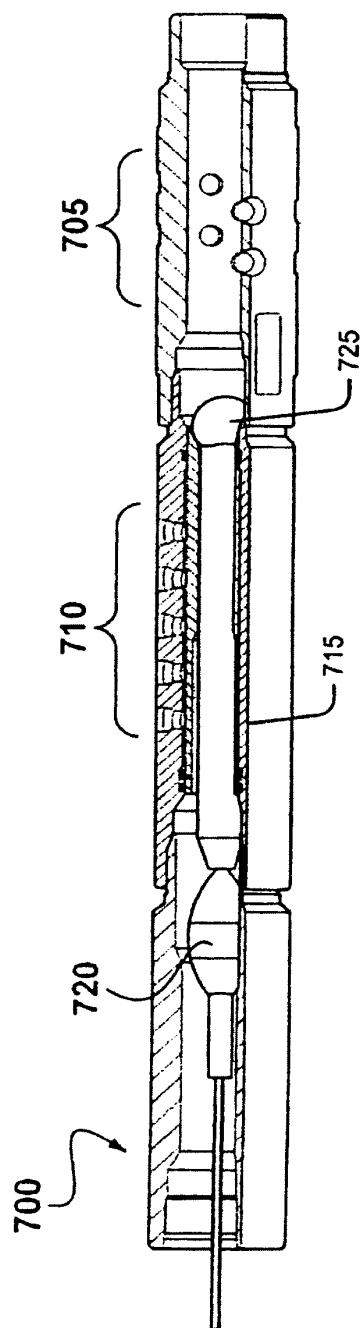


FIG. 7C

11/14

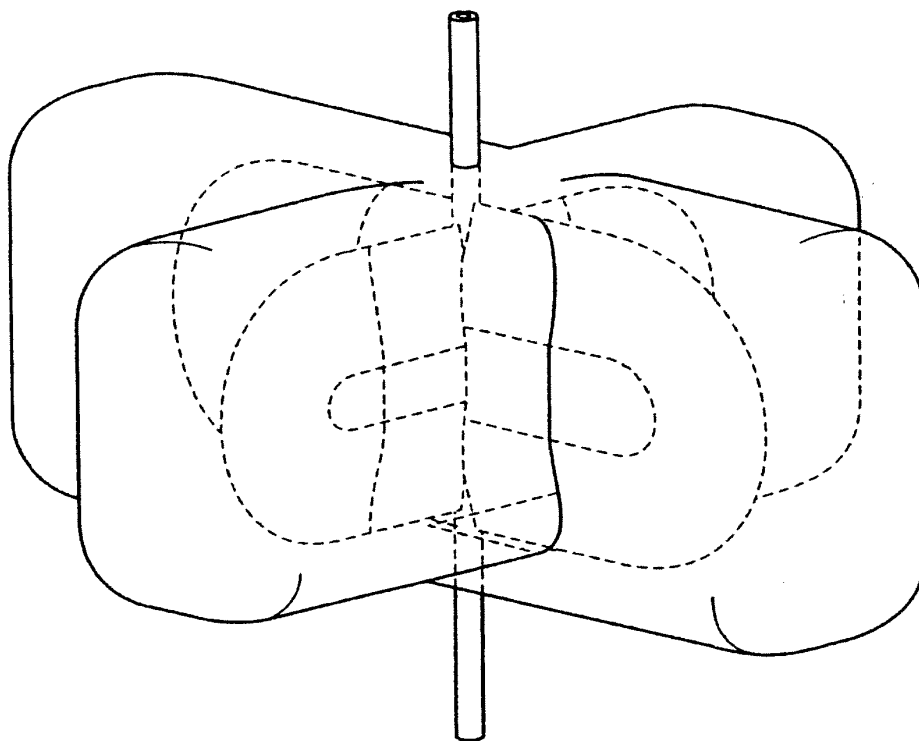


FIG. 8

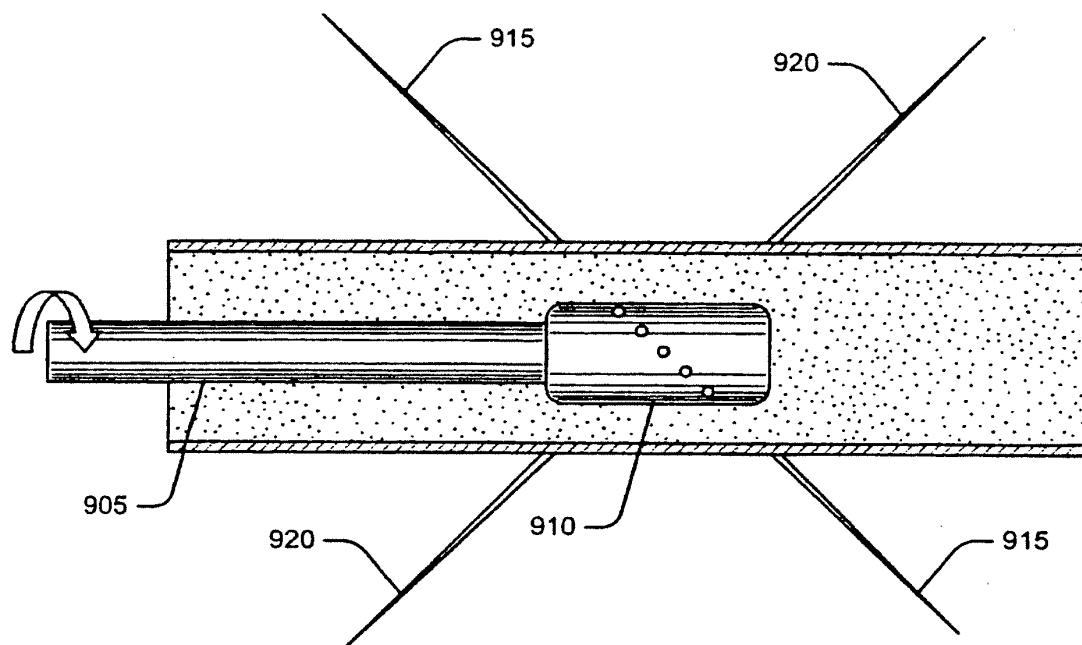
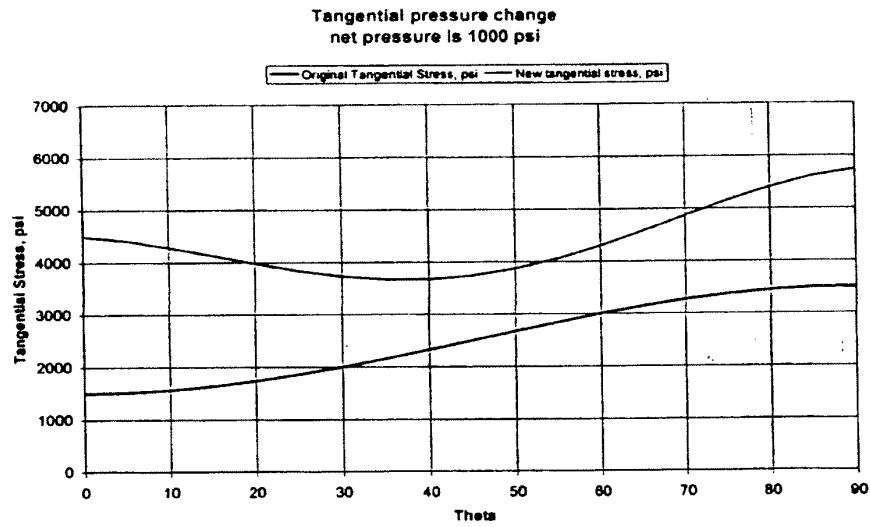


FIG. 9

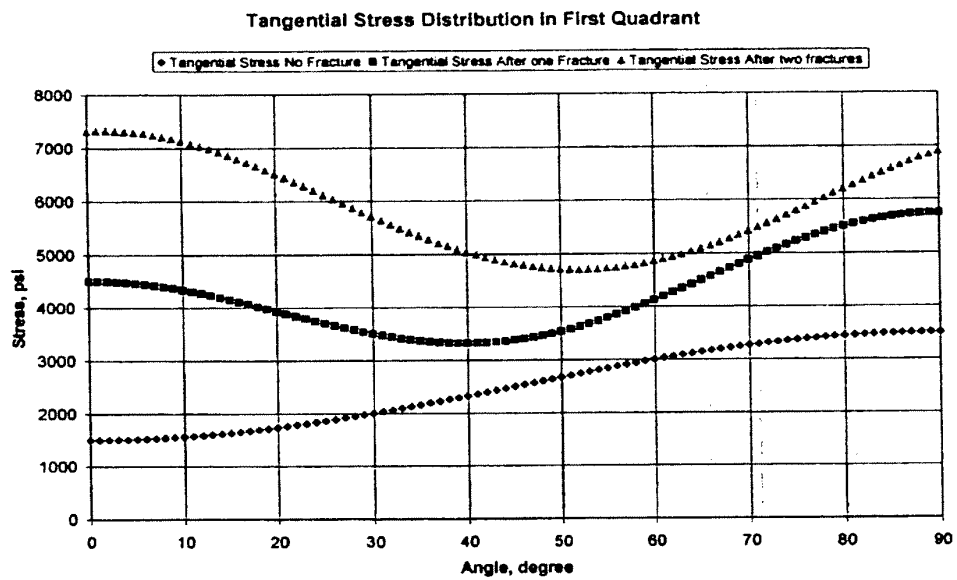
13/14

Figure 10 – Stress profile around the wellbore for net pressure of 1000 psi



14/14

Figure 11 - Stress profile around the wellbore after creating two fractures



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/003809

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/26 E21B43/114 E21B49/00

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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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

A document member of the same patent family

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11/12/2007

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Manolache, Justin

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/003809

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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page 2 of 2

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International application No

PCT/GB2007/003809

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11/753,314 24 May 2007 (24.05.2007) US

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(74) Agents: **CURTIS, Philip, Anthony** et al.; A.A. Thornton & Co., 235 High Holborn, London WC1V 7LE (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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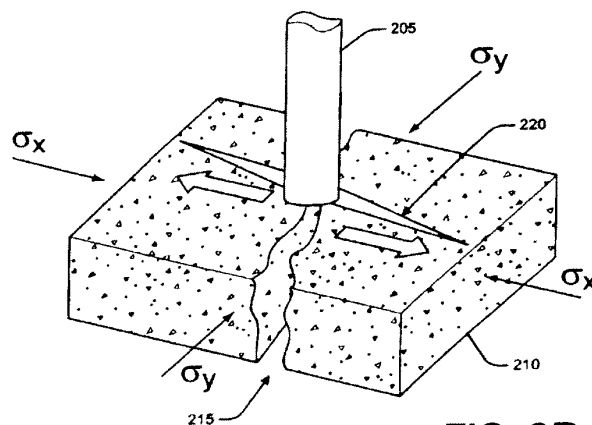


FIG. 2B

(57) Abstract: The present invention relates to methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly to methods and apparatus to place a first fracture (215) with a first orientation (x) in a formation (210) followed by a second fracture (220) with a second angular orientation (y) in the formation. The first and second fractures are initiated at about a fracturing location. The initiation of the first fracture is characterized by a first orientation line. The first fracture temporarily alters a stress field in the subterranean formation. The initiation of the second fracture is characterized by a second orientation line. The first orientation line and the second orientation line have an angular disposition to each other. There is a time delay between inducing the first fracture and inducing the second fracture.

INTERNATIONAL SEARCH REPORT

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INV. E21B43/26

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Authorized officer

Garrido Garcia, M

INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB2008/001730

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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page 2 of 2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2008/001730

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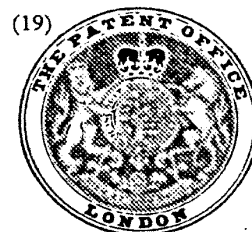
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1 460 647

PATENT SPECIFICATION

(11) 1 460 647

- (21) Application No. 46458/74 (22) Filed 28 Oct. 1974
 (44) Complete Specification published 6 Jan. 1977
 (51) INT CL² E21B 43/26
 (52) Index at acceptance E1F 44
 (72) Inventor OTHAR MEADE KIEL



(54) HYDRAULIC FRACTURING PROCESS

- (71) We, INTERCOMP RESOURCE DEVELOPMENT & ENGINEERING INC., a corporation organised under the laws of the State of Texas, United States of America, of 2000 West Loop South, Houston, State of Texas, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates to hydraulic fracturing of earth formations, and more particularly to the hydraulic fracturing of HC (hydrocarbon) bearing formations, e.g. oil and gas sands, for the purpose of increasing the producing rate and total amount of recovery of the hydrocarbons from a well completed in such a formation, and, in the case of storage wells for the purpose of increasing the injection rate and total capacity.
- The hydraulic fracturing of HC formations is well known and is described for example in the following United States patents number:
- 3263751—Kiel et al.
 - 3376930—Kiel et al.
 - 3373815—Kiel et al.
 - 3378074—Kiel
 - 3399727—Graham & Kiel
 - 3444889—Kiel et al.
 - 3497008—Graham & Kiel
 - 3552494—Kiel
 - 3601198—Ahearn & Kiel

SPECIFICATION NO 1460647

By a direction given under Section 17 (1) of the Patents Act 1949 this application proceeded in the name of OTHAR MEADE KIEL, a citizen of the United States of America, of 5830 Cheena, Houston, State of Texas, United States of America.

Bas 33278/6

THE PATENT OFFICE

- The function of fracturing is to overcome the deficiency in permeability of the formation adjacent the well bore by creating a highly conductive path reaching out into the reservoir rock surrounding the well bore. According to the usual practice, a fluid such as water, oil, oil/water emulsion, gelled water, gelled oil, is pumped down a well bore with sufficient pressure to open a fracture in the HC formation. The fluid may carry a suitable propping agent, such as sand, into the fracture for the purpose of holding the fracture open after the fracturing fluid has been recovered, e.g. by allowing the well to flow. A normal fracture treatment consists of one continuous injection of fluid. In the case of tight, i.e. low permeability wells, i.e. below 1 md permeability, fracturing produces results that are of but a temporary nature as far as increasing rate of flow is concerned and little or no increase in total recovery is achieved. After perhaps a short period of accelerated flow, rate of production may drop off to near previous levels. Repeated stimulation with the same or similar procedure may again produce but a temporary gain.

The reason for the temporary increase in productivity is believed to be that the fracture communicates the well bore with a small portion of the joint system between

PATENT SPECIFICATION

(11) 1 460 647

- (21) Application No. 46458/74 (22) Filed 28 Oct. 1974
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 (72) Inventor OTHAR MEADE KIEL



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 3444889—Kiel et al.
 3497008—Graham & Kiel
 3552494—Kiel
 3601198—Ahearn & Kiel
 3664420—Graham, Kiel & Terry
 3695355—Wood & Kiel
 3700032—Terry, Graham, Sinclair & Kiel
 3722595—Kiel

and in the reference cited against the above listed patents and application.

Further description of the subject is to be found in an article entitled "Reservoirs in Fractured Rock" by Stearns and Friedman appearing at pages 82 et seq. of AAPG Memoir #16 Stratigraphic Oil & Gas Classification Methods and Case Histories—1972 and the bibliography appended thereto.

The function of fracturing is to overcome the deficiency in permeability of the formation adjacent the well bore by creating a highly conductive path reaching out into the reservoir rock surrounding the well bore. According to the usual practice, a fluid such as water, oil, oil/water emulsion, gelled water, gelled oil, is pumped down a well bore with sufficient pressure to open a fracture in the HC formation. The fluid may carry a suitable propping agent, such as sand, into the fracture for the purpose of holding the fracture open after the fracturing fluid has been recovered, e.g. by allowing the well to flow. A normal fracture treatment consists of one continuous injection of fluid. In the case of tight, i.e. low permeability wells, i.e. below 1 md permeability, fracturing produces results that are of but a temporary nature as far as increasing rate of flow is concerned and little or no increase in total recovery is achieved. After perhaps a short period of accelerated flow, rate of production may drop off to near previous levels. Repeated stimulation with the same or similar procedure may again produce but a temporary gain.

The reason for the temporary increase in productivity is believed to be that the fracture communicates the well bore with a small portion of the joint system between

the matrix elements of the formation. However, as soon as the low volume space has been drained, productivity drops off to that controlled by the low permeability reservoir matrix, and since the area exposed to such matrix by a short fracture is low, productivity is low.

Hydraulic fracturing procedure usually has best results in formations of moderate permeability, e.g. one to twenty millidarcies. In order to achieve satisfactory production from a formation of low permeability, e.g. below one millidarcy, it has been the belief of experts that a much longer fracture than that heretofore attainable would be necessary. Prior to the present invention, a conductive fracture extending radially one hundred fifty feet from the well bore is believed to be about maximum.

According to the invention there is provided a method of well treatment by hydraulic fracturing of the formation to be treated, said fracturing including at least one double cycle comprising injecting fluid capable of undergoing fluid loss to said formation once said formation is fractured into the formation at a pressure and for a period of time sufficient to allow hydraulic fracture to occur, discontinuing said fluid injection for a period of time at least long enough to allow a pressure drop in said fluid from fluid loss from said fracture to the formation, resuming injection of said fluid into said formation, and discontinuing said latter injection of fluid.

Otherwise stated, according to the invention there are scheduled periods of pump shut down or reduced rate to cause low fracture pressure to produce spalling, and there are plural periods of injection of fracturing fluid to move the spalls into propping position, to sandblast clear any fracture restrictions, and to sand out prior fractures to initiate secondary fractures transverse to the original.

In the case of an extremely thick section, e.g. in excess of fifty feet of uniform sand body, for the purpose of controlling loss of fracturing fluid to the formation, sand or other material of various sizes may be added to the fracturing material, and the vertical extent of the well bore treated thereby confined to the upper portion of the producing formation.

In general, in accordance with the present invention, well productivity is increased by multiple hydraulic fracturing cycles with high viscosity fluid, first creating a long primary fracturing and holding it open with formation spalls and sand blasting any great restrictions and then successively creating two oppositely directed secondary long fractures transverse to the primary fractures, the loss of fracturing liquid to the formation being controlled with a selected size of sand to filter pack the natural joint system, and in some instances to filter pack the vertical downward extent of joints and fractures with the fracturing limited to the upper portion of the producing formation where upward leakage is inhibited by the overburden.

Further features of the invention will become apparent from the further description appearing hereinafter, by way of example.

In a preferred embodiment the injection pressure during each double cycle subsequent to the first double cycle is at least 10 per cent greater than during the first double cycle. Furthermore, the period of an even numbered injection is preferably $1/4$ to $1/3$ the period of an immediately preceding odd numbered injection, considering that the plurality of injections are numbered consecutively in chronological order.

The periods of the plurality of consecutive pairs of injection periods, considering the first and second injection periods as the first such pair are approximately proportional to the square root of the number of such pair, considering that the several pairs are numbered consecutively in chronological order.

The fracturing fluid is preferably of the formation pressure increasing type. For a detailed description of preferred embodiments of the invention reference will be made to the following drawings wherein:

FIGURE 1 is a plan view of a well site showing graphically the time of travel of a pressure wave front versus radial distance from the well bore, the well being a tight well and having been completed by conventional perforation without further stimulation.

FIGURE 2 is a similar plan view showing the results of conventional fracturing and of an improved form of fracture in accordance with one form of the present invention.

FIGURES 3 and 4 are diagrams illustrating possible reasons for failure of conventional hydraulic fracturing producing very long fractures;

FIGURES 5, 6 and 7 are schematic plan views of dendritic fracture systems in accordance with the invention;

FIGURE 8 is a plan view similar to FIGURES 1 and 2 illustrating the wave front pattern utilizing the dendritic fracture system, esp. of FIGURES 6 and 7;

FIGURE 9 is a plan view similar to FIGURE 8 illustrating another aspect of the invention;

FIGURE 10 is a schematic plan view of a stage in the process of creating the dendritic fracture system of the invention,

FIGURE 11 is an isometric view of a thick sand provided in its upper portion with a dendritic fracture system in accordance with the invention,

FIGURE 12 is a chart comparing well productivities, and

FIGURE 13, 14 and 15 are charts of well productivity.

A. PRIOR ART—NO FRACTURE

According to reservoir engineering theory, the time for a pressure disturbance, e.g. a pressure drop initiated by producing a well, to be propagated radially through an earth formation from the well bore, may be determined the following equation:

$$t_D = (40) (\phi) (u) (c) (D)^2 / k \quad (1)$$

where t_D = diffusion time to radius D (days)

ϕ = porosity (fractional)

u = viscosity in centipoise

c = fluid compressibility in (psi^{-1})

D = Distance to which the pressure disturbance has been propagated measured radially from the well bore in feet.

k = permeability in millidarcies.

Reservoir engineering theory and practice further indicate that the time T to drain the volume within the radius D of the well bore is given approximately by the equation:

$$T = 20 t_D \quad (2)$$

Twenty years is the drainage time conventionally allowed for a well. If $T = 20$ years, $t_D = 20/20 = 1$ year, so that at the end of one year the wave front will reach the distance D_{20} , drained in twenty years. Therefore

$$D_{20}^2 = 9.125k / \phi u c \quad (3)$$

From equation (3) one can calculate the radius D_{20} of volume drainable in a 20 year period, the conventional period of the production life of a well for any particular type of formation.

Assuming that

$\phi = 0.1$

$u = 0.02$ cps

$c = 1/1500$

$k = 0.03$ md

one finds that

$D_{20} = 450$ feet

In other words, for the pressure wave front to reach just a 450 foot radius or 14.6 acre area, in such a tight formation takes a whole year, and it takes twenty years to drain such a small volume. Similar calculation show that the pressure wave will take 21.5 years to reach the perimeter of a 320 acre square centred on the well bore and that the volume extending horizontally over such an area would be drainable in 430 years. The wave would take 34 years in the case of a 640 acre tract (one square mile) which would be drainable in 680 years. The foregoing is shown graphically in FIGURE 1 wherein there is shown well bore 21 and 1, 21.5, and 34 year wave fronts 23, 25, 27 and the perimeters 29, 31 of 320 and 640 acre tracts.

It will be apparent from the foregoing that in order to produce a field of such low permeability within a twenty year period the well spacing would have to be 900 feet, i.e. a well density of 43 wells per square mile. This shows the impracticality of economically producing a well in such tight formation without special productive techniques.

B. CONVENTIONAL SHORT FRACTURES

Referring now to FIGURE 2 there is shown schematically the situation existing in the case of a producing formation that has been processed in accordance with hydraulic fracturing techniques to create a single highly conductive fracture along line 33 extending from the well bore 21 in opposite directions. In this situation we are no longer dealing with radial propagation of the pressure wave nor radial flow. Because of the highly conductive fracture, it may be assumed that pressure throughout the fracture plane is substantially equal to that at the well bore. The pressure disturbance produced by producing the well creates a pair of planar wave fronts parallel to the fracture plane that are propagated in opposite directions perpendicular to the fracture plane. The equation for t_D where D is now the distance measured perpendicularly from the fracture and t_D is the time for the wave front to reach distance D and the other parameters are as before is:

$$t_D = 80(\phi)(u)(c)(D)^2/k \quad (4)$$

If, as before, one assumes that the time T to drain a volume within a distance D from the fracture (including both sides of the fracture) is given by the equation:

$$T = 20t_D \quad (5)$$

then:

$$D_{20} = 4.5625k/\phi uc \quad (6)$$

Using the same parameters as before

$$D_{20} = 320 \text{ feet.}$$

Let (L) be the length of the hydraulic fracture and A be the area of a horizontal section of the volume drained in twenty years. Then

$$A = (2)(320)(L)/43560 = 0.0147(L) \text{ acres.} \quad (7)$$

In the case of a conventional fracture of say 150 feet in each direction from the well bore, indicated on FIGURE 2 by the line segment between points 34 and 35, the area drained would include the rectangular area computed as before.

$$A = .0147(L) \\ \text{or } A = .0147(300) = 4.41 \text{ acres}$$

plus the two semi-circular end areas indicated at 37, 39 whose total area is 14.8 acres, for a total of 19.2 acres, corresponding to a density of 33.3 wells per square mile for 100% draining. While this is better than the 43 wells per square mile for an unfractured well, it is greatly inferior to the results achieved with long fractures made in accordance with the present invention.

C. LONG FRACTURES

According to the present invention a long fracture is obtained by interrupting a conventional fracturing operation somewhere between the beginning and end of the injection period, preferably during the last 1/3—1/4 of the fluid injected. During the shut down period, that is, when the pumps are shut down and the flow rate of the injection fluid drops to zero, the pressure in the fracture is reduced to the sum of the hydrostatic head plus the surface instantaneous shut in pressure. The drop in pressure at the fracture face causes the formation to spall at the fracture face. The spalls remain in place until flow is resumed by starting the pumps again. When flow is resumed, the spalls are displaced by the fluid and carried along a greater or lesser distance according to the size of the spall and the width of the fracture. These spalls will maintain the fracture propped open to nearly its maximum width, and at the same time the advancing fluid will increase the fracture length.

If the fracture length is 3733 feet (the length of one side of a 320 acre tract), $A = 54.8$ acres
and if the fracture length is 5280 feet (the length of one side of a square mile tract), $A = 77.6$ acres.

These are to be compared with the 15 acres drained without a fracture and the 19.2 acres with a conventional or short fracture.

With a long fracture as shown in FIGURE 2 it would be practical to space wells with a density of 11.66 per square mile in the case of a fracture extending the length of a half square mile tract, and 5.7/square mile in the case of a one mile fracture. This of course would be much more economical than in the case of an unfractured well where the required density was 43 wells per square mile, or the case of wells with short fracture requiring 33.3 wells per square mile.

D. RECAP: SHORT & LONG FRACTURES

Recapitulating in order to obtain high productivity from an oil or gas well, it is necessary to produce a relatively long, highly conductive fracture. The lower the permeability of the formation, the longer the fracture must be. However, as the fracture length increases there is a greater and greater chance that the conductive path can be altered so that not all of the generated length will remain connected to the well bore after the fracture fluid is recovered. Some of the reasons that the full length would not be utilized are illustrated in FIGURES 3 and 4.

Referring to FIGURE 3 it is seen that a hydraulic fracture initially, that is, in the dynamic condition while the fracture is being formed, probably includes a plurality of relatively long straight fractures 41, 43, 45 joined by a plurality of short transverse fractures 47, 49 which interconnect the long fracture. In the static condition, the fracture consists of the same plurality of long fractures 41, 43, 45, held open by the frac sand to a limited degree, and the transverse fractures 47, 49 no longer interconnect the long fractures, the overlap of the long fracture at their ends disappearing as the fracture width diminishes, the transverse fractures shutting off the longitudinal fractures like valves.

Referring now to FIGURE 4, it is seen that initially, that is, during fracture fluid injection, the walls 51, 53 of the fracture are held apart and the space therebetween is filled with fluid or sand laden fluid which is free to move. However after the fracturing operation has been completed, the spalls and related fines will gradually fill the open spaces in the fracture. This will effectively shut off highly conductive channels when the well is put on production.

In order to insure that fluid flow is not shut off when the well is put on production either by the fracture closing at the intersection of joints or by the gradual blocking of the fracture by spalls and fines, the method of the invention, previously set forth briefly is employed, as follows:

During the fracture job; at calculated intervals, the pumps are shut down or at least the pressure is greatly reduced by reducing the injection rate for a period of time. This reduction of pressure causes the earth stress next to the fracture to form spalls at the fracture face. The pumps are then started up again to regular fracturing rate with a corresponding increase in pressure. Fluid flow and pressure forces the face of the fracture apart and allows—or forces—the spalls to move out of their original position and be driven into the generated width of the fracture where they will remain supporting the earth forces when pumping ceases.

There will be a concomitant generation of "fines" (small particles of formation) generated when the spalls move. These fines will have a tendency to sand blast any great restriction in the fracture to keep it at maximum conductivity.

It may or may not be necessary to use fracture sand in the fluid to obtain desired results. If such sand is used, its primary function will be that of a fluid loss prevention system.

E. HISTORICAL INVESTIGATION

Analysis of data from fracturing reports relative to well treatments that have been performed in the past five years on a series of wells in the same formation in the same geographical area shows that a recent two months production of wells that had inadvertently been shut down because of mechanical failure of equipment during the fracture job compared to wells that had not been shut down (i.e. had run according to fracture plan) show a marked difference in production.

Twenty-one wells that had had a shut down period during fracturing on the particular months chosen averaged about \$2018 gross production each.

Thirty-six wells that had been run according to plan without the shut down averaged \$783 gross production each.

F. TEST.

A group of wells was then selected that used the same fracturing schedule as a

previous group, but an intentional shut down period of one hour was put in the fracture plan.

First month's production was about double compared to when no shut down period was used.

When the shut down period was used, the wells would flow back treating fluid of about $\frac{1}{2}$ the volume injected, approximately the same as with no shut down period.

G. DENDRITIC FRACTURE

Another well was selected. The same amount of fluid was used as before but three injection periods were used. At the start of the third injection period, even with higher pressure the injection rate was much lower. Then after a period of injection the pressure broke to a lower value and the rate of injection increased. No fracture sand was used in this well. After the job was completed the well flowed back about $\frac{1}{2}$ the treating fluid in the same manner that the others had. However, gas appeared at the surface during swabbing operations much sooner than previous wells. The pressure break along with the early gas production indicated a change in direction of the fracture, as will now be explained.

When the pumps are started the third time, fluid flow in the fracture causes the debris formed by crushing of the spalls that moved during the second fluid injection period to move forward where they bridge against the chips or spalls that have just been formed. This causes a sand-out at the end of the primary fracture. Pressure now increases until a new fracture starts at a weak point of the fracture wall. Since the rock is now under stress perpendicular to the fracture direction, a new or secondary fracture will propagate in a direction approximately perpendicular to the primary fracture. The result is a system of fractures as shown in FIGURE 5, wherein 61 is the well bore, 63 is the initial or primary fracture, and 65 is the secondary or transverse fracture. To produce a long secondary fracture it will be necessary to proceed with the formation of this fracture wing in the same manner (i.e., two slugs of fluid with suitable shut down periods) as the primary fracture.

As noted in FIGURE 5, the secondary fracture, probably, almost surely, will consist of only one wing. However, after completion of the first wing, if the pumps are started once more, there will be a movement of the debris in the single wing transverse fracture causing a sandout thereof and further pumping with suitable shut down periods will extend a fracture wing in the opposite direction from the first secondary wing as shown in FIGURES 6 and 7. The FIGURES 6 and 7 systems are the same as that of FIGURE 5 except that in FIGURE 6 a second wing 69 on the opposite side of the well from wing 65 has been added, and in FIGURE 7 the second wing 69 is added on the same side of the well as the first wing 65. Such a system consisting of a primary fracture and one or more secondary transverse fractures may be called a dendritic fracture system. FIGURE 5, then, shows a single wing dendritic system, and FIGURES 6 and 7 show double wing dendritic systems.

The pumping sequence would be like the following to produce the double dendritic fracture system:

pump, wait, pump, wait (primary), pump, wait, pump, wait (first secondary),
pump, wait, pump, shutdown end (second secondary).

The reason why the dendritic system, which is produced by the above described pumping cycle in accordance with the invention, causes a different, and as will appear, vastly improved well productivity, will next be considered.

Referring now to FIGURE 8, there is shown a well bore 21 from which extend a primary fracture 73 and a pair of transverse fractures 75, 77, the latter being shown as collinear in view of the scale of the drawing, it being assumed that they will both be close to the well bore. The pressure waves from the fracture will move out as indicated by the four chevron wave fronts 79, 81, 83, 85. Subsequent positions of these same wave fronts are shown at 79', 81', 83', 85'.

The four chevron wave fronts shown in FIGURE 8 may be treated as eight linear wave fronts, the two linear wave fronts of each chevron front overlapping in their propagation. For each of the eight linear fronts, reservoir engineering theory shows that

$$t_D = \sqrt{40} \phi u c D^2 / k \quad (7)$$

and remembering from equation (2) that $T = 20 t_D$, so that for $T = 20$ years, $t_D = 1$ year, we find that the distance D drained by each of the eight waves in twenty years is

$$D_{20}^2 = 57.71k/\phi\mu c \quad (8)$$

From equation (7) one finds that for the formation having the same constants as previously considered in the case of unfractured and conventionally fractured wells, the distance to which the formation is drained in twenty years by each of the eight linear fronts is 1140 feet.

Assuming as in the case of a long linear fracture previously described that the primary fracture is 3733 feet (the length of one side of a 320 acre or half square mile tract) and that the two wings of the transverse fracture total 3733 feet, the area drained by the dendritic fracture system is 272 acres. This is readily computed as the area of the square of 3733 feet on a side less the area of the four squares not drained by any of the eight linear wave fronts. The equation is

$$A = 320 - 4(1866 - D_{20})^2/43560 \quad (10)$$

where D_{20} , as before is the distance drained in twenty years by each of the eight linear wave fronts. The foregoing 272 acres drained by the dendritic fracture system is to be compared with the 54.8 acres drained by a single long hydraulic fracture (3732 feet) in accordance with the invention and the 19 acres drained by a conventional 300 foot linear fracture and the 14.6 acres drainable in 20 years without any fracturing at all.

H. COMPARISON OF DRAINAGE

A comparison of the several fracture systems that gives a further insight into their differences is obtained with reference to the shape of the maximum equal pressure surfaces under steady state conditions of a field of several adjacent wells in which the well spacing is so related to the productivity that the wave fronts reach a maximum distance from the well and then cease to propagate further due to interference from waves from adjacent wells. In the case of unfractured wells, the cylindrical (circular horizontal section) waves from the several wells may ultimately meet and thereafter the maximum equal pressure surfaces may be considered to be overlapping cylindrical surfaces. In the case of linear hydraulic fracturing, parallel wave fronts from adjacent wells may meet and thereafter the maximum equal pressure surfaces are fixed planes (lines in horizontal sections) between the wells. But in the case of dendritic fracturing, the chevron wave fronts from adjacent wells overlap and meet at a single vertical line (point in a horizontal section).

I. NATURAL JOINT SYSTEMS

A very important advantage of the dendritic system over any linear fracture system results in the enhancement obtained from natural joint systems.

Consider a tight, well consolidated formation. In geologic time it will have developed a joint system that consists of cracks that are more or less cemented that trend in a general direction. The cement in the cracks is probably not as strong as the rock matrix. In addition, the cracks probably have more fluid transmissibility than the rock matrix. There will also be a secondary joint system more or less perpendicular to the major joint system. These are also planes of weakness.

Referring now to Figure 9, there is shown a chart similar to Figure 1, 2, and 8, showing a plan view of a well bore 21 relative to 320 and 640 acre squares. When a fracturing process as described herein is carried out, the primary fracture 86 probably follows one of the major joints 87. When the secondary fracture system is developed, it will intersect many joints of the major joint system. The addition of the transmissibility of all of the joints cut will further aid in rapid recovery of reservoir fluids. The relatively short arrival times for the pressure wave fronts at the 320 and 640 acre perimeters in the case of several assumed permeabilities of the natural joints in millidarcies is charted in the upper left hand quadrant of Figure 9 such times being calculated as before.

J. USE OF SAND: FLUID LOSS CONTROL

Depending on the strength of the reservoir rock and the configuration desired for the fracture system, it may or may not be necessary to use a propping agent. In the case of strong rock, self propping is achieved. However, fine sand may be useful for fluid loss control, the fine sand blocking fracture fluid from entering into the transected joints. This is illustrated in FIGURE 10 wherat is shown well bore 91,

primary fracture 93, secondary fracture 95, and joints 97, 99 the latter being blocked off with sand as shown in 101, 103.

There are several reasons to keep the amount of fracturing fluid to a minimum, especially in gas wells. Among these are the actual cost of the fluid and injecting the fluid along with the cost of propping agent. In addition, the well must produce back the fluid injected before it can reach its best potential.

In the dendritic fracturing techniques that have been described hereinabove stimulation is at least partially achieved by utilizing natural joint systems in the reservoir. In massive formations, these joint systems probably extend vertically as well as horizontally throughout the reservoir. (see page 87 of article entitled "Reservoirs in Fractured Rock", SUPRA.).

The fracture formed in the producing formation may be confined to the upper portion of the producing formation where lithology (overlying rock) will limit the upward growth of the fracture and sand properly scheduled will limit the downward growth of the fracture. When a dendritic fracture system is formed, the joints are intersected that will connect the reservoir both laterally as well as vertically to the fracture system and thus to the well bore. If the vertical extent of the fracture system is limited, as much as 80%—90% of the fluid that would be required normally could be saved.

The foregoing method of limiting the height of the fracture system is illustrated in FIGURE 11, wherein a portion of the producing formation is shown at 111. From the well bore 113 extends the primary fracture 115, extending parallel to or along a natural joint, and secondary fractures 117, 119 extending transverse thereto. Extending transverse to the natural joints such as 121 are natural transverse joints such as 123. It is these natural transverse joints which are blocked initially by the fracture sand to limit loss of fracture fluid during the second and third cycles of the fracturing method of the invention. As is apparent from FIGURE 10, the fracture sand not only blocks too extensive horizontal travel of fracture fluid along the natural transverse joints but also limits downward travel of the frac fluid along the primary fracture, the secondary fracture, and the natural primary and secondary joints.

K. FURTHER HISTORICAL COMPARISON

FIGURE 12 is a chart prepared from an examination of the fracture reports on a group of wells all in the same formation and all in the same general geographical area and all in what is believed to be a very tight formation. The wells were developed as near as the analyst could do so into two groups. In one group were wells wherein for some reason, e.g. mechanical break down of pumping equipment the fracturing procedure was interrupted; in the other group there was no substantial interruption. The productivity of all of the wells was checked from the monthly reports. It appeared that wells wherein the fracture process had been interrupted were in many cases of higher productivity than those wherein the fracture process was uninterrupted. Averages for the productivity of numbers of wells in the group treated by various types of fracture treatment are shown in FIGURE 12. This is not to imply that in every case the wells with interrupted fracturing produced better than wells similarly treated except for lack of interruption although this may be the case. Also, this is not to imply that such results will be found in the case of groups of wells or individual wells in other areas, although this also may be the case, at least in many instances. It is further to be observed that greater increase in productivity was obtained with interrupted fracturing in the case of viscofrac (viscous oil fracturing), and F.W. (fresh water) emulsion and S.W. (salt water) emulsion than in the cases of gelled F.W. and S.W. fracturing; this being due it is believed to the higher viscosity of the oil and emulsion fracturing fluid compound to the gelled water, the higher viscosity resulting in higher fracturing pressures and widths, the greater fracture width allowing more opportunity for spalling when pumping ceases, thereby to obtain the advantages of the invention on resumed pumping as previously explained.

The invention has also been applied but without success to a single offset from three producing gas wells; the result was a substantial dry hole. This is believed to be due to the fact that the fracture did not contact any gas bearing reservoir.

L. APPARATUS

The methods of the invention can be carried out by any of the known apparatus used for previously known methods of hydraulic fracturing. A suitable apparatus is shown and described in my aforementioned United States patent number 3,722,595 issued March 27, 1973, the disclosure of which is incorporated herein by reference.

My United States patent number 3,378,074 issued April 16, 1968 also shows suitable apparatus and its disclosure is also incorporated herein by reference (the line 39, pump 40 and line 41 may be omitted). The fracturing fluid can be injected through the well tubing, casing, or other available or suitable pipe or conduit. The fluid can be injected through perforations in the tubing or casing extending through the pipe and surrounding outer pipe and/or bore hole annulus cement or directly into the formation, the injection being confined vertically by virtue of the location of the perforations, the pipe, the cement, and the formation above and below the perforation hole. Vertical extents of well pipe of one foot or less to one hundred feet or more are contemplated with respect to injection of fracturing fluid. The pumps used in carrying out the method will normally be positive displacement pumps, with diesel engines or gas turbine drive. Shutting down the engine or turbine will hold the pumps stationary and thereby holds back pressure in the well. In an example hereinafter set forth ISIP stands for Instantaneous Shut In Pressure and is the surface pressure existing at zero injection rate.

M. PARAMETERS

(i) Fracture Fluid

The fracture fluid preferably used in carrying out the method of the present invention desirably is such as to cause little pressure drop in the pipe, maximum pressure in the formation, minimum total fluid loss to the formation, minimum rate of fluid loss to the formation, high carrying capacity for sand or other propping agent with respect to both ratio of sand volume carried to volume of fracture fluid and also distance and time carried, and high and rapid retrieval of fracture fluid when the well is put on production. To a certain extent, some of these factors are related to viscosity, but high viscosity is effective to achieve some results but low viscosity is effective for other purposes. Fluids of time variant viscosity may therefore be used. The viscosity of the injection fluid may range from 30 centipoise or less up to 100 centipoise or more at reservoir temperatures. Other factors to be considered include the physical characteristics of the fluid; the fluid is a liquid or gel or emulsion, not usually pure gas. Preferably, fluids such as those known to the trade as Super Frac and Super Emulsifrac are used. These are described in U.S. patents number 3,710,865—Kiel (emulsion) and number 3,378,074—Kiel (heavy oil) the disclosures of which are incorporated herein by reference. The Super Emulsifrac fluid is the better of these, especially for gas wells. It is to be observed that in fracturing with water, gelled water, light crude oil, gelled light crude oil, and the like, the pressure ordinarily decreases during the fracture job. With the preferred fluids for the present invention, pressure ordinarily increases during the job even when injection rate remains constant. It is to be noted, of course, that pressure drop occurs both in the pipe and the formation; every effort is made to reduce the drop in the pipe and to increase the formation pressure. Therefore fracturing fluids preferred in accordance with the invention may be characterized as formation pressure increasing fluids. It may be surmised that with such fluids, the formation matrix permeability may be temporarily decreased as fluid is injected, thereby causing the formation pressure to rise. The effect is to reduce fluid loss, thereby making it practical to have shut down periods in the course of a treatment. When sufficient fluid loss occurs, the remaining sand blocks the fracture at the well bore. In accordance with the invention, such well sandout are not to occur during the scheduled shut down periods.

(ii) Pressure

In carrying out the methods of the invention, pressures of 1,000 psi or less up to 15,000 psi or more may be employed, usually about 5,000 psi, the resultant formation pressure depending on the pump pressure and the well depth and the pressure drops in the pipe and through the formation.

(iii) Injection Time

The injection time depends on the volume of fracturing fluid to be injected, which is determined by how big a fracture is desired and is calculated in advance, and upon the flow rate, which depends on the pressure and flow resistance. The time typically may be one hour or less to eight hours or more for the entire treatment.

The total injection time will be the sum of the injection times of the several double cycles, that is, the times for the double cycles for each fracture configuration, primary, first transverse, and second transverse. The injection time for each double cycle will be the sum of an initial or first injection time and a following or second

injection time. There will be intra configuration shut down periods between the first and second injections of each double cycle, and there will be inter-configuration shut down periods between each double cycle.

(iv) Injection Volume

5 The division of injection volumes between the several double cycles may be varied. Absent consideration of any distinctions between the several fracture configurations and other factors, one might divide the volume equally between the several double cycles, e.g. 1/3 of the total volume to each double cycle in the case of three double cycles. To take into account fluid loss, one might assume that the total fluid lost is a linear function of the square root of time. On this assumption, it is presently the practice to divide injection volumes between three double cycles in the approximate proportions 10/14/18. However this may change in the light of future experience.

10 The division of injection volumes between the first injection and second injection of each double cycle may be such that the volume injected during the second injection is about 1/4 to 1/3 that injected during the first injection. This is arrived at by considering that it is desirable for the injection pressure during the second injection to rise the same amount above the initial injection pressure during the second cycle as the amount of rise above the initial injection pressure of the first injection that occurred during the first injection cycle.

15 The total volume of fluid injected may be from 3000 barrels or less up to 20000 barrels (42 gallon barrels) or more, preferably three thousand to five thousand barrels.

20 Since injection times are a function of injection volume, injection times for the several double cycles may also be in the ratio of 10/14/18, and the second injection of each double cycle may take 1/4 to 1/3 the time of the first injection. On this basis the minimum injection times is 3.5 minutes.

(v) Shut Down Time

25 In determining shut down time, one may make reference to the time required for decrease in shut in pressure. Time for both the intra configuration and inter-configuration shut down periods has arbitrarily been selected to be such that surface pressure will not decrease more than 1/3 of the amount it increased during the pumping operation. Although shut down time has varied from five minutes or less to an hour or more, fifteen minutes seems to be long enough for spalling to take place.

30 In accordance with the invention, the well is not commercially produced between injections; this distinguishes the method from simple retreatment of a well and from a double cycle occurring accidentally due to mechanical breakdown in the course of a conventional treatment. Also, in accordance with the invention, the discontinuance of fluid injection in the course of the double cycle is intentional, which further distinguishes such a double cycle from that occurring accidentally due to mechanical breakdown. The period of injection interruption will, of course, normally be much less than in the period of commercial production of a well between repeated conventional treatments, which period would be a matter of months or years. The interruption of injection occurring during a double cycle according to the invention may therefore be characterized as scheduled and brief, thereby to distinguish it from accidental interruptions and from the case of retreatment after commercial production.

N. EXAMPLES:

EXAMPLE I.

35 The following is an example of a well stimulation treatment carried out in April of 1973 according to the invention. Permission to publish this information has been obtained.

Formation Thickness: 30'
Depth: 7896' to 7926'

40 Materials: Frac Fluid: Super Emulsifrac (which is an oil water emulsion consisting of 1 part of fresh water and 2 parts of lease condensate or other light hydrocarbon)

Propping Agent: Sand, 100 mesh, 150,000 lb.
20/40 mesh, 50,000 lb.

45 NE (normal emulsifying) agent type: SEM—5
which is quaternary compound, 486 gallons

Gelling Agent Type: WG—6,
which is Guar Gum, 3,000 gallons
pH buffer Type: CW—1,
which is mono sodium phosphate, 800 pounds

5 Casing: New, 4 1/2" O.D., from 0' to 8015', weight 10.5# per foot, maximum psi allowable 4,000. 5

Perforations: 1/2" diameter, from 7896' to 7926' one shot per foot

10 Displacement pressure: 2400 psi
Breakdown pressure: 2550 psi
Maximum pressure: 4100 psi 10

Final Shut In.
Instant Pressure: 1800
5 minutes 1850
15 minutes 1800

15 Hydraulic Horsepower: 15
Ordered: 3000
Available: 3000
Used: 2034

20 Average Rates in Barrels Per Minute: 20
Treating: 21
Displacement: 21
Overall: 21

25 Volumes: 25
PAD Gal 126,000
Treatment Gal 48,000
Displacement Gal 6,000
Total Volume Gal 180,000

Job Log: As follows:

Event No.	Time	Rate (rpm)	Volume (BBL) (GAL) (Incremental Volume)	Pumps C	Pressure (psi) (Casing)	Description of Operation and Materials
1	1018	26	20,000	6	0	Safety Meeting – Discuss Procedure With All Concerned.
2	1025		P		5000	
3	1031	4	A	1	2550	
4	1048	24	D	4	3900	Start Pad – Load Hole
5	1053	24	4,000	4	3800	Test Lines
6	1054	24	2,000	4	3800	Breakdown
7	1055	24	4,000	4	3800	Start 4# No. 1 Sand
8	1058	24	4,000	4	4000	4# No. 1 On Formation
9	1059	21	2,000	4	4000	Pad On Formation
10	1101	24	4,000	4	3950	Start Pad
11	1101	24	4,000	4	3950	4# No. 1 On Formation
12	1105	18	6,000	4	3975	Start 4# No. 1 Sand
13	1106	21		4	3975	Pat Hit
14	1107	26		4	3950	Start Flush
**15	1113			4		4# No. 1 On Formation
17	1127	24	8,000	4	4000	ISIP 2200 – 5 Min. 2000 – 15 Min. 1800
18	1136	21	4,000	4	4000	Start Pad
19	1141	21	6,000	4	3700	Start 4# 20/40 Sand
20	1142	26		4	3400	Start Flush
21	1147	24		4	3900	4# 20/40 On Formation
**22	1147			4		Shut Down
						ISIP 2250 – 5 Min. 2100 – 15 Min. 1900

Event No.	Time	Rate (rpm)	Volume (BBL) (GAL)		Pumps C	Pressure (psi) (Casing)	Description of Operation and Materials
			Incremental Volume)	Volume)			
23	1202	26	20,000		4	3800	Start Pad
24	1223	21	4,000		4	4000	Start 4# No. 1 Sand
25	1228	21	2,000		4	3900	Start Pad
26	1230	26			4	3700	4# No. 1 On Formation
27	1230+	21	4,000		4	3750	Start 4# No. 1 Sand
28	1234	17			4	4000	Pad On Formation
29	1235	24	2,000		4	4000	Start Pad
30	1237	24			4	4000	4# No. 1 On Formation
31	1239	18	4,000		4	4000	Start 4# No. 1 Sand
32	1241	18-1/2			4	4000	Pad On Formation
33	1243	24	6,000		4	4000	Start Flush
34	1244	27			4	4000	4# No. 1 On Formation
35	1249	22			4	4000	Shut Down
**36	1249				4		ISIP 2400 - 5 Min. 2200 - 15 Min. 2100
37	1306	25	8,000		4	4000	Start Pad
38	1313	20	4,000		4	4000	Start 4# 20/40 Sand
39	1319	23	6,000		4	3800	Start Flush
40	1320	26			4	3600	4# 20/40 On Formation
41	1325	23-1/2			4	4000	Shut Down
**42							ISIP 2450 - 5 Min. 2300 - 15 Min. 2200
43	1340	24	20,000		4	4000	Start Pad
44	1402	20	4,000		4	4000	Start 4# No. 1 Sand
45	1408	27	2,000		4	3800	Start Pad
46	1410	24			4	3800	4# No. 1 On Formation
47	1410	19	4,000		4	3800	Start 4# No. 1 Sand
48	1414	24			4	3900	Pad On Formation
49	1415	24	2,000		4	3800	Start Pad
50	1417	24			4	3800	4# No. 1 On Formation
51	1417-1/2	24	4,000		4	3800	Start 4# No. 1 Sand
52	1422	18			4	3900	Pad on Formation

Event No.	Time	Rate (rpm)	Volume (BBL) (GAL)	Pumps C	Pressure (psi)	Description of Operation and Materials
53	1423	24	6,000	4	3900	Start Flush
54	1424	21		4	3800	4# No. 1 On Formation
**55	1429	19-1/2		4	3900	Shut Down
56						ISIP 2800 - 5 Min. 2300 - 15 Min. 2300
57	1444	18	8,000	4	4000	Start Pad
58	1456	12	4,000	4	4000	Start 4# 20/40 Sand
59	1502	18	6,000	4	3600	Start Flush
60	1504	24		4	3400	4# 20/40 On Formation
61	1512	12		4	2500	Finish
						ISIP 1800 30 Min. 1700

In connection with the foregoing example, attention is directed to each of the instantaneous shut in pressures occurring during the treatment. At event #15 the ISIP is 2200 psi, which is normal for the particular area after a conventional treatment. At event #22 the ISIP is still only 2250 psi, reflecting greater width in the initial fracture, which has now a much larger connected length but still is only a single fracture. At event #36, the ISIP is 2400 psi, indicating a change in fracture direction as previously explained. At event #42, the ISIP is 2450 psi, indicating increased fracture width but no new fracture wing. At event #55 the ISIP is 2800 psi, indicative of a new fracture wing. The final ISIP of 1800 at the end of the treatment is with flush water in the hole instead of emulsion; the water being much denser than the emulsion, surface pressure is lower.

EXAMPLE II.

The following is another example of a well stimulation treatment carried out in February of 1973 in accordance with the invention the injection being through the tubing. The formation treated is known as the Muddy J Sand. Permission to publish the information has been obtained.

Allowable Pressure:

Tubing 4600 psi
Casing 1000 psi

15		1,460,647	15
	Job Done Down Tubing.		
	Gas Well		
	New Well		
5	4½" diameter casing.		5
	2½" HD tubing.		
	Tubing Depth: 2230 feet		
	Baker packer.		
	Packer depth: 2230 feet		
10	Casing Volume Below Packer: 100±barrels?		10
	Tubing Volume: 15±barrels?		
	Perforated Intervals:		
	Depth 8083—8117 feet		
	Number of Holes 34		
15	pH Information: Confidential?		15
	Fluid: Superfrac K—1		
	Maximum Pressure: 4600 psi		
	Average Pressure: 4500 psi		
	Final pump in pressure: 3900		
	Adjusted Injection Rate (solids included) 18 barrels/min.		
20	Total Fluid Pumped:		20
	Oil 2365 barrels?		
	Water 1335 barrels?		
	(Note: 24 barrels equal 1000 gallons)		
25	Props and Liquids Injected:		25
	100 mesh sand, 144000 lb.		
	20/40 mesh sand, 48000 lb.		

Time	INJECTION Rate	Bbls In	PRESSURE Csg.	Tbg.	Service Log
12:00					Hook up — Mix chemicals.
					Hook up to well.
6:00	2-22-73				Suspend operations — Not enough time for job completion.
					Resume operations — Complete hook up.
					Hold safety meeting & discuss procedures.
					Test connections — Repair leaks — Load & press. csg.
8:30			1000		Start K-1 Pad.
		86	1000	1500	Hole loaded—breakdown.
	11		1000	1800	Ftm. feeding — Improve rate & press.
	22		1000	4600	Adjust rates in observance of max. press.
	19	480	1000	4600	Start 100 mesh sand 4#/gal.
	22	592	1000	4200	Stop sand — start K-1 spacer.
	19	640	1000	4400	Resume sand @ 4#/gal.
	21	752	1000	4100	Stop sand — start K-1 spacer.
	19	800	1000	4300	Resume sand @ 4#/gal.
	16	912	1000	4500	Stop sand — start K-1 flush.
	18	1027	1000	4400	Flush comp. — S.D. — Observe press.
			1000	2200	ISIP
			1000	1950	14 Min. S.D. — Start K-1 pad — Stage II
	18		1000	4200	Rate & Press. Check.
	17	1219	1000	4500	Start 20-40 Sand 4#/gal.
	20		1000	3900	Rate & Press. Check.
	19	1329	1000	4300	Stop sand — Start K-1 Flush.
	16	1446	1000	4400	Flush Comp. — S.D. — Observe press.
			1000	2200	ISIP
			1000	1950	18 min. S.D. — Start K-1 Pad — Stage III.
	19		1000	4500	Rate & press. Check.

Time	INJECTION		PRESSURE		Service Log
	Rate	Bbls In	Csg.	Tbg.	
	19	1926	1000	4200	Start 100 mesh sand 4#/gal.
	15	2040	1000	4600	Stop sand — Start K-1 spacer.
	16	2088	1000	4400	Resume sand @ 4#/gal.
	16	2198	1000	4300	Stop sand — Start K-1 spacer.
	17	2246	1000	4500	Resume sand @ 4#/gal.
	19	2356	1000	4000	Stop sand — Start K-1 flush.
	18	2471	1000	4300	Flush comp. — S.D. — Observe press.
			1000		7 min. S.D. — Start K-1 pad — Stage IV.
	16		1000	4400	Rate & press. Check.
	18	2663	1000	4600	Start 20-40 sand 4#/gal.
	18	2773	1000	4600	Stop sand — Start K-1 flush.
	18	2888	1000	4500	Flush comp. — S.D. — Observe press.
			1000	2350	ISIP
			1000	2250	9 min. S.D. — Start K-1 pad — Stage V.
	18		1000	4600	Press. & rate check.
	18	3368	1000	4500	Start 100 mesh sand 4#/gal.
	20	3478	1000	4100	Stop sand — Start K-1 spacer.
	20	3526	1000	4320	Resume sand @ 4#/gal.
	18	3636	1000	4600	Stop sand — Start K-1 spacer.
	20	3684	1000	4100	Resume sand @ 4#/gal.
	16	3794	1000	4500	Stop sand — Start K-1 flush.
	19	3909	1000	4600	Flush comp. — S.D. — Observe press.
			1000	2500	ISIP
					12 min. S.D. — Start K-1 pad — Stage VI.
	18		1000	4200	Press. & rate check.
	20	4101	1000	4600	Start 20-40 sand 4#/gal.
	21	4211	1000	4100	Stop sand — Start K-1 flush.
	19	4281	1000	4200	Start H ₂ O flush.
2:05 pm	24	4336	1000	3900	Flush comp. S.D. — Job Completed.
			1000	2100	ISIP
			1000	1500	30 min. ISIP

5 Well tests performed on the well of Example II showed a fracture conductivity of 120,000 millidarcy inches. From experience with other wells not treated according to the invention, the applicant would expect that under the closure stress existing in the well, a fracture 1/4 inch wide fully packed with 100 mesh sand (the sand used in the example) would have a flow capacity of about 1500 millidarcy inches. See "Conductivity of Fracture Proppants in Multiple Layers" by C. E. Cooke, Jr., pp. 1101 et seq, Journal of Petroleum Technology, September 1973. 5

EXAMPLE III.

10 The following is a further example of a well stimulation treatment carried out in August of 1973. Permission to publish this information has been obtained. 10

Formation: J-Sand
Well Type: Gas, Workover
15 Casing: New, 4 1/2 inch diameter, from 0 to 7890 feet, 10 1/2 lb./foot, 4300 maximum allowable psi. 15
Perforations: 7788 to 7856 (15 holes)
7787 to 7793 (1 shot per foot)
7804 to 7856 (1 shot per foot)
20 *Materials:*
Treating Fluid: Super-Emulsifrac 20
Displacement Fluid: Super Emulsifrac
Prop: 100 mesh sand—75,000 lb.
and
20/40 mesh sand—75,000 lb.
25 Acid Type: HCL—500 gal., 15% 25
Surfactant: SEM—5 (300 gal.)
NE Agent: 11—N (3 gal.)

17	1,460,647	17
	Gelling Agent: WG—6 3500 lb. Breaker: CW—1 800 lb. KCL 234 sacks NF—1 60 quarts (See example I for identification of the coded materials. Also, _____.)	5
	<i>Pressures (in PSI)</i> Displacement: 3600 Breakdown: 1400 Average: 4000 Shut In Instant: 2900	10
	<i>Hydraulic Horsepower</i> Ordered: 2500 Available: 3000 Used: 1765	15
	<i>Rates (In BPM)</i> Treating: 18 Displacement: 18 Overall: 19	
	<i>Volumes</i> Preflush 10500 gal. PAD 132000 gal. Treatment 39000 gal. Displacement 5400 gal. Total Volume 186900 gal.	20
		25

Event No.	Time	Rate (rpm)	Volume (BBL) (GAL) (Incremental Volume)	Pumps C	Pressure (psi) (Casing)	Description of Operation and Materials
	0945	3	500	1	400	Safety Meeting
	1010		10,000		400	Pump Acid
						Start Prepad Load Hole
						Test Lines
	1027	4			1400	Breakdown
1	1041	22-1/2	14,000	5	3700	Start Pad
2	1056	22	2,000	4	3950	Start 1-1/3# 20/40 & 2-1/2# 100 Mesh Sand
3	1058	22	3,000	4	3950	Start Spacer
4	1102	22	2,000	4	4000	Start 1-1/3# 2-1/2# as in event 2
5	1104	20-1/2	3,000	4	4000	Start Spacer
6	1107	21	3,000	4	4000	Start 1-1/3# & 2-1/2#
7	1110	21	3,000	4	3950	Start Spacer
8	1114	21	3,000	4	3900	Start 1-1/3# & 2-1/2#
9	1117	20	5,400	4	3950	Start Flush
*10	1124	19		4	4000	Shut Down ISIP 2700
11	1139	20	7,600	4	4000	Start Pad
12	1150	19	3,000	4	4000	Start 1-1/2# 20/40 Sand
13	1155	19	5,400	4	3700	Start Flush
14	1200	19		4	4000	Shut down ISIP 2700
15	1215	18	15,600	4	4000	Start Pad
16	1237	18	2,000	4	3950	Start 1-1/3# 20/40 & 2-1/2# 100 Mesh
17	1240	20	4,000	4	4000	Start Spacer
18	1244	20	2,000	4	4000	Start 1-1/3# & 2-1/2#
19	1247	19	4,000	4	4000	Start Spacer
20	1257	18	3,000	4	4000	Start 1-1/3# & 2-1/2#
21	1255	18	4,000	4	4000	Start Spacer
22	1300	17	3,000	4	4000	Start 1-1/3# & 2-1/2#
23	1305	20	5,400	4	4000	Start Flush
*24	1312	17		4	4000	Shut down ISIP 2950
25	1327	18	7,600	4	4000	Start Pad
26	1338	18	3,000	4	4000	Start 4# 20/40 Sand
27	1342	20-1/2	5,400	4	4000	Start Flush
28	1350	15-1/2		4	4000	Shut down ISIP 2900

Event No.	Time	Rate (rpm)	Volume (BBL) (Incremental Volume)	Pumps C	Pressure (psi) (Casing)	Description of Operation and Materials
29	1405	18	22,600	4	4000	Start Pad
30	1441	12	2,000	3	4000	Start 1-1/3# & 2-1/2# (20/40 & 100 Mesh)
31	1444	16	4,000	4	4000	Start Spacer
32	1450	15	2,000	4	4000	Start 1-1/3# 20/40 & 2-1/2# 100 Mesh
33	1455	10	4,000	4	4000	Start Spacer
34	1501	11-1/2	3,000	4	4000	Start 1-1/3# & 2-1/2#
35	1507	16	4,000	4	4000	Start Spacer
36	1513	13	3,000	4	4000	Start 1-1/3# & 2-1/2#
37	1522	14-1/2	5,400	4	4000	Start Flush
*38	1557	5			4000	Shut down ISIP 3300
39	1611	16	5,600	4	3900	Start Pad
40	1616	16	3,000	4	3900	Start 4# 20/40 Sand
41	1620	18	5,400	4	3900	Finish Flush
42	1624	22		4	3900	Shut down ISIP 2550
						Finished

Again one can note the instantaneous shut in pressures, at events 10 (2700 psi), 24 (2950 psi) and 38 (3300 psi). The latter high ISIP indicates that a new fracture direction has been formed. In this regard it is to be observed, considering a hypothetical cube of formation material, that the stress in the direction perpendicular to one set of parallel vertical faces will usually be different from that in the direction parallel to the other set. Assume that the cube is oriented so that one set of vertical faces are in the direction of minimum formation stress. The initial fracture may be assumed to occur in a direction perpendicular to these faces since this is the direction requiring the least pressure to separate the sides of the fracture. After the fracture has occurred and the fracture has been propped open by dropping the pressure to allow spalling and resumption of high pressure to move the spalls to propping position and sand out the fracture termini, the stress in the formation is changed. The next application of pressure (following the second shut down, during which the sand out occurs) causes a fracture in a different direction because the minimum rock stress is now in a different direction. The result is the dendritic fracture of this invention.

O. FURTHER COMPARISONS

FIGURE 13 is a chart plotting rate of well flow against time for four wells. Continuous line A plots productivity of the best well in this particular field, treated

by conventional fracturing methods. Long-short dashed line B plots the productivity of a well treated in accordance with the invention. Short dashed line C plots the productivity of a nearby well treated the same as the well of line B except the fracturing was continuous rather than interrupted. Long dashed line D plots the productivity of another nearby well treated in accordance with the invention and believed to be in a bad sand. The extra heavy continuous line E plots the average for a group of 74 wells, all treated by various conventional fracturing processes. It is seen that line B shows productivity better than the best other well in the group treated conventionally, line A, and far better than the average of conventionally treated wells, line E, and far better than a conventionally treated nearby well using a continuous but otherwise similar fracturing process, line C, and that even in a bad sand (apparently) the well treated according to the invention was of productivity, line D, of not too far from average.

FIGURE 14 is similar to FIGURE 13 except that it plots against cumulative production instead of time and omits the average line E. These are gas wells, but the invention is equally applicable to oil wells and to HC wells generally.

FIGURE 15 is another comparative chart similar to FIGURE 14, line W being a plot for a well treated according to the invention and lines X, Y and Z referring to wells treated by conventional fracturing methods.

WHAT WE CLAIM IS:—

1. A method of well treatment by hydraulic fracturing of the formation to be treated, said fracturing including at least one double cycle comprising injecting fluid capable of undergoing fluid loss to said formation once said formation is fractured into the formation at a pressure and for a period of time sufficient to allow hydraulic fracture to occur, discontinuing said fluid injection for a period of time at least long enough to allow a pressure drop in said fluid from fluid loss from said fracture to the formation, resuming injection of said fluid into said formation, and discontinuing said latter injection of fluid.

2. A method as claimed in claim 1, including a plurality of double cycles.

3. A method as claimed in claim 1 or 2 including two double cycles.

4. A method as claimed in claim 1 or 2 including three double cycles.

5. A method as claimed in any of claims 2, 3 or 4, wherein the injection pressure during each double cycle subsequent to the first double cycle is at least 10 per cent greater than during the first double cycle.

6. A method as claimed in any of claims 2 to 5, wherein the well is not produced between double cycles.

7. A method as claimed in any of claims 2 to 6, wherein the periods of discontinuance of injection, other than the last one, are such that the shut in pressure does not fall to less than $1/3$ of the amount of the increase in pressure during the previous injection, thereby to avoid excess fluid loss.

8. A method as claimed in any of claims 2 to 7, wherein the period of an even numbered injection is $1/4$ to $1/3$ the period of an immediately preceding odd numbered injection, considering that the plurality of injections are numbered consecutively in chronological order.

9. A method as claimed in any of claims 2 to 8, wherein the periods of the plurality of consecutive pairs of injection periods, considering the first and second injection periods as the first such pair are approximately proportional to the square root of the number of such pair, considering that the plurality of pairs are numbered consecutively in chronological order.

10. A method as claimed in any of the preceding claims, wherein the fracturing fluid is of the formation pressure increasing type.

11. A method as claimed in any of the preceding claims, including injecting sand with the fracturing fluid to limit the vertical conductive extent of the fracturing.

12. A method as claimed in any of the preceding claims, including injecting sand for fluid loss control.

13. A method as claimed in any of the preceding claims wherein the period of fluid injection is at least 3.5 minutes.

14. A method as claimed in any of the preceding claims, wherein each period of said discontinuing injecting fracturing fluid, except the last such period, lasts for from 5 minutes to one hour.

15. A method as claimed in claim 1, wherein the pressure drop is at least 100 pounds per square inch.

16. A method as claimed in claim 1 substantially as hereinbefore described with reference to the accompanying drawings.

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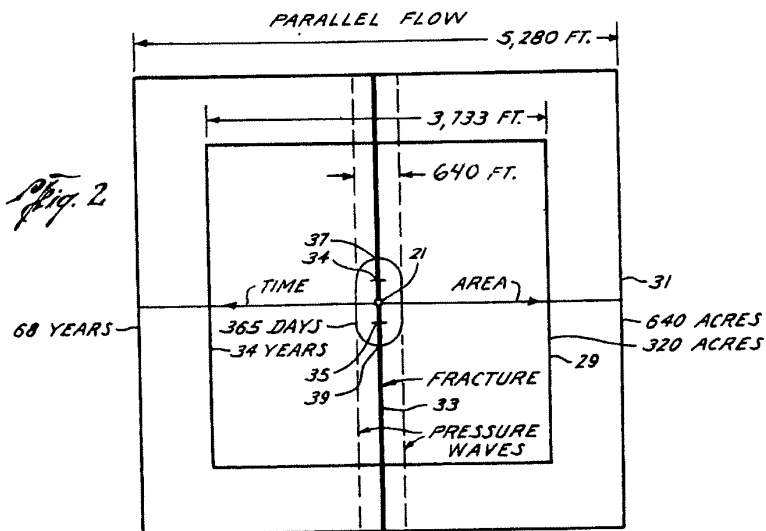
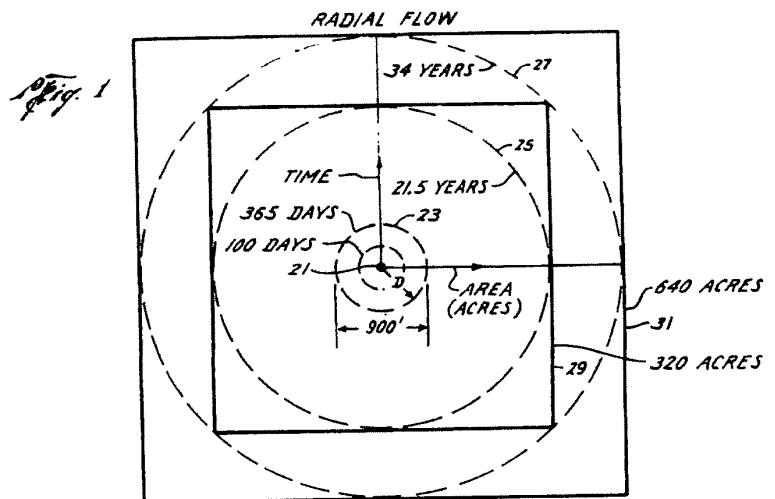
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COMPLETE SPECIFICATION

9 SHEETS

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the Original on a reduced scale

Sheet 1



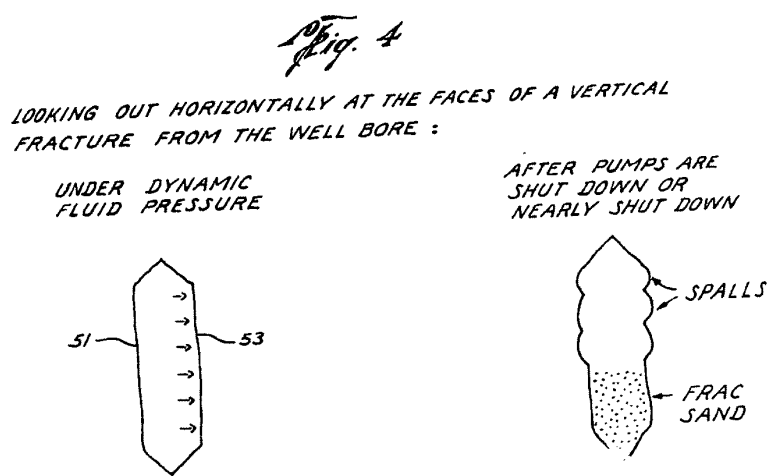
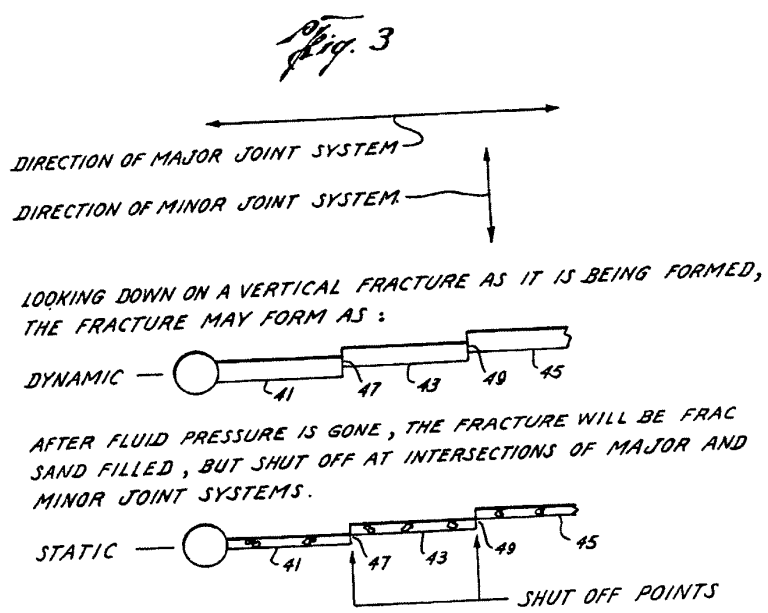


Fig. 5

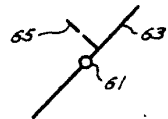


Fig. 6

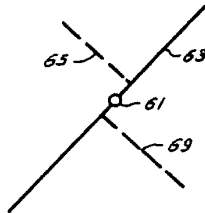


Fig. 7

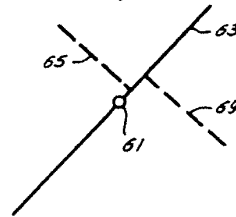


Fig. 8

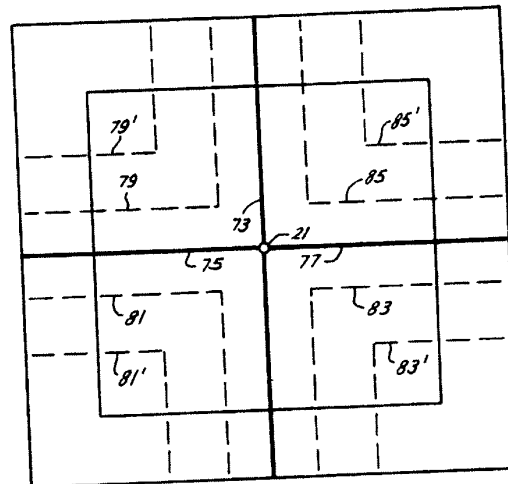


Fig. 10

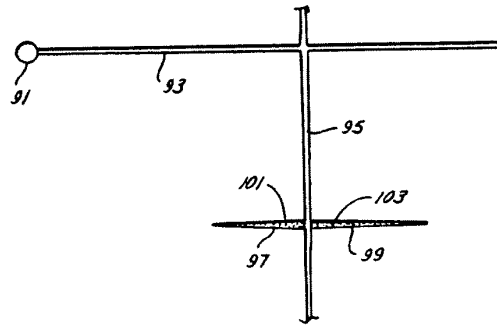


Fig. 11

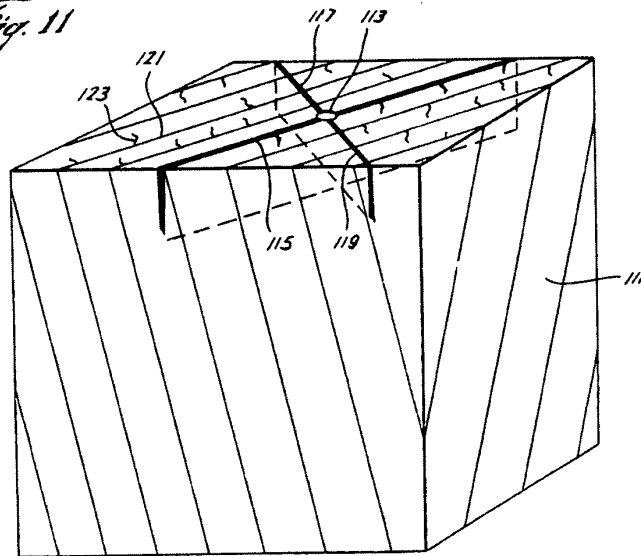
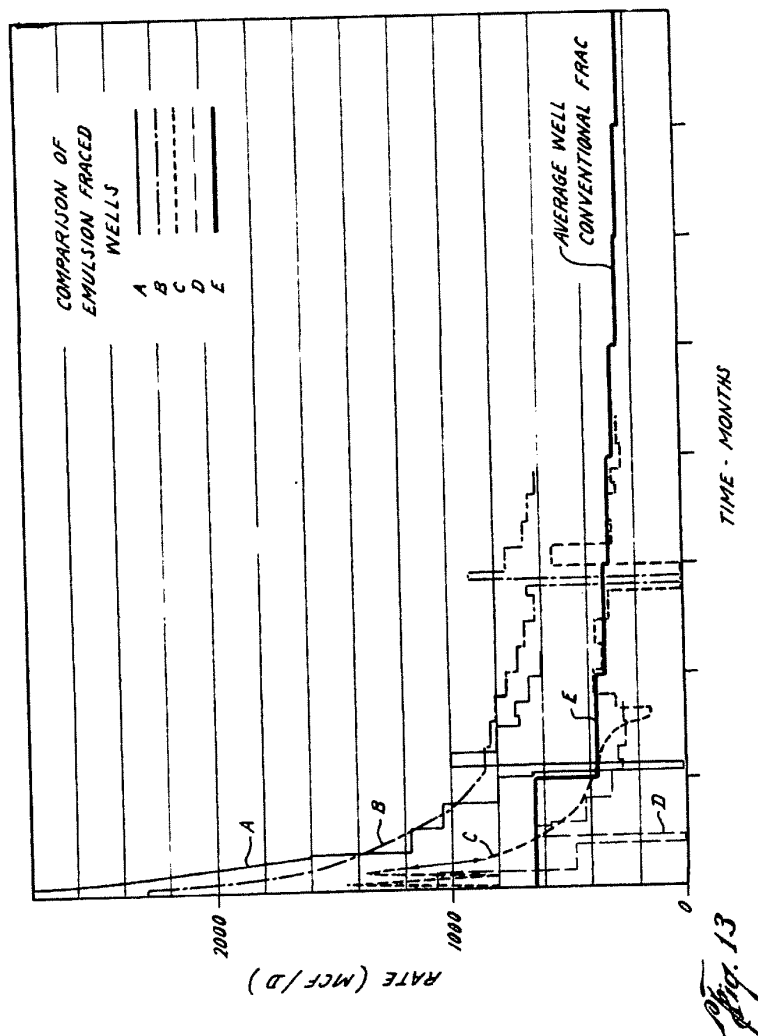


Fig. 12

COMPARISON OF FRACTURING TREATMENTS

TYPE OF TREATMENT	UNINTENTIONAL SHUT DOWN		CONVENTIONAL		YEARS TESTED
	NUMBER OF WELLS	BOPD	NUMBER OF WELLS	BOPD *	
VISOFAC	5	19.80	4	7.60	2
SUPERFAC			4	8.71	2
GELLED F.W.	4	13.46	5	11.20	2
GELLED S.W.	5	23.72	7	11.54	1
F.W. EMULSION	7	37.14	12	8.69	2
S.W. EMULSION	4	27.27	6	9.50	< 3 MO.

* BOPD = BARRELS OIL PER DAY, AVERAGE



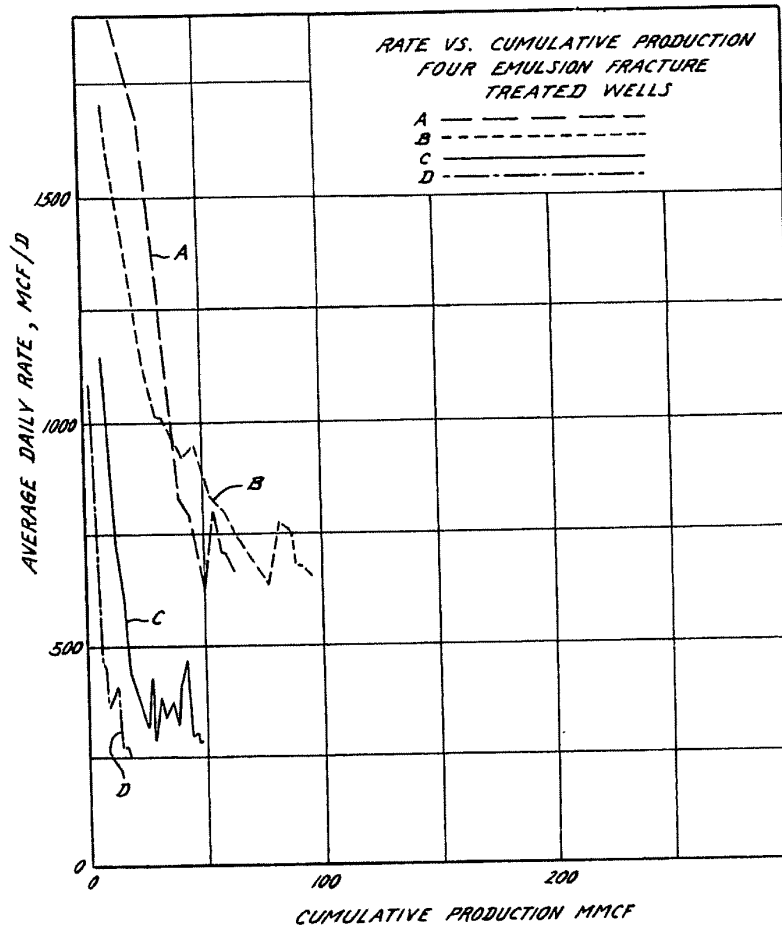


Fig. 14

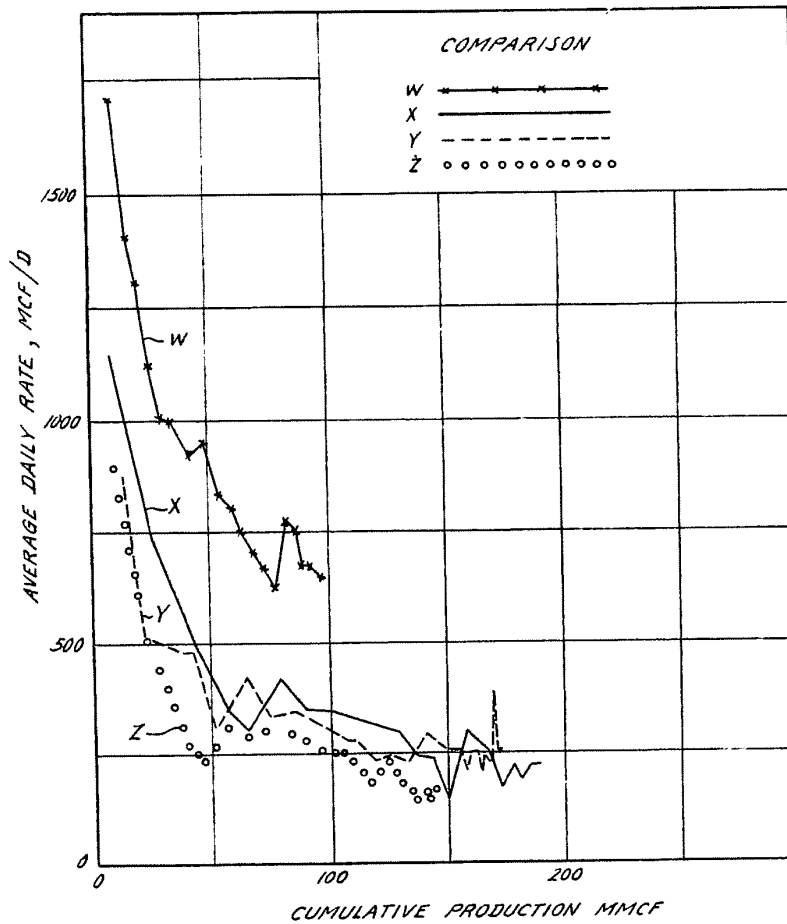


Fig. 15

Electronic Patent Application Fee Transmittal				
Application Number:		11873186		
Filing Date:		16-Oct-2007		
Title of Invention:		Method and System for Centralized Well Treatment		
First Named Inventor/Applicant Name:		Jim B. Surjaatmadja		
Filer:		Carey Christine Jordan./Debbie Allen		
Attorney Docket Number:		2006-IP-021186U1		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
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Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
Total in USD (\$)				180

Electronic Acknowledgement Receipt	
EFS ID:	6977188
Application Number:	11873186
International Application Number:	
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Title of Invention:	Method and System for Centralized Well Treatment
First Named Inventor/Applicant Name:	Jim B. Surjaatmadja
Customer Number:	29920
Filer:	Carey Christine Jordan./Debbie Allen
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Attorney Docket Number:	2006-IP-021186U1
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	Document Description		Start		End
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	Foreign Reference		4		34
	Foreign Reference		35		38
	Foreign Reference		39		69
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New International Application Filed with the USPTO as a Receiving Office

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Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186	
	Filing Date		2007-10-16	
	First Named Inventor	Jim B. Surjaatmadja		
	Art Unit	3676		
	Examiner Name	BATES, ZAKIYA W		
	Attorney Docket Number	2006-IP-021186U1 (063718.1162)		

U.S.PATENTS								
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1	4845981		1989-07-11	Pearson			
	2	5417283		1995-05-23	Ejiogu et al.			
	3	7243726		2007-07-17	Ohmer			
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	1	20020125011		2002-09-12	Snider et al.			
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	1							☐

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	11873186
	Filing Date	2007-10-16
	First Named Inventor	Jim B. Surjaatmadja
	Art Unit	3676
	Examiner Name	BATES, ZAKIYA W
	Attorney Docket Number	2006-IP-021186U1

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	1	Notice of Allowance for U.S. Patent Application Serial No. 11/753,314, dated Dec 17, 2009.	☐
	2	Office Action for U.S. Patent Application Serial No. 11/396,918, dated Dec 1, 2009.	☐
	3	Office Action for U.S. Patent Application Serial No. 11/545,749, dated Jan 27, 2010.	☐
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	11873186
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	Attorney Docket Number	2006-IP-021186U1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

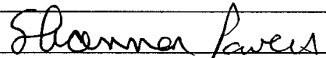
OR

☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

- ☐ See attached certification statement.
- ☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.
- ☐ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature		Date (YYYY-MM-DD)	2010-02-22
Name/Print	Shannon Powers	Registration Number	59,584

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Patent Application Fee Transmittal				
Application Number:		11873186		
Filing Date:		16-Oct-2007		
Title of Invention:		Method and System for Centralized Well Treatment		
First Named Inventor/Applicant Name:		Jim B. Surjaatmadja		
Filer:		Elizabeth L. Durham/Nicci Fowler		
Attorney Docket Number:		2006-IP-021186U1		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
Total in USD (\$)				180

Electronic Acknowledgement Receipt	
EFS ID:	7061781
Application Number:	11873186
International Application Number:	
Confirmation Number:	1172
Title of Invention:	Method and System for Centralized Well Treatment
First Named Inventor/Applicant Name:	Jim B. Surjaatmadja
Customer Number:	29920
Filer:	Elizabeth L. Durham/Nicci Fowler
Filer Authorized By:	Elizabeth L. Durham
Attorney Docket Number:	2006-IP-021186U1
Receipt Date:	22-FEB-2010
Filing Date:	16-OCT-2007
Time Stamp:	18:14:36
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$180
RAM confirmation Number	7950
Deposit Account	020383
Authorized User	
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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	063718-1162-IDS.pdf	149886	no	3
			1a24677a0cc18a48c5d60821852259f47b756111		
Warnings:					
Information:					
2	NPL Documents	063718-NOA-dated-12-17-09.pdf	4930753	no	107
			10f18c7c32e74c25c3c200a9b610777e4f3d951		
Warnings:					
Information:					
3	NPL Documents	063718-OA-dated-12-01-09.pdf	817998	no	21
			580179e9792792063b058677f979e4bd2934f50		
Warnings:					
Information:					
4	NPL Documents	063718-OA-dated-1-27-10.pdf	799678	no	22
			a152e7c88446e5cc724c51a851d47e876156373f		
Warnings:					
Information:					
5	Fee Worksheet (PTO-875)	fee-info.pdf	30223	no	2
			f40629a97e55774af4785531bcf3842c87973e63		
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Total Files Size (in bytes):			6728538		

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

SURJAATMADJA

Serial No.: 11/873,186

Filed: OCTOBER 16, 2007

Title: "METHOD AND SYSTEM FOR
CENTRALIZED WELL TREATMENT"

§

Group Art Unit: 3676

§

Confirmation No.: 1172

§

Examiner: BATES, ZAKIYA W.

§

Atty. Docket No:

HES 2006-IP-021186U1 (063718.1162)

§

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**RESPONSE UNDER 37 C.F.R. § 1.111 TO
OFFICE ACTION, MAILED JANUARY 25, 2010**

Dear Honorable Commissioner:

In response to the Office Action mailed on January 25, 2010 (the "Office
Action"), Applicant submits the following:

- **Amendments to the Claims**, which begin on page 2 of this paper; and
- **Remarks / Arguments** which begin on page 14 of this paper.

LISTING OF THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

Claims:

1. (Original) A method of providing centralized well development services to a plurality of wells, comprising the steps of:

flowing from a centralized well treatment fluid center to one or more centralized service factories one or more well development task fluids, wherein the one or more centralized service factories are selectively configurable to receive the one or more well development task fluids;

preparing, at the one or more centralized service factories, one or more well treatment fluids from the one or more well development task fluids, wherein the one or more centralized service factories are selectively configurable to prepare the one or more well treatment fluids;

flowing from the one or more centralized service factories to at least one of the plurality of wells the one or more well treatment fluids, wherein the one or more centralized service factories are selectively configurable to flow the one or more well treatment fluids;

recovering from the at least one of the plurality of wells the one or more well treatment fluids at the one or more centralized service factories, wherein the one or more centralized service factories are selectively configurable to receive the one or more recovered well treatment fluids; and

flowing from the one or more centralized service factories to the centralized well treatment fluid center the one or more recovered well treatment fluids, wherein the one or more centralized service factories are selectively configurable to flow the one or more recovered well treatment fluids, and wherein the centralized well treatment fluid center is selectively configurable to receive the one or more recovered well treatment fluids.

2. (Previously Presented) The method of claim 1, wherein at least two well development task fluids are provided and they comprise different compositions.

3. (Previously Presented) The method of claim 1, further comprising the step of:
disposing of at least one of the one or more recovered well treatment fluids at the centralized well treatment fluid center, wherein the centralized well treatment fluid center is configurable to dispose of the at least one of the one or more recovered well treatment fluids.

4. (Previously Presented) The method of claim 1, further comprising the step of:
reconditioning at least one of the one or more recovered well treatment fluids at the centralized well treatment fluid center, wherein the centralized well treatment fluid center is configurable to recondition the at least one of the one or more recovered well treatment fluids.

5. (Original) The method of claim 1, wherein at least one of the one or more well treatment fluids comprises a compound selected from the group consisting of drilling fluid, HMP, cement, gas, oil, water, proppant, fracturing fluid, gelling agents, friction reducers, acidizers, conformance fluids, cleaning fluids, brine, cutting abrasives and combinations thereof.

6. (Original) The method of claim 1, further comprising the steps of:
receiving a production fluid at one or more of the one or more centralized service factories from the at least one of the plurality of wells, wherein the one or more of the one or more centralized service factories is configurable to receive the production fluid; and

receiving the production fluid at the centralized well treatment fluid center from the one or more of the one or more centralized service factories, wherein the centralized well treatment fluid center is configurable to receive the production fluid from the one or more of the one or more centralized service factories.

7. (Previously Presented) The method of claim 6, further comprising the step of:

separating the production fluid into at least two or more second production fluids, wherein the centralized well treatment fluid center is configurable to separate the production fluid into at least two or more second production fluids.

8. (Original) The method of claim 7, further comprising the steps of:

conditioning the at least two or more second production fluids, wherein the centralized well treatment fluid center is configurable to condition the at least two or more second production fluids; and

disposing of at least one of the at least two or more second production fluids, wherein the centralized well treatment fluid center is configurable to dispose of the at least one of the at least two or more second production fluids.

9. (Original) The method of claim 7, further comprising:

flowing the at least two or more second production fluids to a distribution center, wherein the centralized well treatment fluid center is configurable to flow the at least two or more second production fluids to the distribution center.

10. (Original) The method of claim 1, further comprising the steps of:

flowing from the centralized well treatment fluid center to the one or more centralized service factories one or more other well development task fluids, wherein the one or more centralized service factories are selectively configurable to receive the one or more other well development task fluids;

flowing from the one or more centralized service factories to the at least one of the plurality of wells the one or more other well treatment fluids, wherein the one or more centralized service factories is selectively configurable to flow the one or more other well treatment fluids;

recovering from the at least one of the plurality of wells the one or more other well treatment fluids at the one or more centralized service factories, wherein the one or more centralized service factories are selectively configurable to receive the one or more recovered other well treatment fluids; and

flowing from the one or more centralized service factories to the centralized well treatment fluid center the one or more other recovered well treatment fluids, wherein the one or more centralized service factories are selectively configurable to flow the one or more other recovered well treatment fluids, and wherein the centralized well treat fluid center is selectively configurable to receive the one or more other recovered well treatment fluids.

11. (Previously Presented) The method of claim 1, further comprising the step of:

storing the one or more recovered well treatment fluids at the centralized well treatment fluid center, wherein the centralized well treatment fluid center is configurable to store the one or more recovered well treatment fluids.

12. (Previously Presented) The method of claim 1, further comprising the step of:

flowing from the centralized well treatment fluid center substantially simultaneously two or more well development task fluids to at least one of the one or more centralized service factories, wherein the centralized well treatment fluid center is configurable to flow substantially simultaneously the two or more well development task fluids, and wherein the at least one of the one or more centralized service factories are configurable to receive substantially simultaneously the two or more well development task fluids.

13. (Previously Presented) The method of claim 12, further comprising the step of:

flowing to a first well of the plurality of wells from the at least one of the one or more centralized service factories any of the one or more well treatment fluids prepared from the two or more well development task fluids substantially simultaneously with flowing to a second well of the plurality of wells from the at least one of the one or more centralized service factories any of the one or more well treatment fluids prepared from the two or more well development task fluids, wherein the at least one of the one or more centralized service factories is configurable to flow substantially simultaneously at least two of the one or more well treatment fluids.

14. (Previously Presented) The method of claim 1, further comprising the step of:

flowing from the centralized well treatment fluid center to the one or more centralized service factories the one or more well treatment fluids, wherein the one or more centralized service factories are selectively configurable to receive the one or more well treatment fluids.

15. (Previously Presented) The method of claim 1, further comprising the steps of:

flowing to two or more wells of the plurality of wells substantially simultaneously the one or more well treatment fluids from at least one of the one or more centralized service factories, wherein the at least one of the one or more centralized service factories is configurable to flow substantially simultaneously the one or more well treatment fluids to the two or more wells of the plurality of wells; and

recovering from the two or more wells of the plurality of wells substantially simultaneously the one or more well treatment fluids at the at least one of the one or more centralized service factories, wherein the at least one of the one or more centralized service factories is configured to recover substantially simultaneously the one or more well treatment fluids.

16. (Original) The method of claim 1, further comprising the steps of:

providing a first plurality of fluid lines from the centralized well treatment fluid center to a first centralized service factory, wherein the first plurality of fluid lines are adapted to flow the one or more well treatment fluids;

providing a second plurality of fluid lines from the centralized well treatment fluid center to the first centralized service factory, wherein the second plurality of fluid lines are adapted to flow the one or more recovered well treatment fluids;

providing a third plurality of fluid lines from the centralized well treatment fluid center to a second centralized service factory, wherein the third plurality of fluid lines are adapted to flow the one or more well treatment fluids; and

providing a fourth plurality of fluid lines from the centralized well treatment fluid center to the second centralized service factory, wherein the fourth plurality of fluid lines are adapted to flow the one or more recovered well treatment fluids.

17. (Previously Presented) A system for centralized distributing, receiving, and treating fluids for a plurality of wells, the system comprising:

a centralized well treatment fluid center;

one or more centralized service factories;

a plurality of distribution lines coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of distribution lines are adapted to flow one or more well development task fluids; and

a plurality of return lines coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of return lines are adapted to flow one or more recovered well treatment fluids.

18. (Previously Presented) The system of claim 17, further comprising:

a plurality of modules disposed about each of the one or more centralized service factories;

a first fluid flow line coupled between the at least one of the plurality of wells and any of the plurality of modules, wherein the first fluid flow line is adapted to flow one or more well treatment fluids to the at least one of the plurality of wells; and

a second fluid flow line coupled between the at least one of the plurality of wells and one or more of the plurality of modules, wherein the second fluid flow line is adapted to recover the one or more well treatment fluids from the at least one of the plurality of wells;

wherein a first configuration of the plurality of modules is operable to flow a first well treatment fluid to the at least one of the plurality of wells; and

wherein a second configuration of the plurality of modules is operable to flow a second well treatment fluid to the at least one of the plurality of wells.

19. (Original) The system of claim 17, wherein each of the plurality of distribution lines are adapted to flow one or more well treatment fluids.

20. (Original) The system of claim 17, wherein the centralized well treatment center is configurable to:

flow the one or more well development task fluids;

receive the one or more recovered well treatment fluids;

recondition the one or more recovered well treatment fluids; and

receive production fluids.

21. (Original) The system of claim 17, wherein the one or more centralized service factories is configurable to:

receive the one or more well development task fluids from the centralized well treatment fluid center;

prepare the one or more well treatment fluids from the one or more well development task fluids;

flow the one or more well treatment fluids to the plurality of wells;

receive the one or more recovered well treatment fluids from the plurality of wells; and

receive production fluids from the plurality of wells.

22. (Original) The system of claim 17, wherein the plurality of modules comprise:

- one or more blending modules;
- one or more additive storage modules, wherein the one or more additive storage modules are operable to connect to the one or more blending modules;
- one or more liquid additive pumps, wherein the one or more liquid additive pumps are operable to connect to the one or more blending modules;
- one or more pumping grids, wherein the one or more pumping grids are operable to connect to the one or more blending modules;
- one or more manifolds, wherein the one or more manifolds are operable to connect to the one or more blending modules; and
- a power grid, wherein the power grid is operable to connect to the one or more blending modules, the one or more additive storage modules, the one or more liquid additive pumps, the one or more pumping grids, and the one or more manifolds.

23. (Original) The system of claim 22, further comprising:

- a third fluid flow line between at least one of a second plurality of wells and the one or more manifolds, wherein the third fluid flow line is directed to delivering at least one of the one or more well treatment fluids;
- wherein the one or more manifolds is operable to deliver substantially simultaneously any of the one or more well treatment fluids through the third fluid flow line and any of the one or more well treatment fluids through the second fluid flow line; and
- a fourth fluid flow line between the second plurality of wells and the one or more manifolds, wherein the fourth fluid flow line is directed to recovering the one or more well treatment fluids from the at least one of the second plurality of wells.

24. (Original) The system of claim 18, wherein at least one of the one or more modules is directed to reconditioning the one or more well treatment fluids substantially simultaneously with recovering the one or more well treatment fluids.

25. (Currently Amended) The system of claim ~~18~~ 23, further comprising:

a fluid reconditioning module disposed about the centralized well treatment fluid center, wherein the fluid reconditioning module is operable to recondition at least one of the one or more recovered well treatment fluids; and

a fifth fluid flow line between the fluid reconditioning module and the third fluid flow line so as to receive the one or more recovered well treatment fluids from the at least one of the one or more centralized service factories.

26. (Original) The system of claim 25, further comprising:

a sixth fluid flow line between the fluid reconditioning module and any of the one or more modules so as to flow the reconditioned well treatment fluids to the one or more centralized service factories.

27. (Original) The system of claim 26, further comprising:

a seventh fluid flow line between the fluid reconditioning module and an additive storage module, wherein the additive storage module is operable to store the reconditioned well treatment fluids.

28. (Original) The system of claim 18, further comprising a disposal module coupled to at least one of the one or more modules, wherein the disposal module is operable to dispose of the recovered well treatment fluids.

29. (Original) The system of claim 18, further comprising a base coupled to at least one of the one or more modules, wherein the base is operable to move the at least one of the one or more modules.

30. (Original) The system of claim 18, further comprising a cleaning module coupled to at least one of the one or more modules, wherein the cleaning module is operable to clean any fluid flow line.

31. (Original) The system of claim 18, further comprising a production fluid module, wherein the production fluid module is operable to receive production fluid from at least one of the one or more centralized service factories.

REMARKS / ARGUMENTS

I. Disposition of the Claims.

Please consider the application in view of the following remarks. Applicant thanks the Examiner for the careful consideration of this application including the references that Applicant has submitted in this case.

At the time of the Office Action, claims 1-31 were pending in this application. Claims 1-15, 17-21, 24, 28, 29 and 31 stand rejected. Claims 16, 22, 23, 25-27 and 30 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. Claim 25 has been amended herein. This amendment is supported by the specification as filed. All the amendments are made in a good faith effort to advance the prosecution on the merits of this case. It should not be assumed that the amendments made herein were made for reasons related to patentability. Applicant respectfully requests that the above amendments be entered and further request reconsideration in light of the amendments and remarks contained herein.

II. Claim Objections

Claims 25-27 are objected to in the Office Action. With respect to this objection, the Office Action states:

[C]laim 25 should depend from claim 23 in order to properly have antecedent basis for a “fifth” fluid flow line. Appropriate correction is required.

(Office Action, at 2). Claim 25 has been amended accordingly. Therefore, Applicant respectfully requests a withdrawal of this objection.

III. Remarks Regarding Claim Rejections Under 35 U.S.C. § 102

Claims 1-15, 17-21, 24, 28, 29 and 31 are rejected under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent No. 7,367,411 issued to Leuchtenberg (hereinafter “Leuchtenberg”). With respect to this rejection, the Office Action states:

With respect to claim 17, the reference discloses a system (Figs. 4-6) for centralized distributing, receiving, and treating fluids for a plurality of wells, the system comprising: a centralized well treatment fluid center 18; one or more centralized service factories (collection of equipment surrounding 18); a plurality of distribution lines (1, 14, 22) coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of distribution lines are adapted to flow one or more well development task fluids; and a plurality of return lines (2, 27) coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of return lines are adapted to flow one or more recovered well treatment fluids. With respect to the depending claims, the reference teaches the limitations as claimed. With respect to the associated method claims, the reference teaches the associated methods. Although the reference only shows one well, it is well within the purview of this invention to apply this system over more than one well.

(Office Action at 3). Applicant respectfully disagrees.

The present invention relates generally to methods and systems for simultaneously treating multiple wells from a centralized location and simultaneously connecting multiple wells to a single manifold. Specification, paragraph [0001]. In contrast, Leuchtenberg is directed to “[a] closed-loop circulating system for drilling wells [that] has control of flow rates in and out of the wellbore.” Leuchtenberg, Abstract. First, the Office Action identifies item 18 in Leuchtenberg as the centralized well treatment fluid center of independent claims 1 and 17. Applicant respectfully disagrees with that characterization. Specifically, with respect to item 18, Leuchtenberg states, in relevant part:

Devices (7), (11), (15) and (25) all acquire data which is directed to a central data point (18) and used to obtain real time values for flow rates, and compared with predicted values and identify any discrepancy.

Leuchtenberg, col. 22, line 67- col. 23, line 4 (emphasis added).

Devices (7), (9), (10), (11), (15), (16), (17), (19), (20), (21), (24), (25) all require data as signals that are directed to a central data acquisition and control system (18). System (18) sends a signal to the pressure/flow control device (12) to open or close it.

Leuchtenberg, col. 23, line 35- col. 23, line 39 (emphasis added).

The central data acquisition and control system (18) is provided with a software designed to predict an expected, ideal value for the outflow, said value being based on calculations taking into account several parameters including but not restricted to rate of penetration, rock and drilling fluid density, well diameter, in and out flow rates, cuttings return rate, bottomhole and wellhead pressures and temperatures.

Leuchtenberg, col. 24, lines 44-52.

Therefore, item 18 identified by the Office Action is merely a central data acquisition and control system, not a well treatment fluid center. There is no fluid flowing to or from item 18 of Leuchtenberg. In contrast, the centralized well treatment fluid center of the present invention includes a plurality of distribution lines coupled thereto which are adapted to flow one or more well development task fluids to one or more centralized service factories. In addition, the centralized well treatment fluid center of the present invention includes a plurality of return lines that are adapted to flow one or more recovered well treatment fluids from the one or more centralized services factories to the centralized well treatment fluid center. Therefore, Leuchtenberg does not disclosed a centralized well treatment fluid center as recited in independent claims 1 and 17.

Additionally, the Office Action identifies items 1, 14 and 27 as the distribution lines and items 2 and 22 as the return lines coupled between the centralized well treatment fluid center and the one or more centralized service factories. Applicant respectfully disagrees with that characterization. With respect to items 1, 2 and 27, Leuchtenberg states:

[A]ccording to FIG. 4 that illustrates the system of the invention, the drilling fluid is injected through the drill string (1), going down towards the bottom hole through the bit (2) and up the annulus (3) and is diverted by a pressure containment device (26) through a closed return line (27) under pressure.

Leuchtenberg, col. 22, lines 54-59. With respect to items 14 and 22, Leuchtenberg states:

The drilling fluid is injected with the aid of pump (6) through an injection line (14) through which said fluid is made to contact mass flow meter (15), fluid flow meter (16), pressure and temperature sensors (17).

Whenever it is deemed necessary, a pump (23) may send fluid directly to the annulus (3) through a dedicated injection line (22) via a mass flow meter (28a), fluid flow meter (28b) and pressure and temperature sensors (28c).

Leuchtenberg, col. 23, lines 32-43. Accordingly, none of the items identified in the Office Action as the distribution line (i.e. items 1, 14, 22) or the return line (i.e. items 2, 27) is coupled to item 18, which is identified in the Office Action as the centralized well treatment fluid center. Moreover, no fluid flows from or to the central data acquisition and control system (18) of Leuchtenberg.

Therefore, Leuchtenberg fails to disclose flowing from a centralized well treatment fluid center to one or more centralized service factories one or more well development task fluids and flowing from the one or more centralized service factories to the centralized well treatment fluid center one or more recovered well treatment fluids, as recited in independent claim 1. Similarly, Leuchtenberg fails to disclose a plurality of distribution lines coupled between the centralized well treatment fluid center and one or more centralized service factories and a plurality of return lines coupled between the centralized well treatment fluid center and the one or more centralized service factories.

Therefore, Applicant respectfully asserts that independent claims 1 and 17 and their dependent claims are not anticipated by Leuchtenberg, nor does Leuchtenberg render these claims obvious. Accordingly, Applicant respectfully requests withdrawal of this rejection with respect to claims 1-15, 17-21, 24, 28, 29 and 31.

IV. Remarks Regarding Double-Patenting Rejections

Claims 1-31 stand provisionally rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1-33 and 40-43 of copending Application No. 11/291,496. Although Applicant does not necessarily agree with the Examiner's rejection, Applicant submits herewith a properly executed terminal disclaimer in regard to claims 1-33 and 40-43 of copending Application No. 11/291,496. Accordingly,

Applicant respectfully submits that the double-patenting rejection over this patent application has been overcome, and respectfully requests the withdrawal of these rejections.

V. Allowable Subject Matter

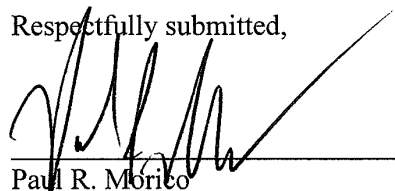
In the Office Action, the Examiner noted that claims 16, 22, 23, 25-27 and 30 would be “allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.” (Office Action at 3.) Applicant gratefully acknowledges the Examiner’s indication that claims 16, 22, 23, 25-27 and 30 would be allowable if rewritten in independent form. Since Applicant has traversed the rejections of independent claims 1 and 17, which are the base claims of claims 16, 22, 23, 25-27 and 30, Applicant respectfully submits that claims 16, 22, 23, 25-27 and 30 are allowable as well.

SUMMARY

In light of the above remarks, Applicant respectfully requests reconsideration and withdrawal of the outstanding rejections. Applicant further submits that the application is now in condition for allowance, and earnestly solicits timely notice of the same. Should the Examiner have any questions, comments or suggestions in furtherance of the prosecution of this application, the Examiner is invited to contact the attorney of record by telephone, facsimile, or electronic mail.

Applicant believes that no fees are due in association with the filing of this Response. However, should the Commissioner deem that any fees are due, including any fees for extensions of time, the Commissioner is authorized to debit Baker Botts L.L.P. Deposit Account No. 02-0383, Order Number 063718.1162, for any underpayment of fees that may be due in association with this filing.

Respectfully submitted,



Paul R. Morico

Registration No. 35,960

One Shell Plaza

910 Louisiana Street

Houston, Texas 77002-4995

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Facsimile: 713.229.7732

email: paul.morico@bakerbotts.com

ATTORNEY FOR APPLICANT

Date: March 16, 2010

**TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING
REJECTION OVER A PENDING "REFERENCE" APPLICATION**

Docket Number (Optional)

In re Application of: Surjaatmadja

Application No.: 11/873,186

Filed: October 16, 2007

For: Method and System for Centralized Well Treatment

The owner*, Halliburton Energy Services, Inc., of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending **reference** Application Number 11/291,496, filed on December 1, 2005, as such term is defined in 35 U.S.C. 154 and 173, and as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the **reference** application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

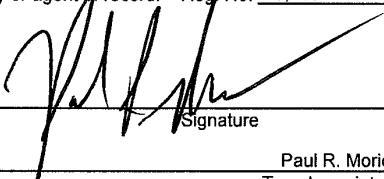
In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term as defined in 35 U.S.C. 154 and 173 of any patent granted on said **reference** application, "as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application," in the event that: any such patent; granted on the pending **reference** application: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

Check either box 1 or 2 below, if appropriate.

1. ☐ For submissions on behalf of a business/organization (e.g., corporation, partnership, university, government agency, etc.), the undersigned is empowered to act on behalf of the business/organization.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2. ☒ The undersigned is an attorney or agent of record. Reg. No. 35,960



Signature

Paul R. Morico
Typed or printed name

March 16, 2010

Date

713.229.1732
Telephone Number

- ☒ Terminal disclaimer fee under 37 CFR 1.20(d) is included.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).
Form PTO/SB/96 may be used for making this statement. See MPEP § 324.

This collection of information is required by 37 CFR 1.321. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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Electronic Patent Application Fee Transmittal				
Application Number:		11873186		
Filing Date:		16-Oct-2007		
Title of Invention:		Method and System for Centralized Well Treatment		
First Named Inventor/Applicant Name:		Jim B. Surjaatmadja		
Filer:		Elizabeth L. Durham/Nicci Fowler		
Attorney Docket Number:		2006-IP-021186U1		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Statutory disclaimer	1814	1	140	140
Total in USD (\$)				140

Electronic Acknowledgement Receipt	
EFS ID:	7221709
Application Number:	11873186
International Application Number:	
Confirmation Number:	1172
Title of Invention:	Method and System for Centralized Well Treatment
First Named Inventor/Applicant Name:	Jim B. Surjaatmadja
Customer Number:	29920
Filer:	Elizabeth L. Durham/Nicci Fowler
Filer Authorized By:	Elizabeth L. Durham
Attorney Docket Number:	2006-IP-021186U1
Receipt Date:	16-MAR-2010
Filing Date:	16-OCT-2007
Time Stamp:	17:08:07
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$140
RAM confirmation Number	4045
Deposit Account	020383
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)					
Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)					
Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)					
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		063718-1162-ROA.PDF	840481	yes	22
			20e3964eebaf4fe73bd03586c3d5d964568062b1		
	Multipart Description/PDF files in .zip description				
	Document Description	Start	End		
	Transmittal Letter	1	2		
	Amendment/Req. Reconsideration-After Non-Final Reject	3	3		
	Claims	4	15		
	Applicant Arguments/Remarks Made in an Amendment	16	21		
	Terminal Disclaimer Filed	22	22		
Warnings:					
Information:					
2	Fee Worksheet (PTO-875)	fee-info.pdf	30203	no	2
			c227614badea36c32c704a0ba138a6b35080f963		
Warnings:					
Information:					
Total Files Size (in bytes):			870684		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

In re Application of:

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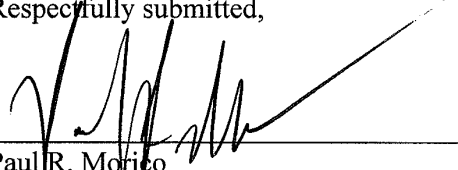
§

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Ex. 1002, p. 667 of 849

debit the Deposit Account of Baker Botts L.L.P., No. 02-0383, order number 063718.1162, for any underpayment of fees that may be due in association with this filing.

Respectfully submitted,



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ATTORNEY FOR APPLICANT

Date: March 16, 2010

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 11/873,186		Filing Date 10/16/2007		☐ To be Mailed	
APPLICATION AS FILED – PART I										
(Column 1)			(Column 2)			SMALL ENTITY ☐ OR		OTHER THAN SMALL ENTITY		
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	OR	RATE (\$)	FEE (\$)			
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A				
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A				
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A				
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$ =		OR	X \$ =				
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$ =			X \$ =				
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.										
APPLICATION AS AMENDED – PART II										
(Column 1)			(Column 2)			SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT	03/16/2010	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(o))	* 31	Minus	** 31	=	X \$ =		X \$ =		
	Independent (37 CFR 1.16(h))	* 2	Minus	*** 3	=	X \$ =		X \$ =		
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))									
	TOTAL ADD'L FEE									
(Column 1)			(Column 2)			SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)		
	Total (37 CFR 1.16(o))	*	Minus	**	=	X \$ =		X \$ =		
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =		X \$ =		
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))									
	TOTAL ADD'L FEE									
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

Legal Instrument Examiner:
/GLORIA ANTHONY/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Application Number 	Application/Control No. 11/873,186	Applicant(s)/Patent under Reexamination SURJAATMADJA, JIM B.	
Document Code - DISQ		Internal Document – DO NOT MAIL	

TERMINAL DISCLAIMER	☒ APPROVED	☐ DISAPPROVED
Date Filed : 03-16-10	This patent is subject to a Terminal Disclaimer	

Approved/Disapproved by:
KAREN L. WARD

U.S. Patent and Trademark Office

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (07-09)

Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186	
	Filing Date		2007-10-16	
	First Named Inventor	Jim Surjaatmadja		
	Art Unit	3676		
	Examiner Name	Zakiya Bates		
	Attorney Docket Number	2006-IP-021186U1		

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					
	2					
	3					
	4					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS						
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS							
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear ^{T5}

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	11873186
Filing Date	2007-10-16
First Named Inventor	Jim Surjaatmadja
Art Unit	3676
Examiner Name	Zakiya Bates
Attorney Docket Number	2006-IP-021186U1

1								☐
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If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵
	1	Notice of Allowance for U.S. Patent Application No. 11/691,623 dated February 18, 2010	☐
	2	Notice of Allowance for U.S. Patent Application No. 11/545,749 dated April 5, 2010	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature		Date Considered	
--------------------	--	-----------------	--

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	11873186
Filing Date	2007-10-16
First Named Inventor	Jim Surjaatmadja
Art Unit	3676
Examiner Name	Zakiya Bates
Attorney Docket Number	2006-IP-021186U1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

- ☐ See attached certification statement.
- ☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.
- ☐ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	<i>Melody B. Wirz</i>	Date (YYYY-MM-DD)	2010-4-20
Name/Print	Melody B. Wirz	Registration Number	53,783

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Acknowledgement Receipt	
EFS ID:	7446383
Application Number:	11873186
International Application Number:	
Confirmation Number:	1172
Title of Invention:	Method and System for Centralized Well Treatment
First Named Inventor/Applicant Name:	Jim B. Surjaatmadja
Customer Number:	29920
Filer:	Melody Bernice Wirz/Debbie Allen
Filer Authorized By:	Melody Bernice Wirz
Attorney Docket Number:	2006-IP-021186U1
Receipt Date:	20-APR-2010
Filing Date:	16-OCT-2007
Time Stamp:	10:37:25
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		0861080099IDS.pdf	383780 bcb8a1c68eb2bf30805d9e6f2ac501258d089a4	yes	13

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Information Disclosure Statement (IDS) Filed (SB/08)	1	3
	NPL Documents	4	7
	NPL Documents	8	13
Warnings:			
The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing			
Information:			
Total Files Size (in bytes):		383780	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)

Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186
	Filing Date		2007-10-16
	First Named Inventor	Surjaatmadja	
	Art Unit	3676	
	Examiner Name	Bates, Zakiya W.	
	Attorney Docket Number	2006-IP-021186U1	

U.S.PATENTS								
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1							
If you wish to add additional U.S. Patent citation information please click the Add button.								
U.S.PATENT APPLICATION PUBLICATIONS								
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1							
If you wish to add additional U.S. Published Application citation information please click the Add button.								
FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²ⁱ	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							☐
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EFS Web 2.1.17

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186
	Filing Date		2007-10-16
	First Named Inventor	Surjaatmadja	
	Art Unit	3676	
	Examiner Name	Bates, Zakiya W.	
	Attorney Docket Number	2006-IP-021186U1	

1	Office Action from U.S. Application Serial No. 11/873,160 dated May 24, 2010	☐
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Examiner Signature		Date Considered
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	11873186
	Filing Date	2007-10-16
	First Named Inventor	Surjaatmadja
	Art Unit	3676
	Examiner Name	Bates, Zakiya W.
	Attorney Docket Number	2006-IP-021186U1

CERTIFICATION STATEMENT	
Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):	
☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).	
OR	
☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).	
☐ See attached certification statement.	
☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.	
☒ None	
SIGNATURE	
A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.	
Signature	<i>Larissa Piccardo</i> Date (YYYY-MM-DD)
Name/Print	Larissa Piccardo Registration Number
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Electronic Acknowledgement Receipt	
EFS ID:	7807469
Application Number:	11873186
International Application Number:	
Confirmation Number:	1172
Title of Invention:	Method and System for Centralized Well Treatment
First Named Inventor/Applicant Name:	Jim B. Surjaatmadja
Customer Number:	29920
Filer:	Elizabeth L. Durham/Nicci Fowler
Filer Authorized By:	Elizabeth L. Durham
Attorney Docket Number:	2006-IP-021186U1
Receipt Date:	14-JUN-2010
Filing Date:	16-OCT-2007
Time Stamp:	15:43:08
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		063718-1162-IDS.PDF	135739	yes	3
			d5b05e64b28c71f8dc775ec80da91a28fc124186		

	Multipart Description/PDF files in .zip description								
	Document Description		Start	End					
	Information Disclosure Statement (IDS) Filed (SB/08)		1	2					
	Transmittal Letter		3	3					
Warnings:									
Information:									
2	NPL Documents	063718-1162-Ref1.PDF	1188464	no	26				
			62ee18929977087844372bc242e8d27971856b60						
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Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (07-09)

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	Filing Date		2007-10-16	
	First Named Inventor	Jim Surjaatmadja		
	Art Unit	3676		
	Examiner Name	Zakiya Bates		
	Attorney Docket Number	2006-IP-021186U1		

U.S.PATENTS						
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	3					
	4					

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U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1	20060243437	A1	2006-11-02	Albers et al.	

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FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ² i	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186	
	Filing Date		2007-10-16	
	First Named Inventor	Jim Surjaatmadja		
	Art Unit	3676		
	Examiner Name	Zakiya Bates		
	Attorney Docket Number	2006-IP-021186U1		

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	1	Office Action for U.S. Patent Application No. 11/291,496 dated May 13, 2010	☐

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**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	11873186
Filing Date	2007-10-16
First Named Inventor	Jim Surjaatmadja
Art Unit	3676
Examiner Name	Zakiya Bates
Attorney Docket Number	2006-IP-021186U1

CERTIFICATION STATEMENT

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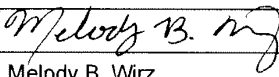
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☐ None

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Signature		Date (YYYY-MM-DD)	2010-06-18
Name/Print	Melody B. Wirz	Registration Number	53,783

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Electronic Patent Application Fee Transmittal				
Application Number:		11873186		
Filing Date:		16-Oct-2007		
Title of Invention:		Method and System for Centralized Well Treatment		
First Named Inventor/Applicant Name:		Jim B. Surjaatmadja		
Filer:		Carey Christine Jordan./Debbie Allen		
Attorney Docket Number:		2006-IP-021186U1		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
Total in USD (\$)				180

Electronic Acknowledgement Receipt	
EFS ID:	7842061
Application Number:	11873186
International Application Number:	
Confirmation Number:	1172
Title of Invention:	Method and System for Centralized Well Treatment
First Named Inventor/Applicant Name:	Jim B. Surjaatmadja
Customer Number:	29920
Filer:	Carey Christine Jordan./Debbie Allen
Filer Authorized By:	Carey Christine Jordan.
Attorney Docket Number:	2006-IP-021186U1
Receipt Date:	18-JUN-2010
Filing Date:	16-OCT-2007
Time Stamp:	10:30:05
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$180
RAM confirmation Number	7191
Deposit Account	500417
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The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees) Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)	

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		0861080099IDS.PDF	251392 6701edb1e088688e87f66ffb958629c3a6531207	yes	17
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	Document Description		Start	End	
	Information Disclosure Statement (IDS) Filed (SB/08)		1	3	
	NPL Documents		4	17	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	11/873,186
	Filing Date	10/16/2007
	First Named Inventor	Surjaatmadja
	Confirmation Number	1172
	Client Number	86108
Page 1 of 2	Matter Number	99

U.S. PATENT DOCUMENTS				
Initials	Cite No.	Document Number	Issue/Publication Date	First Named Inventor
	1	7711487	5/4/2010	Surjaatmadja
	2	20080083531	4/10/2008	Surjaatmadja
	3	3455391	7/15/1969	Matthews
	4	3682246	8/8/1972	Closmann
	5	3822747	7/9/1974	Maguire
	6	5228510	7/20/1993	Jennings#s#Jr
	7	6935424	8/30/2005	Lehman

FOREIGN PATENT DOCUMENTS				
Initials	Cite No.	Document Number	Publication Date	Country
	1	2006109035		WO

OTHER DOCUMENTS		
Initials	Cite No.	Author, Title, Date, Pages, etc.
	1	Search Report and Written Opinion for International Application No. PCT/GB2008/001730 dated May 21, 2008.
	2	Notice of Allowance for U.S. Patent No. 11/691,623 dated July 26, 2010.

Examiner Signature		Date Considered	
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	11/873,186
	Filing Date	10/16/2007
	First Named Inventor	Surjaatmadja
	Confirmation Number	1172
	Client Number	86108
Page 2 of 2	Matter Number	99

TIMING
In accordance with 37 CFR 1.97(c), this Information Disclosure Statement is being filed after the period specified in 37 CFR 1.97(b) and before the mailing date of a Final Action under 37 CFR 1.113, a Notice of Allowance under 37 CFR 1.311, or an Action that otherwise closes prosecution in the application.

CERTIFICATION STATEMENT
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FEE
The Director is hereby authorized to charge \$180 to deposit account number 500417. Please reference attorney docket number 86108-99 for this transaction. This Information Disclosure Statement is being filed in accordance with 37 CFR 1.97(c), and is not accompanied by one of the certification statements of 37 CFR 1.97(e). Therefore, this Information Disclosure Statement is subject to the fee set forth in 37 CFR 1.17(p).

SIGNATURE			
Signature	/ Melody Wirz /	Date	8/10/2010
Name	Melody Wirz	Registration Number	53783

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International Bureau



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19 October 2006 (19.10.2006)

PCT

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(30) Priority Data:

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11/121,278 5 May 2005 (05.05.2005) US

(71) Applicant (for all designated States except US): **HAL-LIBURTON ENERGY SERVICES, INC.** [US/US]; P.O. Box 1431, Duncan, OK 73533 (US).

(71) Applicant (for MW only): **CURTIS, Philip, Anthony** [GB/GB]; A A Thornton & Co, 235 High Holborn, London WC1V 7LE (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **DYKSTRA, Jason, D.** [US/US]; 1112 E. Plato Road, Duncan, OK 73533 (US).
BORGSTADT, Justin, A. [US/US]; 806 W. Hickory, Duncan, OK 73533 (US).

(74) Agents: **CURTIS, Philip, Anthony** et al.; A.A. Thornton & Co., 235 High Holborn, London WC1V 7LE (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AI, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

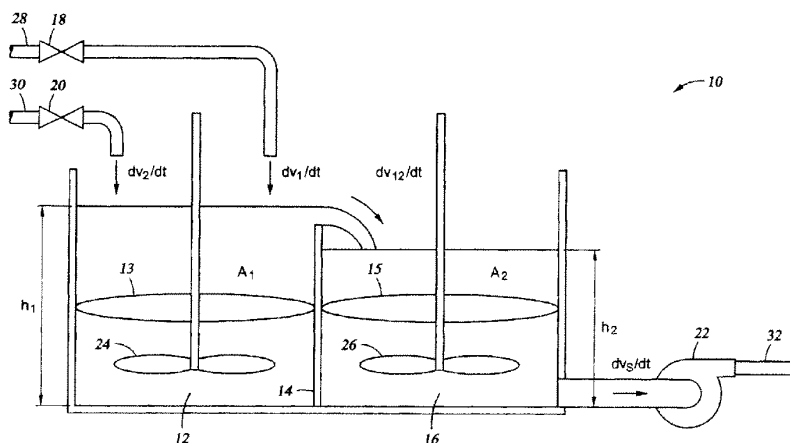
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

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

(54) Title: CONTROL SYSTEM DESIGN FOR A MIXING SYSTEM WITH MULTIPLE INPUTS



(57) Abstract: A control system for mixing at least two materials in a physical system, for example cement and water for a well bore, having two or more tanks comprises at least two actuators, each actuator being operable to introduce a material into a first tank to form a first mixture, the first mixture flowing into a second tank to form a second mixture and a controller operable, based on a commanded input, to control the at least two actuators to obtain a density of either the first mixture or the second mixture and a volume flow rate of the second mixture out of the second tank, wherein the density is controlled independently from the volume flow rate, and wherein the commanded input comprises a commanded combined volume flow rate and a commanded combined mass flow rate of the materials passing through the actuators into the first tank.

WO 2006/109035 A1

Control System Design for a Mixing System with Multiple Inputs**FIELD OF THE INVENTION**

The present disclosure is directed to a control system design for a mixing system having multiple inputs, and more particularly, but not by way of limitation, to a control system design for a cement mixing system used in well bore servicing applications.

BACKGROUND OF THE INVENTION

A control system typically comprises one or more physical system components under some form of automated control that cooperate to achieve a set of common objectives. The control system may be designed to reliably control the physical system components in the presence of external disturbances, variations among physical components due to manufacturing tolerances, and changes in commanded input values for controlled output values, such as a cement mixture density, for example. The control system may also be designed to remain stable and avoid oscillations within a range of specific operating conditions.

In a well bore environment, a control system may be used when mixing materials to achieve a desired mixture output. For example, when drilling an oil or gas well, it is common to install a tubular casing into the well bore and cement the casing in place against the well bore wall. A cement mixing system that supports well bore servicing operations, such as cementing casing into a well bore, may be designed with a control system configured to provide a desired volumetric flow rate of mixed cement having a desired density. In particular, the cement mixing control system may control valves that allow the in-flow of dry cement material and water to obtain the desired cement mixture density and desired cement mixture volumetric flow rate. The control system may operate, for example, by monitoring the cement mixture flow rate and density, and by regulating an in-flow water valve and an in-flow dry cement material valve. However, because such systems conventionally control the output parameters, such as cement mixture flow rate and density, dependently, these systems tend to have long lag times in the response of one valve to changes in the position of the other valve. This can lead to unacceptable oscillations in the monitored parameters, and difficulty in stabilizing the system. Therefore, to make the system more stable, it

would be desirable to control output parameters, such as a mixture flow rate and a mixture density, for example, independently of each other. Accordingly, a need exists for a mixing control system with multiple inputs that decouples the effects of changes in the commanded outputs.

SUMMARY OF THE INVENTION

Disclosed herein is a control system for mixing at least two materials in a physical system having two or more tanks comprising at least two actuators, each actuator being operable to introduce a material into a first tank to form a first mixture, the first mixture flowing into a second tank to form a second mixture and a controller operable, based on a commanded input, to control the at least two actuators to obtain a density of either the first mixture or the second mixture and a volume flow rate of the second mixture out of the second tank, wherein the density is controlled independently from the volume flow rate.

Further disclosed herein is a control system for mixing at least two materials in a tank comprising at least two actuators, each actuator being operable to introduce a material into the tank to form a mixture and a controller operable, based on a commanded input, to control the at least two actuators to obtain a density of the mixture and a volume flow rate of the mixture out of the tank, wherein the density is controlled independently from the volume flow rate.

Further disclosed herein is a control system for mixing at least two materials comprising a controller operable to control a physical system comprising a plurality of actuators, each actuator being operable to introduce a material into a first tank to form a first mixture, wherein the controller operates the actuators to control a desired characteristic of the first mixture.

Further disclosed herein is a method for mixing at least two materials comprising introducing the at least two materials into a physical system, combining the at least two materials to form a mixture thereof, and independently controlling a desired characteristic of the mixture of the at least two materials and a desired parameter of the physical system.

Further disclosed herein is a method for mixing at least two materials comprising determining a commanded combined mass flow rate of the at least two materials into a first tank [commanded dm_{in}/dt], determining a commanded combined

volume flow rate of the at least two materials into the first tank [commanded dv_{in}/dt], and independently controlling, based on the commanded dm_{in}/dt and the commanded dv_{in}/dt , a density of a mixture of the at least two materials in the first tank [ρ_{12}] and a volume flow rate of the mixture out of the first tank [dv_{12}/dt].

These and other features and advantages will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description, wherein like reference numerals represent like parts.

Figure 1 is a diagram of one embodiment of a physical plant within which a control system for a mixing system may be implemented;

Figure 2 is a block diagram of one embodiment of a control system;

Figure 3 is a block diagram of one embodiment of a flow modulator component of the control system of Figure 2;

Figure 4 is a block diagram of one embodiment of a flow regulator component of the control system of Figure 2;

Figure 5A is a block diagram of two embodiments of a state feedback controller with command feed forward component of the control system of Figure 2;

Figure 5B is a block diagram of the first embodiment of the state feedback controller with command feed forward component of Figure 5A;

Figure 5C is a block diagram of the second embodiment of the state feedback controller with command feed forward component of Figure 5A;

Figure 6 is a block diagram of the components of the control system of Figure 2 in the context of the physical plant;

Figure 7 is a flow diagram illustrating an exemplary use of the control system of Figure 2;

Figure 8A is a block diagram of one embodiment of a height observer component;

Figure 8B is a block diagram of one embodiment of a control system comprising first and second height observer components;

Figure 9A is a block diagram of one embodiment of a density observer component;

Figure 9B is a block diagram of one embodiment of a control system comprising first and second density observer components;

Figure 10A is a block diagram of a first portion of an embodiment of a control system for a physical plant having a single tank, the first portion including a height controller;

Figure 10B is a block diagram of a second portion of the embodiment of the control system for a physical plant having a single tank, the second portion including a density controller;

Figure 11 is a block diagram of one embodiment of a control system having a density observer associated with a first tank and no automated height control;

Figure 12 is a block diagram of one embodiment of a control system having a density observer associated with the first tank and a height observer associated with a second tank; and

Figure 13 illustrates one example of a general purpose computer system suitable for implementing the several embodiments of the control system and its various components.

DETAILED DESCRIPTION

It should be understood at the outset that the present disclosure describes various implementations of different embodiments of a control system having one or more inputs. However, the present control system may also be implemented using any number of other techniques, whether currently known or in existence. The present disclosure should in no way be limited to the descriptions, drawings, and techniques illustrated below, including the design and implementation illustrated and described herein.

In an embodiment shown in Figure 1, a physical plant 10 to be controlled comprises a first tank 12 joined by a weir 14 to a second tank 16, a first actuator 18 dispensing a first material to be mixed, a second actuator 20 dispensing a second material to be mixed, and an outflow pump 22. A first mixture 13 is formed from the in-

flow of the first material from the first actuator 18 and the second material from the second actuator 20 into the first tank 12. When the first mixture 13 fills the first tank 12 to the height of the weir 14, the first mixture 13 overflows into the second tank 16. The mixture in the second tank 16 is referred to as a second mixture 15. A first stirrer 24 and a second stirrer 26 may be provided to promote homogeneity of the first mixture 13 in the first tank 12 and the second mixture 15 in the second tank 16, respectively. The second mixture 15 exits the second tank 16 via an outflow pump 22 and a discharge line 32. In other embodiments, additional actuators may feed additional materials into the first tank 12. In other embodiments, a single tank or three or more tanks may be used.

In an embodiment, the physical plant 10 is a well bore servicing fluid mixing system, such as, for example, a cement mixer used to provide a continuous stream of a cement slurry for cementing a tubular casing against a well bore wall. In this embodiment, a dry cement material may be fluidized by the introduction of pressurized air, which promotes fluid flow of the dry cement through a first feed line 28, to be dispensed into the first tank 12 through the first actuator 18, for example, and a carrier fluid, such as water, for example, may flow through a second feed line 30 to be dispensed into the first tank 12 through the second actuator 20. In this embodiment, the first and second actuators 18, 20 may be valves, for example. These two materials, the dry cement material and the carrier fluid, are mixed by the first stirrer 24 to obtain the first mixture 13. Non-fluidized sand or other particulate matter may be dispensed through a third actuator (not shown), such as a screw feeder, for example, into the first tank 12 to mix with the cement slurry. In various embodiments, any of the actuators may comprise a valve, a screw feeder, an auger, an elevator, or other type of actuator known to those skilled in the art. The first mixture 13 is preferably substantially homogenous. The physical plant 10 should provide the cement slurry via the outflow pump 22 and the discharge line 32 at a volumetric flow rate sufficient to support the well bore servicing operation, and should mix the dry concrete material, the carrier fluid, and any particulate material in appropriate proportions so that the cement slurry dispensed thereby achieves a desired density. The physical plant 10 in other embodiments may support other mixing operations of other materials. For example, in another embodiment, proppants and a carrier fluid may be dispensed

through the first and second actuators 18, 20 into the first tank 10 to form a portion of a fracturing fluid.

Figure 1 also identifies several parameters of a control system, e.g., a first control system 100 depicted in Figure 2, coupled to the physical plant 10 and functional to control the operation thereof. The first tank 12 has a cross-sectional area represented by the constant A_1 , and the second tank 16 has a cross-sectional area represented by the constant A_2 . The height of the first mixture 13 in the first tank 12 is represented by the variable h_1 , and the height of the second mixture 15 in the second tank 16 is represented by the variable h_2 . The volumetric flow rate of the first material, for example dry cement, through the first actuator 18 into the first tank 12 is represented by dv_1/dt . The volumetric flow rate of the second material, for example water, through the second actuator 20 into the first tank 12 is represented by dv_2/dt . The volumetric flow rate of the first mixture 13, for example a cement slurry, over the weir 14 into the second tank 16 is represented by dv_{12}/dt . The volumetric flow rate of the second mixture 15 out of the second tank 16 and through the outflow pump 22 is represented by dv_3/dt .

The first control system 100 disclosed hereinafter is expected to reduce control oscillations due to system time lags and to promote independent control of a mixture density and a mixture flow rate.

Turning now to Figure 2, a first control system 100 is depicted that is coupled to the physical plant 10 of Figure 1 and controls the first actuator 18 and the second actuator 20. In an embodiment, the first control system 100 controls the actuators 18, 20 to obtain sensed parameter values that approach or equal the following input parameter values that are input into the first control system 100 by an operator through an interface with the first control system 100: a height h_2 of the second mixture 15 in the second tank 16, a volumetric flow rate dv_3/dt of the second mixture 15 out of the second tank 16, and a density ρ_s of the second mixture 15 out of the second tank 16. In other embodiments, the first control system 100 may control the first actuator 18 and the second actuator 20 to obtain sensed parameter values that approach or equal other input parameter values. For example, the first control system 100 may be said to control the volumetric flow rate of the first mixture 13 over the weir 14 into the second tank 16, represented by dv_{12}/dt , and the density of the second mixture 15 as it

leaves the second tank 16, represented by ρ_s . However, the first control system 100 actually controls the first actuator 18 and the second actuator 20, for example, by adjusting a valve position or by modifying a rotation rate of a screw feeder.

The first control system 100 comprises a controller 102 that receives input parameter values from an operator through an interface with the first control system 100, and also receives sensed parameter values from sensors coupled to or integral with the physical plant 10. The controller 102 distributes as output parameter values commands to the first actuator 18 and the second actuator 20. An input parameter value 104 for h_2 provides to the controller 102 the desired height h_2 of the second mixture 15 in the second tank 16, an input parameter value 106 for dv_s/dt provides the desired volumetric flow rate dv_s/dt of the second mixture 15 out of the second tank 16, and an input parameter value 108 for ρ_s provides the desired density ρ_s of the second mixture 15 out of the second tank 16. A h_1 sensor 110 provides an indication of the height h_1 of the first mixture 13 in the first tank 12, a h_2 sensor 112 provides an indication of the height h_2 of the second mixture 15 in the second tank 16, a ρ_{12} sensor 114 provides an indication of the density ρ_{12} of the first mixture 13, and a ρ_s sensor 116 provides an indication of the density ρ_s of the second mixture 15. These indications may be referred to as sensed parameter values.

In an embodiment, the first control system 100 controls the actuators 18, 20 to achieve a desired volumetric flow rate dv_{12}/dt of the first mixture 13 over the weir 14 into the second tank 16, and a density ρ_s of the second mixture 15 out of the second tank 16, independently of each other. For example, changing the dv_s/dt input parameter value 106 causes the controller 102 to control the actuators 18, 20 so that the actual volumetric flow rate dv_{12}/dt of the first mixture 13 over the weir 14 into the second tank 16 changes until it substantially equals the dv_s/dt input parameter value 106. Actual values may also be referred to as nominal values in some contexts by those skilled in the control systems art. However, the density ρ_s of the second mixture 15 as it leaves the second tank 16 remains substantially unchanged because the density and flow rate parameters are controlled independently. Similarly, changing the ρ_s input parameter value 108 causes the controller 102 to alter the control signals to actuators 18, 20 until the sensed density ρ_s of the second mixture 15 as read by the ρ_s sensor 116 substantially equals the ρ_s input parameter value 108. However, the

volumetric flow rate dv_{12}/dt of the first mixture 13 over the weir 14 into the second tank 16 remains substantially unchanged because the flow rate and density parameters are controlled independently.

Turning now to Figure 3, a flow modulator 150 for use with one or more embodiments of the first control system 100 is depicted. The flow modulator 150 comprises a first flow modulator 152 and a second flow modulator 154 to modulate the first actuator 18 and the second actuator 20, respectively. In some embodiments, the first flow modulator 152 and the second flow modulator 154 may be combined in an integrated modulator unit 155 or combined in a single functional block, such as, for example, within a computer programmed to modulate the first actuator 18 and the second actuator 20. The first and second flow modulator 152, 154 provide a mechanism for modulating or converting between the preferred control parameters, for example volumetric rate and mass flow rate, and the physical controls of the physical system, for example control signals to the first actuator 18 and the second actuator 20. Both the first flow modulator 152 and the second flow modulator 154 receive from another component of the controller 102 a commanded first volume flow rate signal 151 for dv_{in}/dt and a commanded first mass flow rate signal 153 for dm_{in}/dt . For example, the commanded first volume flow rate dv_{in}/dt signal 151 and the commanded first mass flow rate dm_{in}/dt signal 153 may be received from a flow regulator 200 to be discussed hereinafter, or from some other component of the controller 102. The commanded first volume flow rate dv_{in}/dt signal 151 corresponds to a desired combined volumetric in-flow rate of materials, for example dry cement and carrier fluid, from the first actuator 18 and the second actuator 20 into the first tank 12. The commanded first mass flow rate dm_{in}/dt signal 153 represents a desired combined mass in-flow rate of these materials from the first actuator 18 and the second actuator 20 into the first tank 12.

In an embodiment, the flow modulator 150 generates an actuator₁ signal to control the first actuator 18, and this actuator₁ signal may be expressed mathematically as proportional to a function f_1 as follows:

$$\text{actuator}_1 \text{ signal} \propto f_1 = [dm_{in}/dt - (dv_{in}/dt)\rho_{m2}]/(\rho_{m1} - \rho_{m2}) \quad (1)$$

Similarly, the flow modulator 150 generates an actuator₂ signal to control the second actuator 20, and the actuator₂ signal may be expressed mathematically as proportional to a function f_2 as follows:

$$\text{actuator}_2 \text{ signal} \propto f_2 = [(dv_{in}/dt)\rho_{m1} - dm_{in}/dt]/(\rho_{m1} - \rho_{m2}) \quad (2)$$

where dm_{in}/dt is the combined mass flow rate entering the tank, dv_{in}/dt is the combined volume flow rate entering the tank, ρ_{m1} is the density of the first material, for example dry cement, flowing into the first tank 12 from the first actuator 18, and where ρ_{m2} is the density of the second material, for example water, flowing into the first tank 12 from the second actuator 20. One skilled in the art will readily be able to determine a suitable first constant of proportionality for equation (1) to drive the first actuator 18 and a suitable second constant of proportionality for equation (2) to drive the second actuator 20 in a particular embodiment. In an embodiment, the actuator₁ and actuator₂ signals may be conditioned by one or more components (not shown) between the flow modulator 150 and the actuators 18, 20 to conform the actuator₁ and actuator₂ signals to a non-linear response of one or more of the actuators 18, 20.

Turning now to Figure 4, a flow regulator 200 for use with one or more embodiments of the first control system 100 is depicted. The flow regulator 200 comprises a first flow regulator 202 and a second flow regulator 204. In some embodiments, the first flow regulator 202 and the second flow regulator 204 may be combined in an integrated unit 205 or combined in a single functional block, such as, for example, within a computer programmed to perform flow regulation. The first flow regulator 202 receives from another component of the controller 102 a commanded volumetric flow rate signal 201 for dv_{12}/dt of the first mixture 13 over the weir 14 into the second tank 16, and a sensed height h_1 of the first mixture 13 in the first tank 12 from the h_1 sensor 110. The first flow regulator 202 may receive the commanded volumetric flow rate dv_{12}/dt signal 201, for example, from a flow₁ state feedback controller with command feed forward 250, to be discussed hereinafter, or from some other component of the controller 102. The first flow regulator 202 generates the commanded first volumetric flow rate dv_{in}/dt signal 151 that is received as a commanded value by the flow modulator 150 or by the first and second flow modulators 152, 154 as described above with reference to Figure 3.

The second flow regulator 204 receives from another component of the controller 102 a commanded mass flow rate signal 203 for dm_{12}/dt of the first mixture 13 over the weir 14 into the second tank 16, a sensed height h_1 of the first mixture 13 in the first tank 12 from the h_1 sensor 110, and a sensed density ρ_{12} of the first mixture 13 from sensor 114. The second flow regulator 202 may receive the commanded mass flow rate dm_{12}/dt signal 203, for example, from a flow₂ state feedback controller with command feed forward 252, to be discussed hereinafter, or from some other component of the controller 102. The second flow regulator 204 generates the commanded first mass flow rate dm_{in}/dt signal 153 that is received as a commanded value by the flow modulator 150 or by the first and second flow modulators 152, 154 described above with reference to Figure 3.

In an embodiment, the function of the first flow regulator 202 may be expressed mathematically as:

$$\text{commanded } dv_{in}/dt = F(h_1)(1 - K_v) + K_v(\text{commanded } dv_{12}/dt) \quad (3)$$

and the function of the second flow regulator 204 may be expressed mathematically as:

$$\text{commanded } dm_{in}/dt = F(h_1)\rho_{12}(1 - K_m) + K_m(\text{commanded } dm_{12}/dt) \quad (4)$$

where $F(h_1)$ is a non-linear function of the height h_1 of the first mixture 13 in the first tank 12 and provides an estimate of a volumetric flow rate dv_{12}/dt of the first mixture 13 over the weir 14 into the second tank 16; where commanded dv_{12}/dt is the commanded volumetric flow rate dv_{12}/dt signal 201; where commanded dm_{12}/dt is the commanded mass flow rate dm_{12}/dt signal 203; where ρ_{12} is an indication of density of the first mixture 13 in the first tank 12 based on the input from the ρ_{12} sensor 114; and where K_v and K_m are constants of proportionality that are greater than zero. The values for K_v and K_m may be chosen through a closed form solution and/or iteratively so as to minimize overall response time while maintaining stability and desired flow rate and density trajectories during transition phases. An exemplary non-linear function $F(h_1)$ for volumetric flow rate over a rectangular weir is given in *Engineering Fluid Mechanics*, 5th Edition, by Roberson and Crowe, published by Houghton Mifflin, 1993, and may be represented as:

$$dv_{12}/dt = F(h_1) = KL(h_1 - h_w)^{(3/2)} \quad (5)$$

where L is the length of the weir 14 dividing the tanks 12, 16, K is a flow coefficient that may be empirically determined over a set of operating conditions for a specific weir geometry, and h_w is a constant representing the height of the weir.

The volumetric outflow of the first mixture 13 dv_{12}/dt and the mass outflow of the first mixture 13 dm_{12}/dt from the first tank 12 to the second tank 16 may be modeled as negative state feedbacks in the physical plant 10. In equation (3), the effect of the $1xF(h_1)$ term is to cancel or decouple the negative state feedback associated with dv_{12}/dt , and in equation (4), the effect of the $1xp_{12}F(h_1)$ term is to decouple the negative state feedback associated with dm_{12}/dt . The control system 102 may be more robust as a result of the state feedback decoupling in the first and second flow regulators 202, 204 because the control system 102 only has to correct for errors between desired and actual mass rate and desired and actual volumetric flow rate without having to also compensate for the first mixture 13 leaving the first tank 12.

Turning now to Figure 5A, a flow₁ state feedback controller with command feed forward 250 and a flow₂ state feedback controller with command feed forward 252 for use with one or more embodiments of the first control system 100 are depicted. The flow₁ state feedback controller with command feed forward 250 receives the h_2 input parameter value 104 and the dv_9/dt input parameter value 106 from an operator interfacing with the first control system 100, and also receives an indication of the height h_2 of the second mixture 15 in the second tank 16 from the h_2 sensor 112. Based on these inputs, the flow₁ state feedback controller with command feed forward 250 produces the commanded volumetric flow rate dv_{12}/dt signal 201 that is received as a commanded value by the first flow regulator 202 described above with reference to Figure 4. The flow₁ state feedback controller with command feed forward 250 may also be referred to as a height controller with command feed forward.

The flow₂ state feedback controller with command feed forward 252 receives the dv_9/dt input parameter value 106 and the ρ_s input parameter value 108, from an operator interfacing with the first control system 100, and also receives an indication of the density ρ_s of the second mixture 15 in the second tank 16 from the ρ_s sensor 116. Based on these inputs, the flow₂ state feedback controller with command feed forward 252 produces the commanded mass flow rate dm_{12}/dt signal 203 that is received as a

commanded value by the second flow regulator 204 described above with reference to Figure 4. The flow₂ state feedback controller with command feed forward 252 may also be referred to as a density controller with command feed forward. The flow state feedback controllers with command feed forward 250, 252 receive different inputs but serve the same purpose of providing a commanded value signal to a flow regulator 202, 204. In some embodiments, the flow₁ state feedback controller with command feed forward 250 and the flow₂ state feedback controller with command feed forward 252 may be combined in an integrated unit 251 or combined in a single functional block, such as, for example, within a computer programmed to perform the indicated functions.

Turning now to Figure 5B, a block diagram shows processing details of one embodiment of the flow₁ state feedback controller with command feed forward 250. A first summation component 253, represented by the Σ symbol within a circle as is conventional in mathematical notation, determines a first error term $e_1(t)$ by negatively summing the indication of the height h_2 of the second mixture 15 in the second tank 16 from the h_2 sensor 112 with the h_2 input parameter value 104. The inputs to any summation component, for example the first summation component 253, are positively or negatively summed together to determine the output of the summation component. Specifically, the inputs associated with a "+" (plus) sign are positively summed, while the inputs associated with a "-" (minus) sign are negatively summed. The output of the first summation component 253, namely the first error term $e_1(t)$, is then processed by a first proportional-integral (PI) controller 255 having a gain K_{p1} for a first proportional component 254 and an integral gain K_{i1} for a first integral component 256 associated with a first integration factor 258, as represented by $1/S$ inside the box, as is conventional in control system art to suggest integration. The proportional and integral operations on the first error term $e_1(t)$ are positively summed by a second summation component 259. A twenty-fifth summation component 257 sums the output of the second summation component 259 with the dv_2/dt input parameter value 106 of the second mixture 15 out of the second tank 16. The output of the twenty-fifth summation component 257 is the commanded volumetric flow rate dv_{12}/dt signal 201 that is received as a commanded value by the first flow regulator 202 described above with reference to Figure 4. The temporal response of the flow₁ state feedback

controller with command feed forward 250, represented as a function $u_1(t)$, may be expressed mathematically as:

$$\text{commanded } dv_{12}/dt = u_1(t) = dv_s/dt + K_{p1}e_1(t) + K_{i1} \int e_1(t)dt \quad (6)$$

The outflow of the second mixture 15 from the second tank 16 may be modeled as negative state feedback in the physical plant 10. In equation (6), the effect of the dv_s/dt term, which is the command feed forward term, is to decouple the negative state feedback associated with the outflow of the second mixture 15 from the second tank 16. While this may not be strict state feedback decoupling, the same benefits of robustness may be at least partially obtained using this technique.

Turning now to Figure 5C, a block diagram shows processing details of one embodiment of the flow₂ state feedback controller with command feed forward 252. A third summation component 261 determines a second error term $e_2(t)$ by negatively summing the indication of the density ρ_s of the second mixture 15 in the second tank 16 from the ρ_s sensor 116 with the ρ_s input parameter value 108. The second error term $e_2(t)$ is then processed by a second PI controller 263 having a gain K_{p2} for a second proportional component 260 and an integral gain K_{i2} for a second integral component 262 associated with a second integration factor 264. The proportional and integral operations on the second error term $e_2(t)$ are positively summed by a fourth summation component 265. A twenty-sixth summation component 287 sums the output of the fourth summation component 265 with the output of a first multiplier component 266 and the output of a second multiplier component 267. The first multiplier component 266 output equals the ρ_s input parameter value 108 multiplied by $(dh_2/dt)A_2$, where A_2 is the cross-sectional area of the second tank 16 and dh_2/dt is the height rate of change of the second mixture 15 in the second tank 16. In an embodiment, the first multiplier component 266 may be omitted, as for example when the parameter dh_2/dt is not readily available. The second multiplier component 267 outputs the product of the ρ_s input parameter value 108 multiplied by the input parameter value 106 of dv_s/dt of the second mixture 15 out of the second tank 16. The output of the twenty-sixth summation component 287 is the commanded mass flow rate dm_{12}/dt signal 203 that is received as a commanded value by the second flow regulator 204 described above with reference to Figure 4. Thus, the temporal

response of the flow₂ state feedback controller with command feed forward 252, represented as a function $u_2(t)$, may be expressed mathematically as:

$$\text{commanded } dm_{12}/dt = u_2(t) = \text{input } \rho_s \{ (dh_2/dt)A_2 + dv_s/dt \} + K_{p2}e_2(t) + K_{I2} \int e_2(t)dt \quad (7)$$

The outflow of mass from the second tank 16 may be modeled as negative state feedback in the physical plant 10. In equation (7), the effect of the $\rho_s(dv_s/dt)$ term, the command feed forward term, is to decouple the negative state feedback associated with the outflow of mass from the second tank 16. While this may not be strict state feedback decoupling, the same benefits of robustness may be at least partially obtained using this technique. An additional refinement of this relaxed state feedback decoupling technique may be obtained by decoupling the effect of a loss of mass associated with changes of height of the second mixture 15 in the second tank 16. In equation (7), the $\rho_s(dh_2/dt)A_2$ term also contributes to decoupling the negative state feedback associated with the outflow of mass from the second tank 16. The dh_2/dt factor may be determined from a series of indications of the height of the second mixture 15 in the second tank 16 or by other means such as an estimate of dh_2/dt produced by a height observer as discussed below.

One skilled in the art will recognize that the results of the analysis of the flow₁ state feedback controller with command feed forward 250 and the flow₂ state feedback controller with command feed forward 252 above may be applied to digital signals as well as analog signals. For example, analog parameters such as the indication of density ρ_s of the second mixture 15 in the second tank 16 from the ρ_s sensor 116 may be converted by an analog-to-digital converter (D/A converter) to a digital signal. Similarly, analog outputs may be produced by a digital-to-analog converter (A/D converter), optionally combined with an amplifier to provide sufficient power to drive an electromechanical device, converting a digital control signal to an analog control signal suitable for controlling the first actuator 18 and the second actuator 20.

Turning now to Figure 6, the major components of the first control system 100 are depicted coupled together and to the actuators 18, 20 of the physical plant 10 described above with reference to Figure 1. In particular, Figure 6 depicts an embodiment of the first control system 100 of Figure 2, showing the various components that may comprise the controller 102.

Referring to the right side of the drawing, the first and second flow modulators 152, 154, as described above with reference to Figure 3, are shown cross-coupled and connected to control the first and second actuators 18, 20. The first flow modulator 152 receives the commanded first volume flow rate dv_{in}/dt signal 151 from the first flow regulator 202 and the commanded first mass flow rate dm_{in}/dt signal 153 from the second flow regulator 204 to generate an actuator₁ control signal to control the first actuator 18. The second flow modulator 154 receives the commanded first volume flow rate dv_{in}/dt 151 signal from the first flow regulator 202 and the commanded first mass flow rate dm_{in}/dt 153 signal from the second flow regulator 204 to generate an actuator₂ control signal to control the second actuator 20. Thus, the first and second flow modulators 152, 154 may be said to control the actuators 18, 20 based on the dv_{in}/dt and dm_{in}/dt system parameters, which are not the parameters desired to be controlled. Instead, these system parameters dv_{in}/dt and dm_{in}/dt are associated closely with the operation of the first and second actuators 18, 20 by the flow modulators 152, 154. However, it is desired to control other system parameters, namely the input parameter values, which are derived from the states of the first and second actuators 18, 20 and the characteristics of the physical plant 10, for example the cross-sectional area of the first and second tanks 12, 16, and are time lagged with respect to the the states of the actuators 18, 20. The possible states of the actuators 18, 20 depend on the actuator type. For example, a valve opens or closes, whereas a screw feeder turns at different speeds. The various other components of the controller 102, which will be discussed herein, enable control of the desired system parameters by bridging between the states of the actuators 18, 20 and those parameters desired to be controlled.

The first flow regulator 202 receives the commanded volumetric flow rate dv_{12}/dt signal 201 from the flow₁ state feedback controller with command feed forward 250 and the h_1 indication from the h_1 sensor 110 to generate the commanded first volume flow rate dv_{in}/dt signal 151 that feeds into the flow modulators 152, 154. As discussed above with reference to Figure 4, the first flow regulator 202 uses the indication of h_1 to decouple the negative state feedback associated with the flow of the first mixture 13 out of the first tank 12. For example, the volumetric outflow can be

determined from $F(h_1)$, as discussed above, and then the volumetric outflow can be decoupled.

The second flow regulator 204 receives the commanded mass flow rate dm_{12}/dt signal 203 from the flow₂ state feedback controller with command feed forward 252, the indication from the h_1 sensor 110, and the p_{12} indication from the p_{12} sensor 114 to generate the commanded first mass flow rate dm_{in}/dt signal 153 that feeds into the flow modulators 152, 154. As discussed above with reference to Figure 4, the second flow regulator 204 uses the indications of h_1 and of p_{12} to decouple the negative state feedback associated with the flow of the first mixture 13 out of the first tank 12. For example, the mass outflow can be calculated from the product of the indication of p_{12} and the volumetric outflow dv_{12}/dt , where the volumetric outflow dv_{12}/dt is determined from $F(h_1)$, and the mass outflow then can be decoupled. The first and second flow regulators 202, 204 may be said to provide one level of removal from the system parameters dv_{in}/dt and dm_{in}/dt directly associated with the states of the first and second actuators 18, 20.

The flow₁ state feedback controller with command feed forward 250 receives the h_2 input parameter value 104 and the dv_s/dt input parameter value 106 from an operator interfacing with the first control system 100, and also receives the indication of h_2 from the h_2 sensor 112 to generate the commanded volumetric flow rate dv_{12}/dt signal 201 that feeds into the first flow regulator 202. As discussed above, the flow₁ state feedback controller with command feed forward 250 may be referred to as a height controller, because it controls the height h_2 of the second mixture 15 in the second tank 16. The command feed forward term, namely the dv_s/dt input parameter value 106, may be considered to decouple the negative state feedback of volumetric flow out of the second tank 16 as discussed above with reference to Figure 5B.

The flow₂ state feedback controller with command feed forward 252 receives the dv_s/dt input parameter value 106 and the p_s input parameter value 108 from an operator interfacing with the first control system 100, and also receives the indication of p_s from the p_s sensor 116 to generate the commanded mass flow rate dm_{12}/dt signal 203 that feeds into the second flow regulator 204. As discussed above, the flow₂ state feedback controller with command feed forward 252 may be referred to as a density controller, because it controls the density p_s of the second mixture 15 in the second

tank 16. The command feed forward term, formed by the product of the ρ_s input parameter value 108 multiplied by the dv_s/dt input parameter value 106, may be considered to decouple the negative state feedback of mass flow out of the second tank 16 as discussed above with reference to Figure 5C.

The $flow_1$ and $flow_2$ state feedback controller with command feed forward 250, 252 may be said to provide yet another level of removal from the system parameters dv_{in}/dt and dm_{in}/dt directly associated with the states of the first and second actuators 18, 20, and provide the desired responsiveness to the parameters desired to be controlled.

It will be readily appreciated by one skilled in the art that portions of the control components described above may be combined, for example within a computer program implementing the functional blocks of the control components.

In operation, as set out in the logic flow diagram of Figure 7, the first control system 100 disclosed herein may, for example, be used to control a physical plant 10 comprising a cement slurry mixing system that provides cement slurry for cementing a tubular casing into a well bore. During such an operation, the operator may want the first control system 100 to provide a cement slurry having a desired density ρ_s , while pumping the cement slurry out of the second tank 16 at a desired volumetric flow rate dv_s/dt , and while maintaining the height of the cement slurry in the second tank 16 at a desired height h_2 .

The process begins at block 400 in which the well bore servicing equipment, including the physical plant 10 and the first control system 100, is brought to the well bore site and assembled. The discharge line 32 of Figure 1 is coupled to the well bore, for example, using connected lengths of pipe, one end of which connects to a manifold or header at the well bore. Vessels containing blended dry cement and water in sufficient quantities are positioned to continuously supply the first feed line 28 and the second feed line 30 of Figure 1.

Once the equipment has been set up at the well site, the process proceeds to block 402 where an operator provides input parameter values to the controller 102, for example through a console or lap top computer coupled to the controller 102, for example via a serial cable or a wireless link. The input parameter values may include the h_2 input 104, the dv_s/dt input 106, and the ρ_s input 108. In operation, the controller

102 will act to control the first and second actuators 18, 20, for example valves, such that the corresponding actual quantities of p_s , dv_s/dt , and h_2 approach or equal the input parameter values.

The process proceeds to block 404 where the operator engages the controller 102. The process continues hereinafter along two independent but at least partially coupled paths. Proceeding to block 406, the controller 102 actively controls the first and second actuators 18, 20 in accordance with the input parameter values and the sensed conditions of the physical plant 10. When the controller 102 is first engaged, it is likely that the first and second tanks 12, 16 will be empty. In this case, the controller 102 may open one of the first or second actuators 18, 20 fully open and then open the other of the first or the second actuators 18, 20 so as to achieve the desired cement slurry density as indicated by the p_s input parameter value 108. The controller 102 continually determines and updates the actuator control signals that are output to the first and second actuators 18, 20, and the controller 102 may be said to be operating within a control loop represented by blocks 406 and 408. The controller 102 remains in this control loop 406, 408 while compensating for changes of indications returned from the physical plant 10, for example the sensed density p_s of the cement slurry in the second tank 16 according to sensor 116, and for changes of input values, for example the h_2 input parameter value 104.

The process also concurrently proceeds along a second branch to block 410 where the physical plant 10 begins to pump cement slurry via the outflow pump 22, through the discharge line 32, through the coupled pipes, and downhole into the well bore. As the flow rate dv_s/dt of the cement slurry exiting the second tank 16 via the outflow pump 22 changes, for example due to fluctuations in electrical power driving the outflow pump 22 or due to fluctuations in well bore back pressure, the controller 102 adjusts and maintains the actual physical parameters of the physical plant 10 to approach or equal the input parameter values.

The process proceeds to block 412 where the operator may modify an input parameter value, for example the p_s input 108. This change causes the controller 102 to change the control signals that are output to the first and second actuators 18, 20 in the control loop 406, 408, for example by further opening the first actuator 18 and further closing the second actuator 20. The coupling between this action of modifying

an input parameter value in block 412 and the control loop in blocks 406, 408 is indicated by a dotted line in Figure 7.

The process proceeds to block 414 where the operator stops the controller 102. This action in block 414 will affect the control loop in blocks 406, 408 as indicated by a dashed line in Figure 7. Specifically, stopping the controller 102 in block 414 causes the control loop in blocks 406, 408 to be exited. The process proceeds to block 416 where the physical plant 10 may be disconnected from the supply lines 28, 30 for water and dry cement, respectively, and the discharge line 32 may be disconnected from the pipes coupling the physical plant 10 to the well bore. The other equipment may be disassembled, the well bore may be closed in for a period to allow the cement to set, and the equipment of the physical plant 10 may be flushed and/or cleaned. The process exits at block 418.

In an embodiment, the indication of the height h_1 of the first mixture 13 in the first tank 12, and the indication of the height h_2 of the second mixture 15 in the second tank 16 are provided by two height observer components, which estimate rather than directly sense h_1 and h_2 . In another embodiment, a single height observer may be employed to provide an indication of the height h_2 of the second mixture 15 in the second tank 16. In yet another embodiment, a single height observer may be employed to provide an indication of the height h_1 of the first mixture 13 in the first tank 12, for example in a physical plant 10 having only one tank.

Under field conditions, the height indications h_1 , h_2 provided by the h_1 sensor 110 and the h_2 sensor 112 may be subject to various errors, for example height oscillations due to movement of the physical plant 10 onboard a floating platform or ship. Additionally, the stirring action of the first stirrer 24 and second stirrer 26 may significantly agitate the level surface of the first mixture 13 in the first tank 12 and of the second mixture 15 in the second tank 16, introducing variations in the height indications h_1 and h_2 . The introduction of the first and second materials into the first tank 12, for example dry cement and/or water, may introduce further variations in the height indication h_1 provided by the h_1 sensor 110. All of these surface height variations may be analyzed as noise in the height signals. It may be desirable to employ estimated height indications of h_1 and h_2 rather than propagate the noise or

oscillation that may be present in the indications of direct sensors, for example the h_1 sensor 110 and the h_2 sensor 112, into the controller 102.

Generally, a height observer is implemented as a dynamic control system to obtain an estimated height of the mixture in the tank in real time. First, this estimate of the mixture height is compared to the measured mixture height to obtain a height error. Then this mixture height error is used to drive the estimated mixture height to an actual mixture height through the use of a proportional-integral type controller, also referred to as a PI controller. By setting the gains of the PI controller, the noise and oscillations of the mixture in the tank can be substantially removed from the mixture height estimate while tracking the actual value of the mixture height. The height observer according to the present disclosure reduces the negative effects of noise and poor sensor performance due to environmental effects such as cement dust in the air or tank oscillations from the height readings. This height observer reflects the state of the actual mixture height with substantially no time lag.

Turning now to Figure 8A, a block diagram depicts a general height observer 270. The height observer 270 includes a height PI controller component 272 and a height tank model component 274. An estimated height negative feedback term 273 is negatively summed by a fifth summation component 269 with a sensed height input 271 to determine a third error term $e_3(t)$. As shown in Figure 8A, the estimated height negative feedback term 273 is the same signal as the final output produced by the general height observer 270, an estimated height 277, as described herein. While the value of the estimated height negative feedback term 273 and the estimated height 277 are the same, different labels are used herein to distinguish the different functions to which the signals are applied. The estimated height negative feedback term 273 is fed back into the height observer 270 as an input, thereby creating an estimating control loop, which yields a more accurate estimated height 277 each time through. The third error term $e_3(t)$ is processed by the height PI controller component 272 having a gain K_{p3} for a third proportional component 275 and an integral gain K_{i3} for a third integral component 276 associated with a third integration factor 278. The proportional and integral operations on the third error term $e_3(t)$ are then positively summed by a sixth summation component 280. The temporal response of the height

PI controller component 272 to the third error term $e_3(t)$ input, represented by the function $u_3(t)$, may be expressed mathematically as:

$$u_3(t) = K_{p3}e_3(t) + K_{I3} \int e_3(t) dt \quad (8)$$

The output of the height PI controller component 272 may be employed as an estimate of system errors, for example the difference between the desired and actual volumetric flow rates as well as other parameter estimations, for example the cross sectional area A_1 of the first tank 12. These errors may be collected and referred to as a disturbance, where the disturbance accounts for the discrepancies between what is demanded from the first control system 100 and what the first control system 100 actually produces, unmeasured quantities such as air flows into or out of the subject tank, and inaccuracies of estimates of system parameters. When the physical plant 10 mixes dry cement, there may be differences between the desired cement rate and the actual cement rate, because the cement delivery may be inconsistent. Differences between the desired cement rate and the actual cement rate may be accommodated by the disturbance. The output of the height PI controller component 272 may be referred to as a first disturbance estimate 281. The first disturbance estimate 281 may be fed back into the controller 102 to provide disturbance decoupling. Disturbance decoupling is described in more detail hereinafter.

The output of the height PI controller component 272 (*i.e.*, the output from the sixth summation component 280) is positively summed by a seventh summation component 282 with one or more height feed forward inputs 283, for example volumetric flow rates such as the difference between the commanded volumetric flow rate dv_{in}/dt into the first tank 12 and the volumetric flow rate dv_{12}/dt of cement slurry out of the first tank 12 over the weir 14 into the second tank 16. The performance of the height observer 270 is expected to be improved by using height feed forward inputs 283 as compared to the performance of more traditional controllers, which only employ feedback terms with no feed forward inputs. Because the height of a mixture in a tank, for example the height h_1 of the first mixture 13 in the first tank 12, will increase or decrease due to a net positive or negative volumetric flow rate into the tank, the estimate of the height of the mixture in the tank depends upon the net positive or negative volumetric flow rate into the tank: the height feed forward inputs

283. The height feed forward inputs 283 may be summed either negatively or positively at the seventh summation component 282. The output of the seventh summation component 282 conforms to a volumetric flow rate that may be represented generally as dv/dt .

The height tank model component 274 multiplies the volumetric flow rate output of the seventh summation component 282 by a fourth integral component 284 associated with a fourth integration factor 286. The fourth integral component 284 corresponds to the inverse of the cross-sectional area of the tank, represented by "1/A" in the block for the fourth integral component 284. Multiplying a volumetric flow rate term (dv/dt) by the inverse of an area term, for example the inverse of a cross-sectional tank area expressed as $1/A$, results in a velocity term (dx/dt), or more particularly in the case of a height controller, an estimated height rate of change dh/dt 285. The intermediate result of the estimated height rate of change dh/dt 285 may be used by other components in the controller 102, for example by the flow₂ state feedback controller with command feed forward 252.

Integrating the velocity term via the fourth integration factor 286 results in a displacement x , or in the present case a height h . Thus, the output of the height tank model component 274 is an estimated height 277 of the mixture in the tank. One skilled in the art will recognize that the results of the analysis of the height observer 270 above may be applied to digital signals as well as analog signals. For example, analog parameters such as the sensed height input 271 may be converted by an analog-to-digital converter (A/D converter) to a digital signal. Similarly, analog outputs may be produced by a digital-to-analog converter (D/A converter), optionally combined with an amplifier to provide sufficient power to drive an electromechanical device, converting a digital control signal to an analog control signal suitable for controlling the first actuator 18 and the second actuator 20. Height observers, such as the height observer 270, are further disclosed in related U.S. Patent Application Serial No. 11/029,072, entitled "Methods and Systems for Estimating a Nominal Height or Quantity of a Fluid in a Mixing Tank While Reducing Noise," filed January 4, 2005, which is incorporated herein by reference for all purposes.

Turning now to Figure 8B, a block diagram shows a portion of one embodiment of the first control system 100 depicted in Figure 2 and Figure 6, incorporating a first

height observer 270-a and a second height observer 270-b rather than directly using the h_1 sensor 110 and the h_2 sensor 112. In the embodiment depicted in Figure 8B, the h_1 sensor 110 provides an indication of the height h_1 of the first mixture 13 in the first tank 12 to the first height observer 270-a, which is negatively summed by a ninth summation component 269-a with a first estimated height negative feedback term 273-a of the first mixture 13 in the first tank 12 to obtain an error term $e_{3-a}(t)$ that is fed into a first height PI controller component 272-a. The output of the first height PI controller component 272-a is positively summed by a tenth summation component 282-a with a height feed forward input 283-a from an eleventh summation component 279, and the output of the tenth summation component 282-a is processed by a first height tank model component 274-a to produce an estimated height 277-a of the first mixture 13 in the first tank 12. The first proportional factor 284 (i.e., $1/A$) for the first height tank model component 274-a employs the cross-sectional area A_1 of the first tank 12. The estimated height 277-a of the first mixture 13 in the first tank 12, which may be referred to as an indication of the height of the first mixture in the first tank 12, is output to the first flow regulator 202 and also to the second height observer 270-b. Note that the estimated height 277-a and the first estimated height negative feedback term 273-a are the same signals but are identified by different labels to point out their different functions in the controller 102. The output from the first height PI controller component 272-a, as a first disturbance estimate signal 281-a, optionally may be negatively summed with the output of the first flow regulator 202 by the eleventh summation component 279 to provide disturbance decoupling to the determination of the commanded volumetric flow rate dv_{in}/dt of material into the first tank 12. In another embodiment, disturbance decoupling is provided by a second disturbance estimate signal 281-b that is negatively summed with the output of the first flow regulator 202 by the eleventh summation component 279. The second disturbance estimate signal 281-b is determined by the second height observer 270-b, as discussed in more detail below. The commanded volumetric flow rate dv_{in}/dt output by the eleventh summation component 279 is the commanded first volume flow rate dv_{in}/dt signal 151 to the flow modulator 150 or to the first and second flow modulators 152, 154 as described above with reference to Figure 3.

The h_2 sensor 112 provides an indication of the height h_2 of the second mixture 15 in the second tank 16 to the second height observer 270-b, which is negatively summed by a twelfth summation component 269-b with a second estimated height negative feedback term 273-b of the second mixture 15 in the second tank 16 to obtain an error term $e_{3-b}(t)$ that is fed into a second height PI controller component 272-b. The output of the second height PI controller component 272-b is positively summed by a thirteenth summation component 282-b with a second height feed forward input 283-b output by a first calculation component 268. The first calculation component 268 outputs the result of the function $F(h_1)$ based on the estimated height 277-a of the first mixture 13 in the first tank 12. In an embodiment, the value of $F(h_1)$ is calculated by the first flow regulator 202 and provided to the thirteenth summation component 282-b as the second height feed forward input 283-b. In this embodiment, the first calculation component 268 is not employed. The output of the thirteenth summation component 282-b is then processed by a second height tank model component 274-b to produce a second estimated height 277-b of the second mixture 15 in the second tank 16. The first proportional factor 284 (i.e., $1/A$) for the second height tank model component 274-b employs the cross-sectional area A_2 of the second tank 16. Note that the second estimated height 277-b and the second estimated height negative feedback term 273-b are the same signals but are identified by different labels to point out their different functions in the controller 102.

Within the second height observer 270-b, the output from the second height PI controller component 272-b provides the second disturbance estimate signal 281-b that is negatively summed by the eleventh summation component 279, as previously discussed. In an embodiment, the second disturbance estimate signal 281-b may provide a more accurate estimate of the volumetric rate disturbance in the system 100 as compared to the first disturbance estimate signal 281-a because the height of the second mixture 15 in the second tank 16 varies more than the height of the first mixture 13 in the first tank 12. Additionally, in the two tank system of Figure 1, the surface of the first mixture 13 in the first tank 12 may not be level but may slope downwardly from the point where the actuators 18, 20 dispense the materials to the weir 14. The second estimated height 277-b of the second mixture 15 in the second tank 16, which may be referred to as an indication of the height h_2 of the second

mixture 15 in the second tank 16, is fed into the flow₁ state feedback controller with command feed forward 250 as an input, and the control process is repeated. The estimated height rate of change dh/dt 277 of the second height observer 270-b, dh_2/dt , is used for state feedback decoupling by the flow₂ state feedback controller with command feed forward 252.

The advantages of the height observer 270, such as, for example, attenuation of noise and improvement of poor sensor performance, estimation of a disturbance term, and estimation of a parameter rate of change, may be obtained in a density observer having a structure related to the height observer 270. In an embodiment, the indication of the density ρ_{12} of the first mixture 13 in the first tank 12 and the indication of the density ρ_s of the second mixture 15 in the second tank 16 are provided by two density observer components which estimate rather than directly sense the densities ρ_{12} , ρ_s of the mixtures 13, 15, respectively. In another embodiment, the density observer may be used to estimate the density of other mixtures or materials in systems other than the physical plant 10 depicted in Figure 1.

Turning now to Figure 9A, a general density observer 290 operable to determine an estimated density of a mixture in a tank is depicted. The density observer 290 includes a density PI controller component 292 and a density tank model component 294. An eighth summation component 299 negatively sums an estimated density negative feedback term 295 with a sensed density input 291 to determine a fourth error term $e_4(t)$. The fourth error term $e_4(t)$ is processed by the density PI controller component 292, which has a gain K_{p4} for a fourth proportional component 296 and an integral gain K_{i4} for a fifth integral component 298 associated with a fifth integration factor 300. In an embodiment, the fourth error term $e_4(t)$ may be processed by a filter instead of by the density PI controller component 292, such as an analog filter or a digital filter, to introduce desirable time lags or to attenuate and/or amplify certain frequency components of the fourth error term $e_4(t)$.

The output of the density PI controller component 292 may be employed as an estimate of system errors, for example the difference between the desired and actual mass flow rates as well as other parameter estimations. These errors may be collected and referred to as a disturbance, where the disturbance accounts for the discrepancies between what is demanded from the first control system 100 and what

the first control system 100 actually produces, unmeasured quantities such as air flows into or out of the subject tank, and inaccuracies of estimates of system parameters. The output of the density PI controller component 292 may be referred to as a second disturbance estimate 301. The second disturbance estimate 301 may be fed back into the controller 102 to provide disturbance decoupling. Disturbance decoupling is described in more detail hereinafter.

The output of the density PI controller component 292, which conforms to a mass flow rate, is summed with one or more density feed forward inputs 293, for example a mass flow rate, such as the difference between the commanded mass flow rate into the first tank 12 and the mass flow rate of cement slurry out of the first tank 12 over the weir 14 into the second tank 16, by a third summation component 302. The output of a twelfth multiplication component 435 and the output of a thirteenth multiplication component 440 are also negatively summed by the third summation component 302. Generally, the density feed forward inputs 293 are associated with mass flow into the associated tank and the outputs of the twelfth and thirteenth multiplication components 435, 440 are associated with mass flow out of the associated tank. The output of the third summation component 302 is processed by the density tank model component 294. The density tank model component 294 multiplies the output of the third summation component 302 by a sixth integral component 304 associated with a sixth integration factor 306. The sixth integral component 304 is inversely proportional to the height of the mixture times the cross-sectional area of the tank, as represented by " $1/hA$ " in the block for the sixth integral component 304. Note that dividing a mass flow rate by hA is substantially equivalent to dividing through by the volume of the tank resulting in an estimated density rate of change 307 dp/dt . The height may be provided by a height sensor, for example the h_1 sensor 110, or the height observer 270. Alternatively, the height may be a fixed constant determined by experimentation to provide a preferred response rate of the general density observer 290. Integrating this quotient with respect to time results in a density. The output of the density tank model component 294 is thus the estimated density 297 of the mixture in the tank. The estimated density negative feedback term 295 is the same signal as the estimated density 297, but the estimated density feedback term 295 is fed back into the eighth summation component 299 at the input

to the density observer 290 to be processed through the PI controller 292 and tank model component 294 to yield a more accurate estimated density 297 each time through. The estimated density negative feedback term 295 is multiplied by a factor $A(dh/dt)$ by the twelfth multiplication component 435 to produce a $\rho A(dh/dt)$ term that is negatively fed back to the third summation component 302 as described above. The $\rho A(dh/dt)$ term corresponds to a mass rate of change based on changes in the height of the mixture in the tank. The dh/dt factor may be determined from a height sensor or a height observer. Alternatively, in an embodiment of the system 100 that provides no indication or estimate of height of the mixture, the twelfth multiplication 435 may be absent from the general density observer 290. The estimated density negative feedback term 295 is also multiplied by a factor dv/dt by the thirteenth multiplier component 440 to produce a $\rho(dv/dt)$ term that is negatively fed back to the third summation component 302 as described above. The $\rho(dv/dt)$ term corresponds to a mass rate of change due to flow of the mixture out of the tank. In an embodiment, the sensed density input 291 may be provided by a density sensor, for example the ρ_{12} sensor 114, installed in a recirculation line or an outflow line, such as the discharge line 32, associated with the tank. Thus, the density of the mixture as measured in the recirculation line may lag several seconds behind the density of the mixture in the tank. In this embodiment, a time delay of several seconds, such as three seconds, for example, may be introduced in the estimated density negative feedback term 295 before negatively summing with the sensed density 291 at the eighth summation component 299 to determine the fourth error term $e_4(t)$. This allows the sensed and estimated density to be in the same time reference frame before determining the fourth error term $e_4(t)$. The appropriate time delay may be readily determined from experimentation by one skilled in the art and depends upon the viscosity of the mixture and the speed of mixing.

Because the structures of the height observer 270 and the density observer 290 are related, one skilled in the art need only determine the gains appropriate to the height observer 270, determine the gains appropriate to the density observer 290, and configure the two observer structures 270, 290 accordingly. One skilled in the art will recognize that the results of the analysis of the density observer 290 above may be applied to digital signals as well as analog signals. For example, analog parameters

such as the indication of density ρ_s of the second mixture 15 in the second tank 16 from the ρ_s sensor 116 may be converted by an analog-to-digital converter (A/D converter) to a digital signal. Similarly, analog outputs may be produced by a digital-to-analog converter (D/A converter), optionally combined with an amplifier to provide sufficient power to drive an electromechanical device, converting a digital control signal to an analog control signal suitable for controlling the first actuator 18 and the second actuator 20.

Turning now to Figure 9B, a block diagram shows a portion of one embodiment of the first control system 100 incorporating a first density observer 290-a and a second density observer 290-b. The ρ_{12} sensor 114 provides an indication of the density ρ_{12} of the first mixture 13 in the first tank 12 to the first density observer 290-a, which is negatively summed by a fourteenth summation component 299-a with a first estimated density negative feedback term 295-a of the first mixture 13 in the first tank 12 to obtain an error term $e_{4-a}(t)$. As described above, in an embodiment where the ρ_{12} sensor 114 is located in a recirculation line, the estimated density negative feedback term 295-a may be delayed several seconds before it is input to the fourteenth summation component 299-a. The $e_{4-a}(t)$ error term is fed into a first density PI controller component 292-a. The output of the first density PI controller component 292-a is positively summed with a first density feed forward input 293-a from a seventeenth summation component 305 by a fifteenth summation component 302-a. The output of a fourteenth multiplication component 435-a and a fifteenth multiplication component 440-a, corresponding to a mass rate of change due to changes in height in the first tank 12 and the mass flow rate out of the first tank 12, respectively, are negatively summed by the fifteenth summation component 302-a. The sum output by the fifteenth summation component 302-a is processed by a first density tank model component 294-a. Note that the sixth integral component 304 for the first density tank model component 294-a employs the cross sectional area A_1 of the first tank 12 and the height h_1 of the first mixture 13 in the first tank 12. Note that the first estimated density negative feedback term 295-a and a first estimated density 297-a are the same signals but are identified by different labels to point out their different functions in the controller 102.

The output from the first density PI controller component 292-a, as the second disturbance estimate 301, is negatively summed by the seventeenth summation component 305 with the output from the second flow regulator 204 plus the output generated by a fifth multiplier component 321 to determine the commanded mass flow rate dm_{12}/dt signal 203. The second disturbance estimate 301 provides disturbance decoupling to the determination of the commanded mass flow rate dm_{12}/dt signal 203, while the fifth multiplier component 321 provides state feedback decoupling. The fifth multiplier component 321 outputs the product formed by multiplying the first estimated density 297-a of the first mixture 13 in the first tank 12 by the height rate of change dh_1/dt of the first mixture 13 in the first tank 12 and by the area A_1 of the first tank 12, obtaining the height rate of change dh_1/dt , for example, from the estimated height rate of change 285 output of the first height observer 270a. In another embodiment, the second disturbance estimate 301 may be provided by the second density observer 290-b.

To estimate the density ρ_s of the second mixture 15, the ρ_s sensor 116 provides an indication of the density ρ_s of the second mixture 15 in the second tank 16 to the second density observer 290-b. This indication of ρ_s is summed by an eighteenth summation component 299-b with a second estimated density negative feedback 295-b of the second mixture 15 in the second tank 16 to obtain an error term $e_{4-b}(t)$. As described above, in an embodiment where the ρ_s sensor 116 is located in a recirculation line or in an outflow line, such as the discharge line 32, the estimated density negative feedback term 295-b may be delayed several seconds before it is input to the eighteenth summation component 299-b. The error term $e_{4-b}(t)$ is fed into a second density PI controller component 292-b. A second density feed forward input 293-b, output by a sixth multiplier component 322, is positively summed by a nineteenth summation component 302-b with the output of the second density PI controller component 292-b. The sixth multiplier component 322 outputs the product formed by multiplying the first estimated density 297-a of the first mixture 13 in the first tank 12 by the volumetric flow rate dv_{12}/dt of the first mixture 13 into the second tank 16. The output of a sixteenth multiplication component 435-b and a seventeenth multiplication component 440-b, corresponding to a mass rate of change due to changes in height in the second tank 16 and mass flow rate out of the second tank 16,

respectively, are negatively summed by the nineteenth summation component 302-b. The output of the nineteenth summation component 302-b is processed by a second density tank model component 294-b. Note that the sixth integral component 304 for the second density tank model component 294-b employs the cross sectional area A_2 of the second tank 16 and the height h_2 of the second mixture 15 in the second tank 16. The second estimated density 297-b of the second mixture 15 in the second tank 16 is provided as an input to the flow₂ state feedback controller with command feed forward 252 for use in generating the commanded mass flow rate dm_{12}/dt , which is the commanded mass flow rate dm_{12}/dt signal 203 provided as a commanded parameter value to the second flow regulator 204 as described above with reference to Figure 4. Note that the second estimated density negative feedback term 295-b and the second estimated density 297-b are the same signals but are identified by different labels to point out their different functions in the controller 102.

One skilled in the art will readily appreciate that the components of the first control system 100 disclosed above are susceptible to many alternate embodiments. While several alternate embodiments are disclosed hereinafter, other embodiments are contemplated by the present disclosure.

Turning now to Figure 10A, a portion of a second control system 364 is depicted. The second control system 364 controls a physical plant 10 having a single tank, such as the first tank 12 of Figure 1, and first and second actuators 18, 20. The second control system 364 uses a height observer 270, which is substantially similar to that described above with respect to Figure 8A, to estimate the height of the first mixture 13 in the first tank 12 and to determine the first disturbance estimate 281.

Several components are combined to provide a first height controller 366 that is substantially similar to the flow₁ state feedback controller with command feed forward 250 described above with reference to Figure 5B. Specifically, an eighteenth summation component 346 determines a fifth error term $e_5(t)$ by negatively summing the estimated height 277 produced by the height observer 270 with an h_1 input 340, provided for example by an operator. The fifth error term $e_5(t)$ is processed by a proportional gain term N_p in a seventh multiplication component 344. A thirtieth summation component 426 sums the output of the seventh multiplication component 344 positively with the dv_3/dt input 106 that provides command feed forward. A

twenty-eighth summation component 422 negatively sums the first disturbance estimate 281 with the output of the thirtieth summation component 426. The twenty-eighth summation component 422 provides the same function as the flow₁ regulator 202 as described above with reference to Figure 8B. The output of the twenty-eighth summation component 422 is the commanded first volume flow rate dv_{in}/dt signal 151 that is fed to the first and second flow modulators 152, 154 and into the seventh summation component 282 of the height observer 270 as the volume feed forward inputs 283. A first dv_s/dt term 445 is fed negatively into the seventh summation component 282, and the first dv_s/dt term 445 may be obtained either from a flow sensor or may be based on the dv_s/dt input 106. The first flow modulator 152 controls the first actuator 18 based on the commanded first volume flow rate dv_{in}/dt signal 151 and the commanded first mass flow rate dm_{in}/dt signal 153, which is generated as described below with reference to Figure 10B.

Turning now to Figure 10B, another portion of the second control system 364 is depicted. Several components are combined to provide a first density controller 368 that is substantially similar to the flow₂ state feedback controller with command feed forward 252 described above with reference to Figure 5C, with the exception that the $(dh_2/dt)A_2$ term associated with the first multiplication component 266 is omitted, because there is no second tank 16 in this embodiment. A twentieth summation component 350 determines a sixth error term $e_6(t)$ by negatively summing the density estimate 297 produced by the modified density observer 356 with the input ρ_s 108. The sixth error term $e_6(t)$ is processed by a proportional gain term K_m in a ninth multiplication component 352. A tenth multiplication component 360 multiplies the density estimate 297 by the dv_s/dt input 106. The second disturbance estimate 362 is negatively summed with the outputs of the ninth and tenth multiplication components 352, 360 by a twenty-ninth summation component 424. The output of the tenth multiplication component 360 may be considered to provide command feed forward to a density controller 368 that comprises the twentieth summation component 350, the ninth multiplication component 352, the tenth multiplication component 360, and the twenty-ninth summation component 424. The output of the twenty-ninth summation component 424 is the commanded first mass flow rate dm_{in}/dt signal 153 that is fed into the first and second flow modulators 152, 154 and into the density observer 290

as the density feed forward inputs 293. The second flow modulator 154 controls the second actuator 20 based on the commanded first volume flow rate dv_{in}/dt signal 151 and the commanded first mass flow rate dm_{in}/dt signal 153, which is generated as described above with reference to Figure 10A.

One of ordinary skill in the art will readily appreciate that no integral processing is employed in the first height controller 366 described above with reference to Figure 10A or in the density controller 368 because the effect of command feed forward and disturbance decoupling is to reduce steady-state error to substantially zero, thereby transforming the second control system 364 from a first order non-linear system (as in the first control system 100), to a first order linear system that may be controlled by proportional controllers. In general, if the disturbances are decoupled or removed using the observers, for example by the height observer 270 and/or the density observer 290, and the command feed forward terms, then a proportional (P) controller may be used with substantially zero steady state error, since the second control system 364 will behave in accordance with a linear first order differential equation. If the disturbances are not decoupled, it may be preferable to use a PI controller, so that the integral term acts to ensure substantially zero steady state error.

Turning now to Figure 11, a third control system 376 is depicted. The third control system 376 controls a physical plant 10 having two actuators 18, 20; two tanks 12, 16; and only a single sensor, the p_{12} sensor 114, measuring the density p_{12} of the first mixture 13 in the first tank 12. In this embodiment, the commanded first volume flow rate dv_{in}/dt signal 151 to the first and second flow modulators 152, 154 is provided directly by the dv_s/dt input 106 without employing a flow regulator or other components as in the first control system 100. Also, this embodiment contains no height controller, so an operator may adjust the actual volumetric flow rate dv_s/dt out of the second tank 16 by controlling the outflow pump 22, and thereby maintain the desired height h_2 of the second mixture 15 in the second tank 16.

The density observer 290 determines the density estimate 297 of the density p_{12} of the first mixture 13 in the first tank 12 and the second disturbance estimate 362 based on the output of the p_{12} sensor 114 and density feed forward inputs 293. Because this embodiment provides no indication of height, the $A(dh/dt)$ term in Figure 9A that is associated with the twelfth multiplier component 435 is omitted. As described above

with reference to Figure 9A, in the present embodiment the height component of the sixteenth integral component 304 is a constant value chosen to provide a desirable system response time. A twenty-second summation component 380 negatively sums the density estimate 297 with a ρ_{12} input parameter value 370 to determine a seventh error term $e_7(t)$, which is multiplied by a proportional gain K_m by an eleventh multiplication component 382. The ρ_{12} input 370, for example, may be provided by an operator through an interface. The twenty-second summation component 380 and the eleventh multiplication component 382 comprise a second density controller 372 that controls the density ρ_{12} of the first mixture 13 in the first tank 12. In steady state conditions, the density of the second mixture 15 in the second tank 16 will follow the controlled density ρ_{12} of the first mixture 13 in the first tank 12. When the ρ_{12} input 370 is changed, the density ρ_s of the second mixture 15 in the second tank 16 will substantially equal the density ρ_{12} of the first mixture 13 in the first tank 12 after a time lag.

A twelfth multiplication component 384 multiplies the density estimate 297 by the approximate actual volumetric flow dv_{12}/dt . Because h_1 is not measured, and the function $F(h_1)$ may not be used, the dv_9/dt input 106 is used to approximate the actual volumetric flow dv_{12}/dt over the weir 14. The output of the twelfth multiplication component 384 provides state feedback decoupling to the control system 376 to compensate for mass leaving the first tank 12.

The second disturbance estimate 362 is negatively summed with the output of the eleventh and twelfth multiplication components 382, 384 by a twenty-first summation component 374 to determine the commanded first mass flow rate dm_{in}/dt signal 153. The commanded first mass flow rate dm_{in}/dt signal 153 is provided to the first and second flow modulators 152, 154 to control the first and second actuators 18, 20 as described above. The output of the twenty-first summation component 374 also provides the density feed forward inputs 293 to the density observer 290.

Turning now to Figure 12, a fourth control system 378 is depicted. The fourth control system 378 is substantially similar to the third control system 376, with the exception that the fourth control system 378 includes the height observer 270 and a second height controller 428. The height observer 270 determines the estimated height 277 of the second mixture 15 in the second tank 16 based on input from the h_2

sensor 112 and the height feed forward inputs 283. A second dv_s/dt factor 450 is negatively summed with the height feed forward inputs 283 and the output of the height PI controller 272 by the seventh summation component 282. The estimated height 277 is negatively summed with the h_2 input 104 by a twenty-third summation component 386 to generate an eighth error term $e_8(t)$. The eighth error term $e_8(t)$ is processed by a third PI controller 390 to produce a commanded height signal 430, which is summed with the dv_s/dt input 106 by a twenty-fourth summation component 388 to produce the dv_{in}/dt signal 151 provided to the flow modulators 152, 154. Based on the dv_{in}/dt signal 151 and the dm_{in}/dt signal 153, the first and second flow modulators 152, 154 control the states of the first and second actuators 18, 20 as described above.

While the physical plant 10 controlled by the several embodiments of the control systems 100, 364, 376, and 378 described above included either one or two tanks, in other embodiments the control systems may control mixing parameters of more than two tanks connected in series. In other embodiments, one or more sensors may be employed selected from the ρ_{12} sensor 114, the ρ_s sensor 116, the h_1 sensor 110, the h_2 sensor 112, and a flow rate sensor. Embodiments may use a mixture of sensors with no height observer 270 or density observer 290. Other embodiments may use one or more sensors with one or more height observers 270 and/or density observers 290. While the height observer 270 and the density observer 290 are discussed above, the observer concept may be extended to other sensors to reduce noise output from these and other sensors and to obtain the benefits associated with decoupling or removing disturbances and estimating intermediate rate terms. One skilled in the art will readily appreciate that coupling among control components may be altered to simplify processing, as for example combining two summation components in series by directing all the inputs to the two summation components to a single summation component or by replacing two components that calculate the same value by one component and routing the output of the one component to two destinations. Alternately, in an embodiment, a summation component summing more than two inputs may be expanded into a series of two or more summation components that collectively sum the several inputs.

The controller 102 used in the various control systems 100, 364, 376, and 378 described above may be implemented on any general-purpose computer with sufficient processing power, memory resources, and network throughput capability to handle the necessary workload placed upon it. Figure 13 illustrates a typical, general-purpose computer system 580 suitable for implementing one or more embodiments of the several control system embodiments disclosed herein. The computer system 580 includes a processor 582 (which may be referred to as a central processor unit or CPU) in communication with memory devices including secondary storage 584, read only memory (ROM) 586, random access memory (RAM) 588, input/output (I/O) 590 devices, and network connectivity devices 592. The processor may be implemented as one or more CPU chips. The commands or signals output to the first actuator 18 and the second actuator 20 may be converted from a digital to an analog signal by a digital to analog converter (DAC), not shown, or otherwise conditioned to make the actuator signal conformable to a control input to the first actuator 18 and a control input to the second actuator 20.

The secondary storage 584 typically comprises one or more disk drives or tape drives and is used for non-volatile storage of data and as an over-flow data storage device if RAM 588 is not large enough to hold all working data. Secondary storage 584 may be used to store programs that are loaded into RAM 588 when such programs are selected for execution. The ROM 586 is used to store instructions and perhaps data that are read during program execution. ROM 586 is a non-volatile memory device which typically has a small memory capacity relative to the larger memory capacity of secondary storage 584. The RAM 588 is used to store volatile data and perhaps to store instructions. Access to both ROM 586 and RAM 588 is typically faster than to secondary storage 584.

I/O devices 590 may include printers, video monitors, liquid crystal displays (LCDs), touch screen displays, keyboards, keypads, switches, dials, mice, track balls, voice recognizers, card readers, paper tape readers, or other well-known input devices. The network connectivity devices 592 may take the form of modems, modem banks, ethernet cards, universal serial bus (USB) interface cards, serial interfaces, token ring cards, fiber distributed data interface (FDDI) cards, wireless local area network (WLAN) cards, radio transceiver cards such as Global System for Mobile

Communications (GSM) radio transceiver cards, and other well-known network devices. These network connectivity devices 592 may enable the CPU 582 to communicate with an Internet or one or more intranets. With such a network connection, it is contemplated that the CPU 582 might receive information from the network, or might output information to the network in the course of performing the above-described method steps. Such information, which is often represented as a sequence of instructions to be executed using processor 582, may be received from and outputted to the network, for example, in the form of a computer data signal embodied in a carrier wave.

Such information, which may include data or instructions to be executed using processor 582 for example, may be received from and outputted to the network, for example, in the form of a computer data baseband signal or signal embodied in a carrier wave. The baseband signal or signal embodied in the carrier wave generated by the network connectivity devices 592 may propagate in or on the surface of electrical conductors, in coaxial cables, in waveguides, in optical media, for example optical fiber, or in the air or free space. The information contained in the baseband signal or signal embedded in the carrier wave may be ordered according to different sequences, as may be desirable for either processing or generating the information or transmitting or receiving the information. The baseband signal or signal embedded in the carrier wave, or other types of signals currently used or hereafter developed, referred to herein as the transmission medium, may be generated according to several methods well known to one skilled in the art.

The processor 582 executes instructions, codes, computer programs, scripts which it accesses from hard disk, floppy disk, optical disk (these various disk based systems may all be considered secondary storage 584), ROM 586, RAM 588, or the network connectivity devices 592.

While several embodiments have been provided in the present disclosure, it should be understood that the disclosed systems and methods may be embodied in many other specific forms without departing from the spirit or scope of the present disclosure. The present examples are to be considered as illustrative and not restrictive, and the intention is not to be limited to the details given herein, but may be modified within the scope of the appended claims along with their full scope of

equivalents. For example, the various elements or components may be combined or integrated in another system or certain features may be omitted, or not implemented.

Also, techniques, systems, subsystems and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present disclosure. Other items shown or discussed as directly coupled or communicating with each other may be coupled through some interface or device, such that the items may no longer be considered directly coupled to each other but may still be indirectly coupled and in communication, whether electrically, mechanically, or otherwise with one another. Other examples of changes, substitutions, and alterations are ascertainable by one skilled in the art and could be made without departing from the spirit and scope disclosed herein.

What is claimed is:

1. A control system for mixing at least two materials in a physical system having two or more tanks, comprising:
 - at least two actuators, each actuator being operable to introduce a material into a first tank to form a first mixture, the first mixture flowing into a second tank to form a second mixture; and
 - a controller operable, based on a commanded input, to control the at least two actuators to obtain a density of either the first mixture or the second mixture and a volume flow rate of the second mixture out of the second tank;
 - wherein the density is controlled independently from the volume flow rate.
2. The control system of Claim 1, wherein the actuators are selected from the group consisting of valves, screw feeders, augurs, and elevators.
3. The control system of Claim 1, wherein the materials are selected from the group consisting of water, carrier fluid, dry cement material, sand, and proppants.
4. The control system of Claim 1 wherein the commanded input comprises:
 - a commanded combined volume flow rate of the materials passing through the actuators into the first tank [commanded dv_{in}/dt]; and
 - a commanded combined mass flow rate of the materials passing through the actuators into the first tank [commanded dm_{in}/dt].
5. The control system of Claim 4, wherein a first actuator is controlled by a first signal based on a function f_1 where:

$$f_1 = [\text{commanded } dm_{in}/dt - (\text{commanded } dv_{in}/dt) \times \rho_{m2}] / (\rho_{m1} - \rho_{m2})$$
 - wherein: ρ_{m1} = density of a first material; and
 - ρ_{m2} = density of a second material.
6. The control system of Claim 4, wherein a second actuator is controlled by a second signal based on a function f_2 where:

$$f_2 = [(\text{commanded } dv_{in}/dt) \times \rho_{m1} - \text{commanded } dm_{in}/dt] / (\rho_{m1} - \rho_{m2})$$
 - wherein: ρ_{m1} = density of a first material; and
 - ρ_{m2} = density of a second material.
7. The control system of Claim 4, wherein the commanded dv_{in}/dt is based, at least in part, on a volumetric flow rate command feed forward input [dv_g/dt input] and the

commanded dm_{in}/dt is based, at least in part, on a first indication of density of the first mixture and a first commanded density of the first mixture or the second mixture.

8. The control system of Claim 7, wherein the commanded dv_{in}/dt is further based, at least in part, on an indication of height of the second mixture in the second tank and an operator input height of the second mixture.

9. The control system of Claim 7, wherein the commanded dv_{in}/dt is further based, at least in part, on the quantity:

$$F(h)(1-K_v) + K_v(\text{commanded } dv_{12}/dt)$$

wherein: K_v = a first constant of proportionality;

$F(h)$ = a non-linear function of a height of the first mixture in the first tank;

and

commanded dv_{12}/dt = a commanded volume flow rate of the first mixture flowing from the first tank into the second tank.

10. The control system of Claim 10, wherein the commanded dv_{12}/dt is based on:

a first error term determined by subtracting an indication of a height of the second mixture in the second tank from an operator input desired height of the second mixture in the second tank [h_2 input]; and

an operator input desired volume flow rate of the second mixture out of the second tank [dv_s/dt input].

11. The control system of Claim 10, wherein the first error term is processed by either a first proportional integral controller component or a first proportional controller component.

12. The control system of Claim 7, wherein the commanded dv_{in}/dt is further based, at least in part, on a volumetric disturbance estimate.

13. The control system of Claim 7, wherein the commanded dm_{in}/dt is further based, at least in part, on the quantity:

$$F(h)(\rho_{12})(1-K_m) + K_m(\text{commanded } dm_{12}/dt);$$

wherein: K_m = a second constant of proportionality;

$F(h)$ = a non-linear function of a height of the first mixture in the first tank;

commanded dm_{12}/dt = a commanded mass flow rate of the first mixture flowing from the first tank into the second tank; and

ρ_{12} = an indication of the density of the first mixture in the first tank.

14. The control system of Claim 13, wherein the commanded dm_{12}/dt is based on a second error term determined by subtracting the first indication of density from the first commanded density.
15. The control system of Claim 13, wherein the commanded dm_{12}/dt is based on a second error term determined by subtracting a second indication of density of the second mixture from the first commanded density of the second mixture.
16. The control system of Claim 15, wherein the second error term is processed by either a second proportional integral controller component or a second proportional controller component.
17. The control system of Claim 15, wherein the commanded dm_{12}/dt is further based on a parameter selected from the group consisting of:
 - an operator input desired volume flow rate of the second mixture out of the second tank [dv_o/dt input]; and
 - an indication of a height rate of change of the second mixture in the second tank.
18. The control system of Claim 7, wherein the commanded dm_{in}/dt is further based, at least in part, on a mass disturbance estimate.
19. The control system of Claim 7, wherein the commanded dv_{in}/dt is further based, at least in part, on an indication of height of the first mixture in the first tank and a commanded height of the first mixture in the first tank.
20. The control system of Claim 19, further comprising:
 - a first height sensor operable to produce a first sensed height output of the first mixture in the first tank; and
 - a first height observer operable to provide the indication of height of the first mixture in the first tank based on the first sensed height output, the commanded height, and a commanded volumetric flow rate.
21. The control system of Claim 20, wherein the first height observer is further operable to provide a first disturbance estimate.
22. The control system of Claim 20, further comprising:
 - a second height sensor operable to produce a second sensed height output of the second mixture in the second tank; and

- a second height observer operable to provide an indication of height of the second mixture in the second tank based on the second sensed height output and on the indication of height of the first mixture in the first tank.
23. The control system of Claim 22, wherein the second height observer is further operable to provide the first disturbance estimate.
24. The control system of Claim 7, further comprising:
- a first density sensor operable to produce a first sensed density output of the first mixture in the first tank; and
 - a first density observer operable to provide the indication of density of the first mixture in the first tank based on the first sensed density output, the first commanded density of the first mixture, and a mass flow rate.
25. The control system of Claim 24, wherein the first density observer comprises:
- a third proportional integral controller responsive to a third error term determined as the sensed density output minus the first indication of density of the first mixture in the first tank; and
 - a tank model having an integrating component and a gain component, the gain component inversely proportional to the area of the first tank and to the height of the first mixture in the first tank, the tank model responsive to the output of the third proportional integral controller.
26. The control system of Claim 25, wherein the first indication of density is delayed before determining the third error term.
27. The control system of Claim 24, wherein the first density observer is further operable to provide a second disturbance estimate.
28. The control system of Claim 24, further comprising:
- a second density sensor operable to produce a second sensed density output of the second mixture in the second tank; and
 - a second density observer operable to provide an indication of the density of the second mixture in the second tank based on the second sensed density output and the indication of density of the first mixture in the first tank.
29. The control system of Claim 28, wherein the second density observer is further operable to provide the second disturbance estimate.

30. A control system for mixing at least two materials in a tank, comprising:
 at least two actuators, each actuator being operable to introduce a material into the tank to form a mixture; and
 a controller operable, based on a commanded input, to control the at least two actuators to obtain a density of the mixture and a volume flow rate of the mixture out of the tank;
 wherein the density is controlled independently from the volume flow rate.
31. The control system of Claim 30, wherein the commanded input comprises:
 a commanded combined volume flow rate of the materials passing through the actuators into the tank [commanded dv_{in}/dt]; and
 a commanded combined mass flow rate of the materials passing through the actuators into the tank [commanded dm_{in}/dt].
32. The control system of Claim 31, wherein a first actuator is controlled by a first signal based on a function f_1 , where:

$$f_1 = [\text{commanded } dm_{in}/dt - (\text{commanded } dv_{in}/dt) \times \rho_{m2}] / (\rho_{m1} - \rho_{m2})$$
 wherein: ρ_{m1} = density of a first material; and
 ρ_{m2} = density of a second material.
- and wherein a second actuator is controlled by a second signal based on a function f_2 , where:

$$f_2 = [(\text{commanded } dv_{in}/dt) \times \rho_{m1} - \text{commanded } dm_{in}/dt] / (\rho_{m1} - \rho_{m2}).$$
33. The control system of Claim 31, wherein the commanded dv_{in}/dt is based, at least in part, on a volumetric flow rate command feed forward input [dv_s/dt input] and the commanded dm_{in}/dt is based, at least in part, on an indication of density of the mixture and a first commanded density of the mixture.
34. The control system of Claim 33, wherein the indication of density is provided by a density observer and the commanded dm_{in}/dt is further based, at least in part, on a mass flow rate disturbance estimate output by the density observer.
35. The control system of Claim 33, wherein the commanded dv_{in}/dt is further based, at least in part, on an indication of height of the mixture in the tank and a commanded height of the mixture in the tank.

36. The control system of Claim 35, wherein the indication of height is provided by a height observer and the commanded dv_{in}/dt is further based, at least in part, on a volumetric disturbance estimate output by the height observer.

37. A control system for mixing at least two materials, comprising:

a controller operable to control a physical system comprising a plurality of actuators, each actuator being operable to introduce a material into a first tank to form a first mixture;

wherein the controller operates the actuators to control a desired characteristic of the first mixture.

38. The control system of Claim 37, wherein the actuators are selected from the group consisting of valves, screw feeders, augurs, and elevators.

39. The control system of Claim 37, wherein the materials are selected from the group consisting of water, carrier fluid, dry cement material, sand, and proppants.

40. The control system of Claim 37, wherein the controller further operates the actuators to control a desired operating parameter of the physical system.

41. The control system of Claim 37, wherein the controller further operates the actuators based on a combination of sensors, the sensors selected from the group consisting of: a density sensor measuring the density of the first mixture, a flow rate sensor, and a mixture height sensor measuring the height of the first mixture.

42. The control system of Claim 41, wherein the mixture height sensor comprises a height observer.

43. The control system of Claim 41, wherein the density sensor comprises a density observer.

44. The control system of Claim 41, wherein the first mixture overflows the first tank into a second tank to form a second mixture, and wherein the controller further operates the actuators to control a desired characteristic of the second mixture.

45. The control system of Claim 44, wherein the controller employs feed forward based on an input selected from the group consisting of: a combined inflow volume of the materials introduced by the actuators, a volume of the first mixture flowing into the second tank, a volume of the second mixture flowing out of the second tank, a density of the first mixture, and a density of the second mixture.

46. The control system of Claim 44, wherein the sensors are further selected from the group consisting of: a density sensor measuring the density of the second mixture and a mixture height sensor measuring the height of the second mixture.
47. The control system of Claim 46, wherein the mixture height sensor measuring the height of the second mixture comprises a height observer.
48. The control system of Claim 46, wherein the density sensor measuring the density of the second mixture comprises a density observer.
49. A method for mixing at least two materials, comprising:
- introducing the at least two materials into a physical system;
 - combining the at least two materials to form a mixture thereof;
 - independently controlling a desired characteristic of the mixture of the at least two materials and a desired parameter of the physical system.
50. The method of Claim 49, wherein the controlling involves decoupling a volumetric flow rate disturbance parameter.
51. The method of Claim 49, wherein the controlling involves decoupling a mass flow rate disturbance parameter.
52. A method for mixing at least two materials, comprising:
- determining a commanded combined mass flow rate of the at least two materials into a first tank [commanded dm_{in}/dt];
 - determining a commanded combined volume flow rate of the at least two materials into the first tank [commanded dv_{in}/dt]; and
 - independently controlling, based on the commanded dm_{in}/dt and the commanded dv_{in}/dt , a density of a mixture of the at least two materials in the first tank [ρ_{12}] and a volume flow rate of the mixture out of the first tank [dv_{12}/dt].
53. The method of Claim 52, wherein the controlling includes regulating at least two actuators, each actuator being operable to dispense one of the at least two materials, respectively, into the first tank.
54. The method of Claim 52, further including:
- determining a commanded mass flow rate of the mixture from the first tank into a second tank [commanded dm_{12}/dt]; and wherein determining the commanded dm_{in}/dt is based on an indication of the density of the mixture in the first tank and the commanded dm_{12}/dt ; and

determining a commanded volume flow rate of the mixture from the first tank into the second tank [commanded dv_{12}/dt]; and wherein determining the commanded dv_{12}/dt is based on an indication of a height of the mixture in the first tank and the commanded dv_{12}/dt .

55. The method of Claim 54, further comprising:

determining a desired height of the mixture in the second tank [input h_2];

determining a desired volume flow rate of the mixture out of the second tank [input dv_2/dt], wherein determining the commanded dv_{12}/dt is based on the input h_2 , the input dv_2/dt , and an indication of a height of the mixture in the second tank; and

determining a desired density of the mixture in the second tank [input ρ_s], wherein determining the commanded dm_{12}/dt is based on the input ρ_s and an indication of a density of the mixture in the second tank.

56. The method of Claim 55, further comprising:

sensing the density of the mixture in the first tank [ρ_{12} sensor];

determining an estimated density of the mixture in the first tank [estimated ρ_{12}] based on the ρ_{12} sensor and on the commanded dm_{12}/dt ;

providing the estimated ρ_{12} as the indication of the density of the mixture in the first tank;

sensing the density of the mixture in the second tank [ρ_s sensor];

determining an estimated density of the mixture in the second tank [estimated ρ_s] based on ρ_s sensor and on the indication of the density of the mixture in the first tank; and

providing the estimated ρ_s as the indication of the density of the mixture in the second tank.

57. The method of Claim 55, further comprising:

sensing the height of the mixture in the first tank [h_1 sensor];

determining an estimated height of the mixture in the first tank [h_1 estimated] based on h_1 sensor and on the commanded dv_{12}/dt ;

providing the estimated h_1 as the indication of the height of the mixture in the first tank;

sensing the height of the mixture in the second tank [h_2 sensor];

determining an estimated height of the mixture in the second tank [h_2 estimated]
based on h_2 sensor and on the indication of the height of the mixture in the
first tank; and
providing the estimated h_2 as the indication of the height of the second mixture in
the second tank.

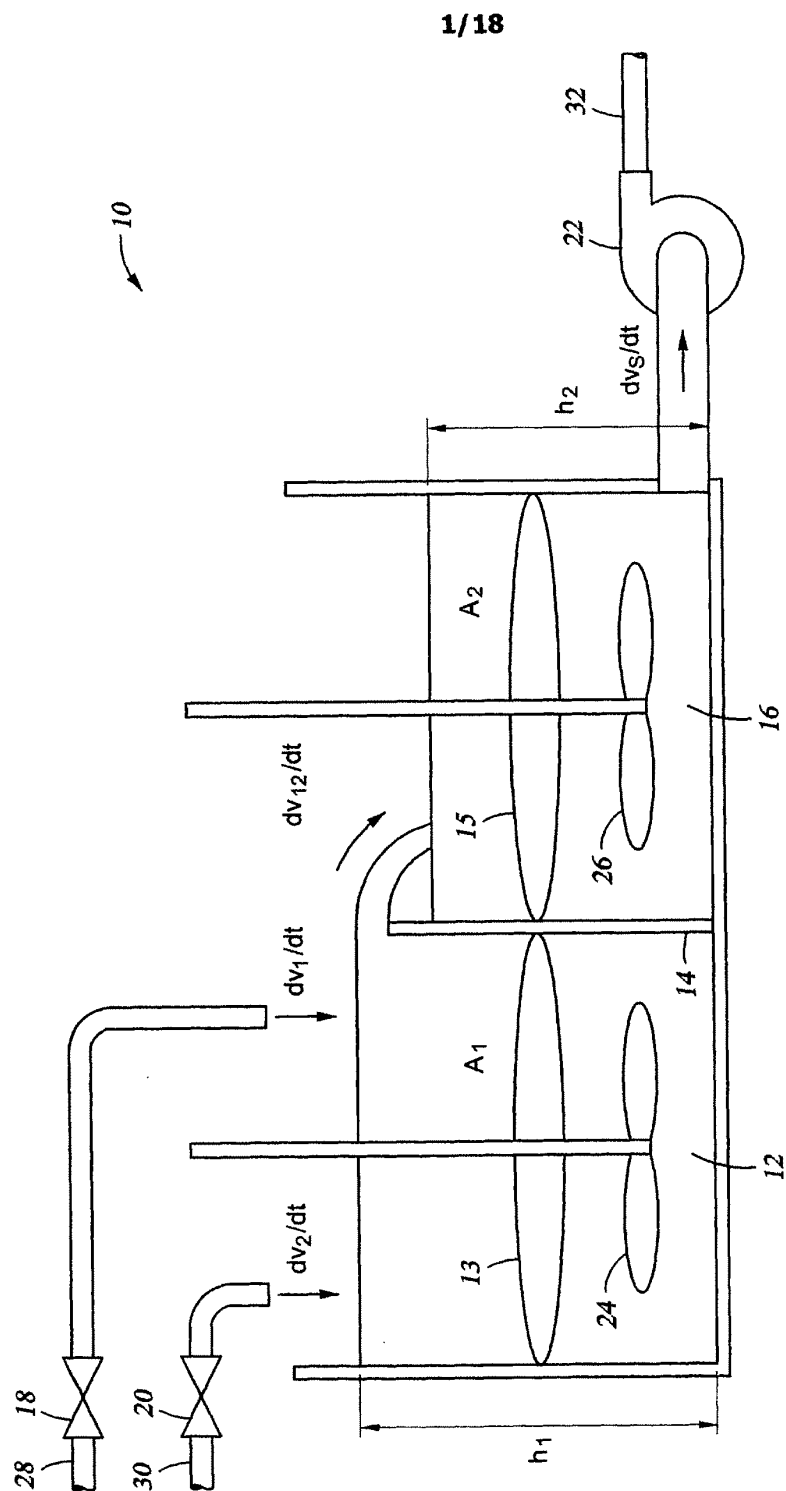
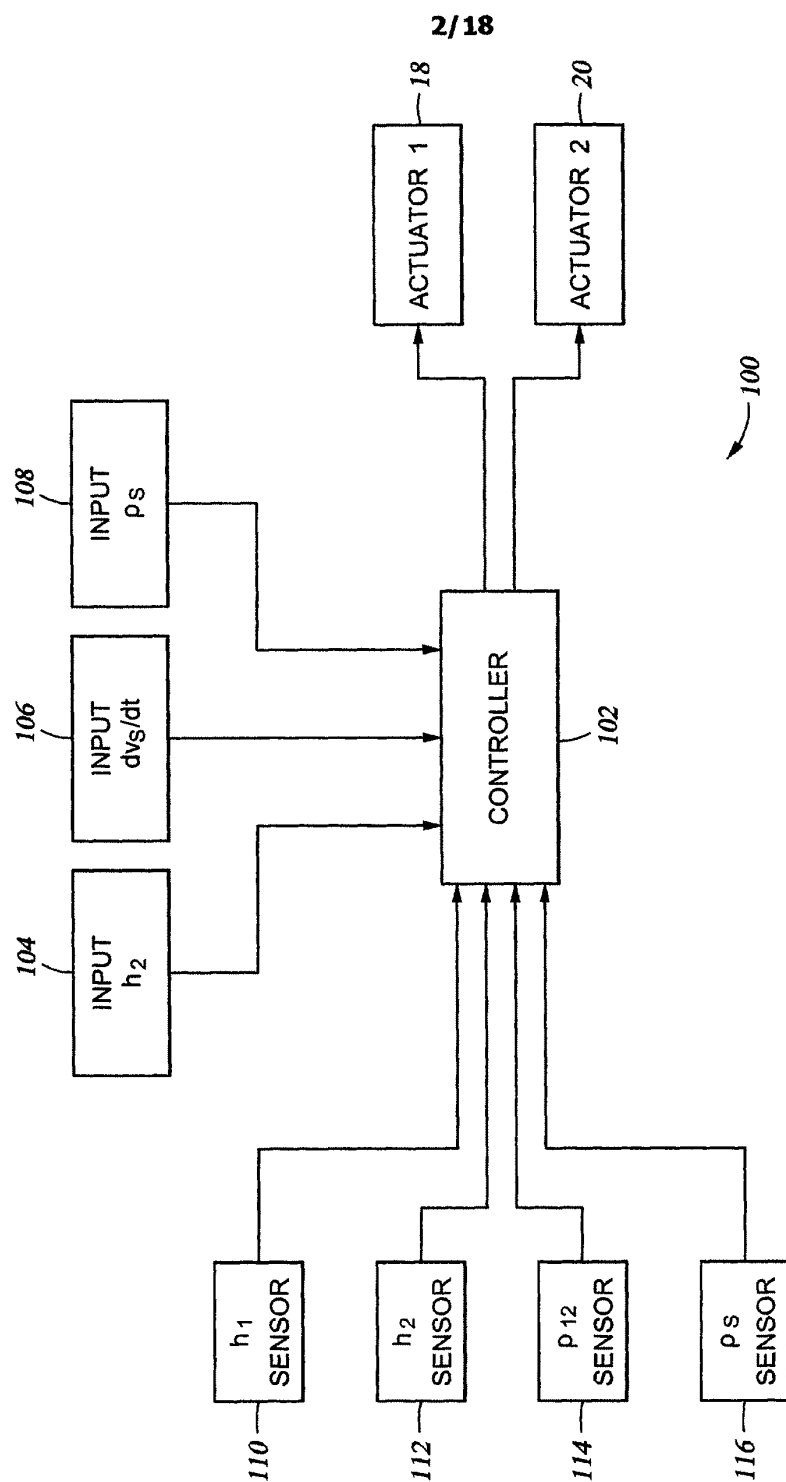


Fig. 1

**Fig. 2**

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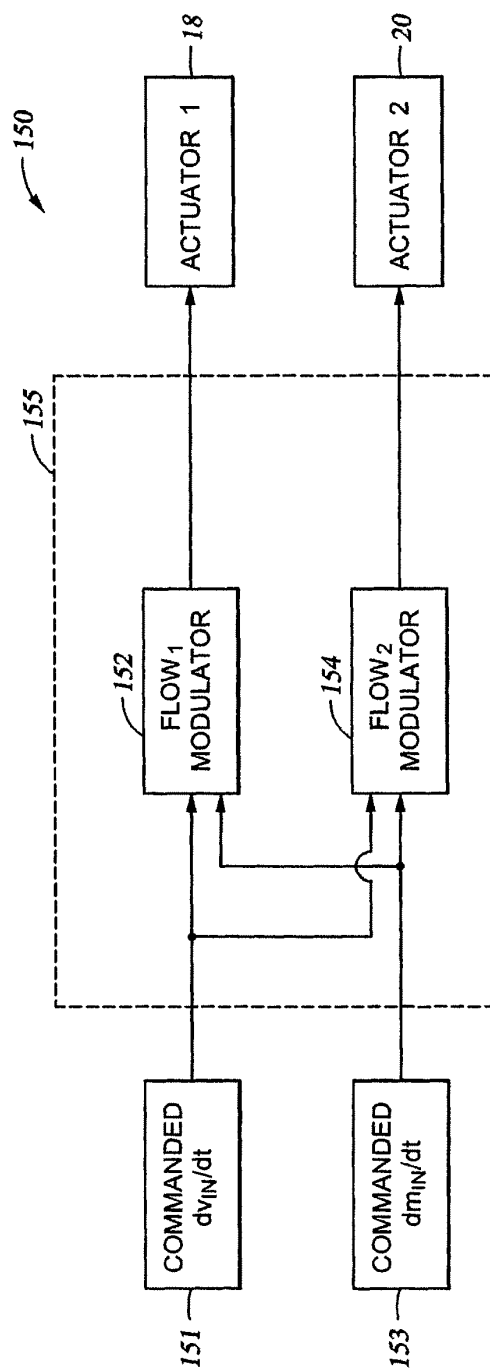


Fig. 3

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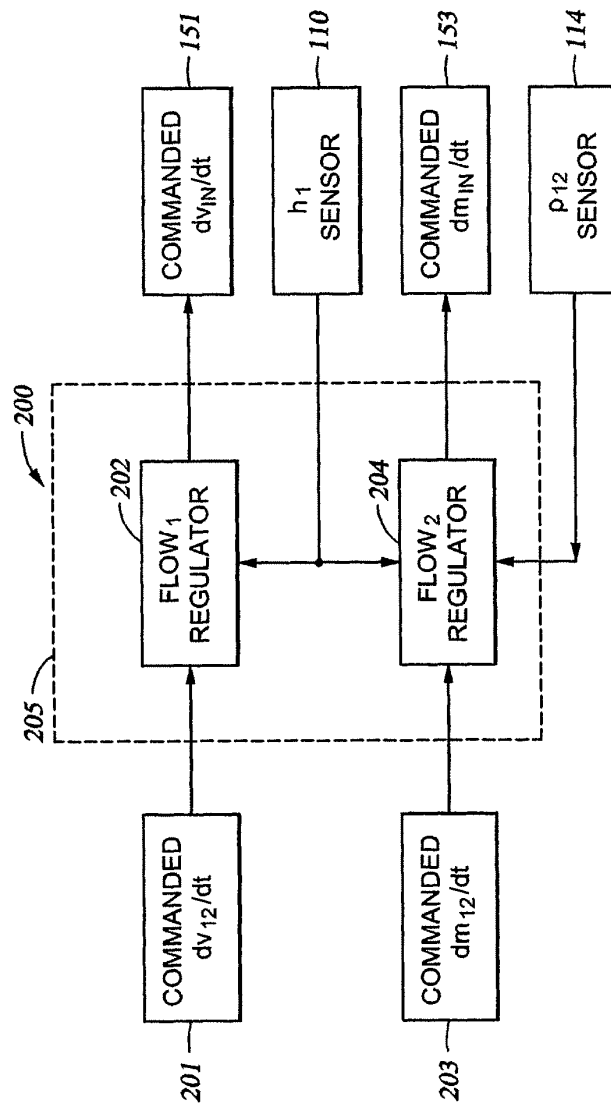


Fig. 4

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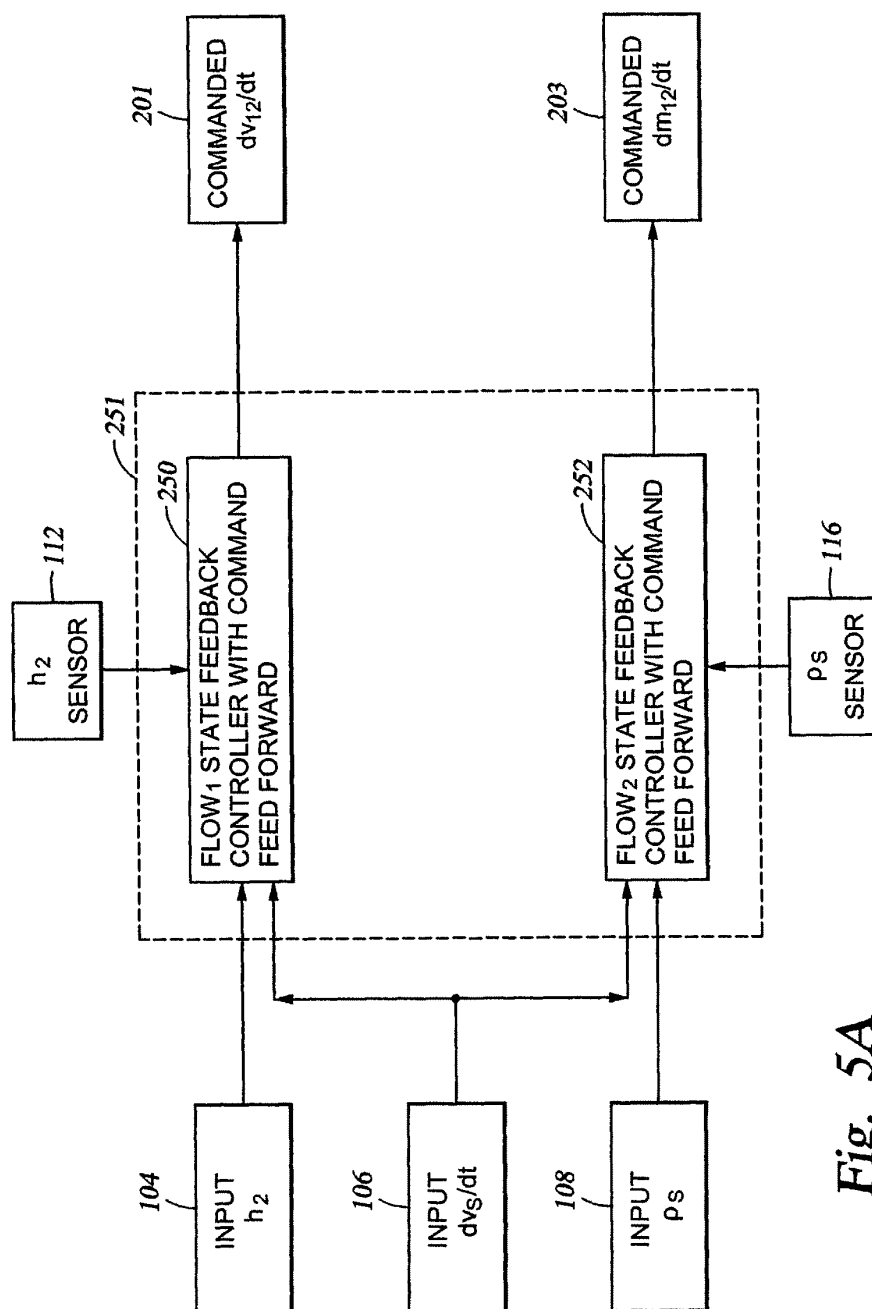


Fig. 5A

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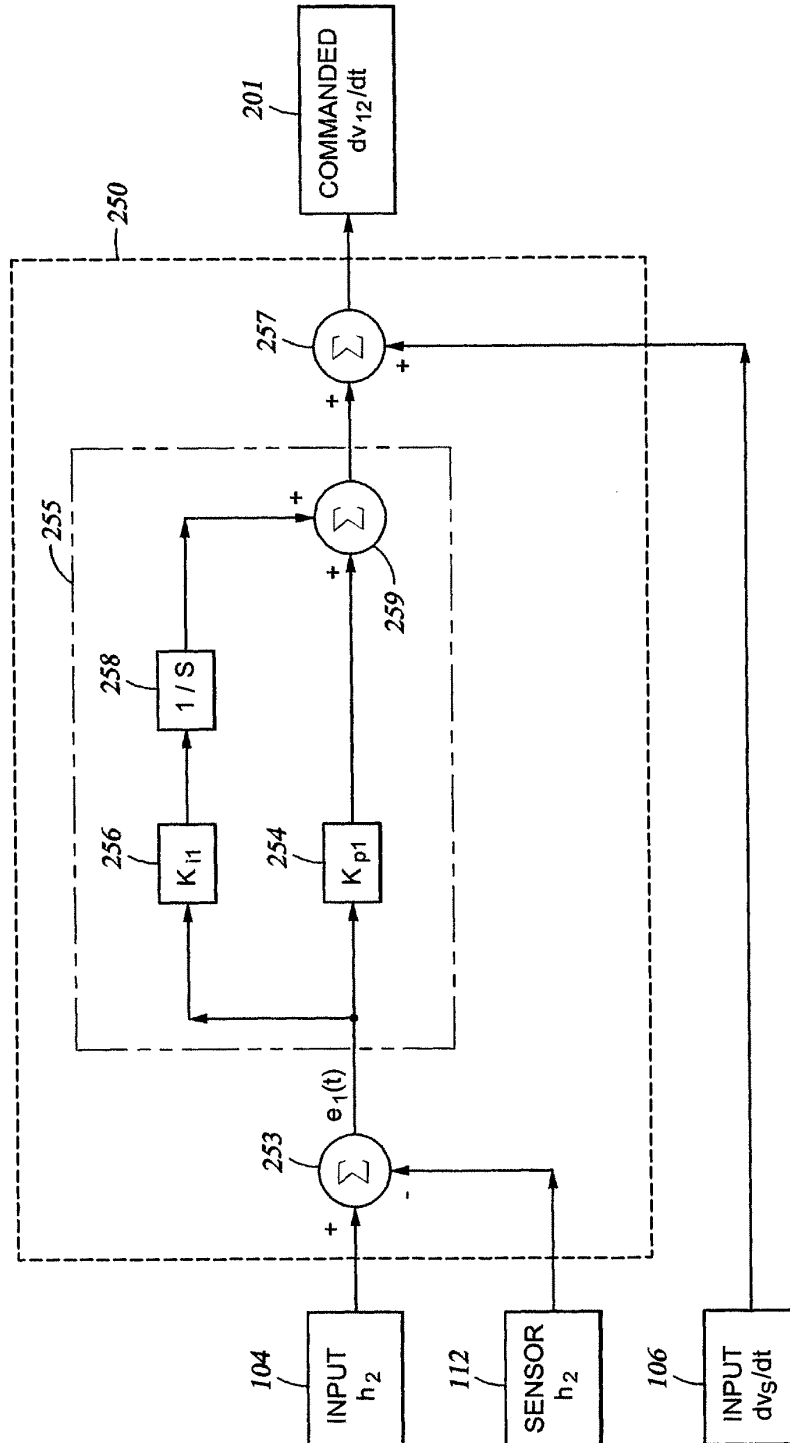


Fig. 5B

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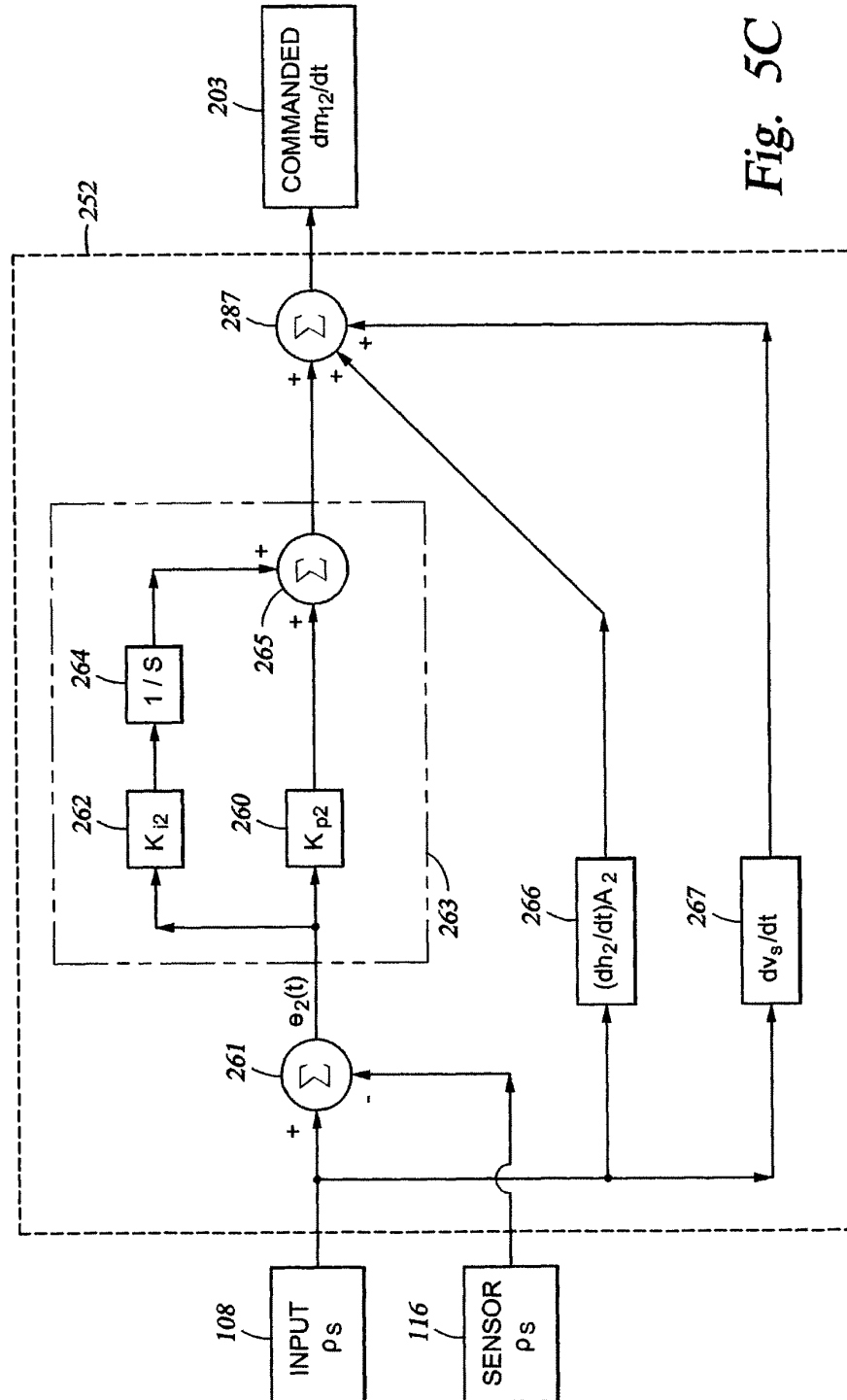


Fig. 5C

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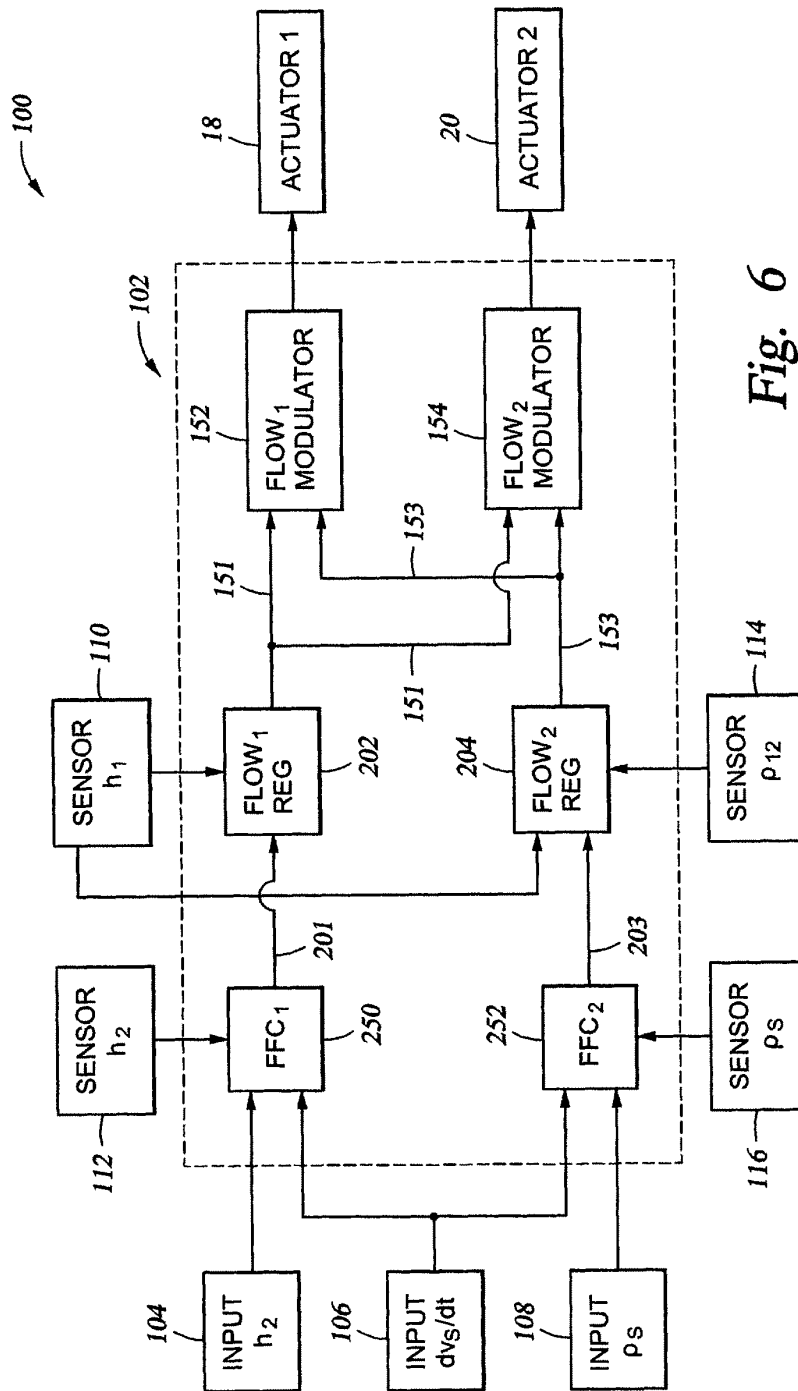
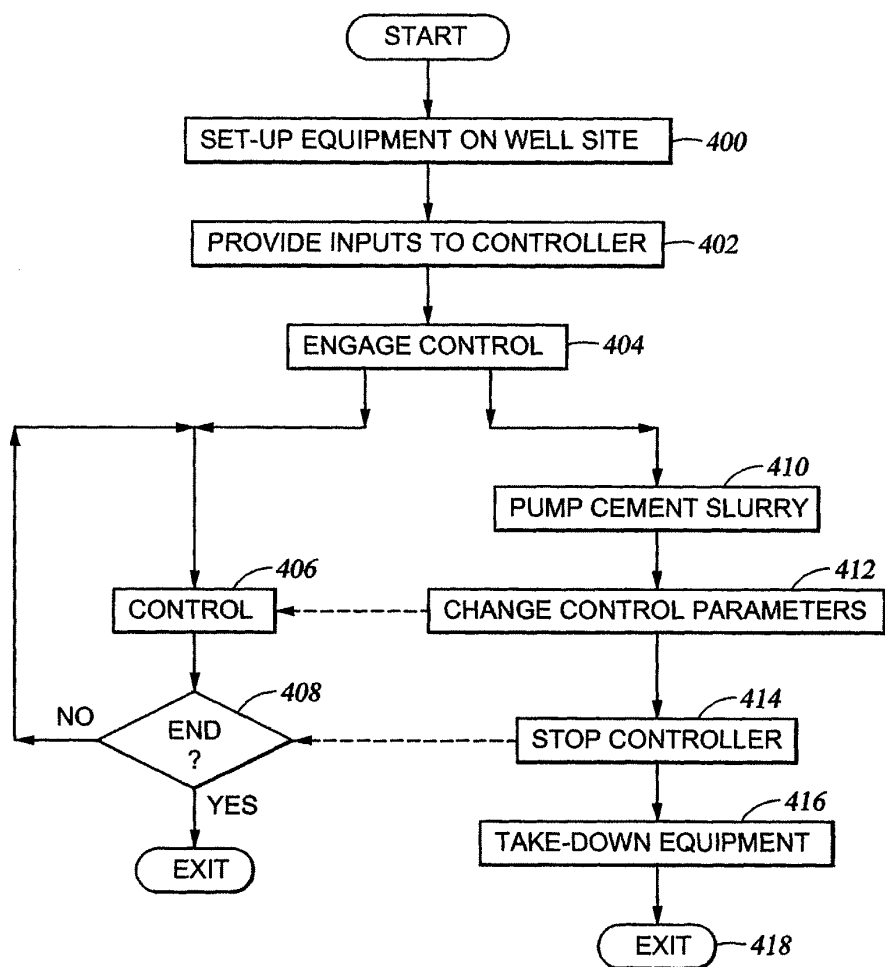


Fig. 6

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*Fig. 7*

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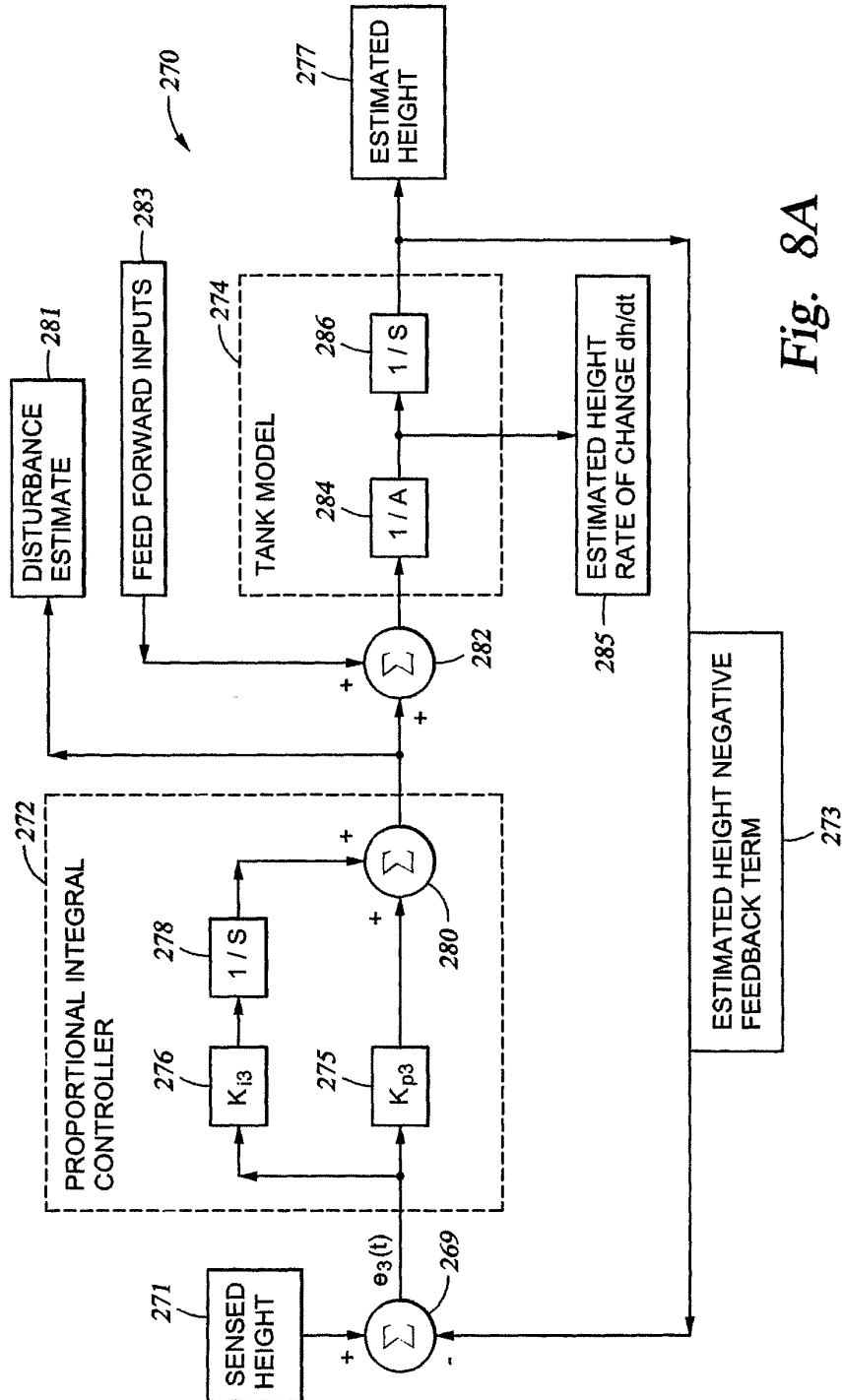


Fig. 8A

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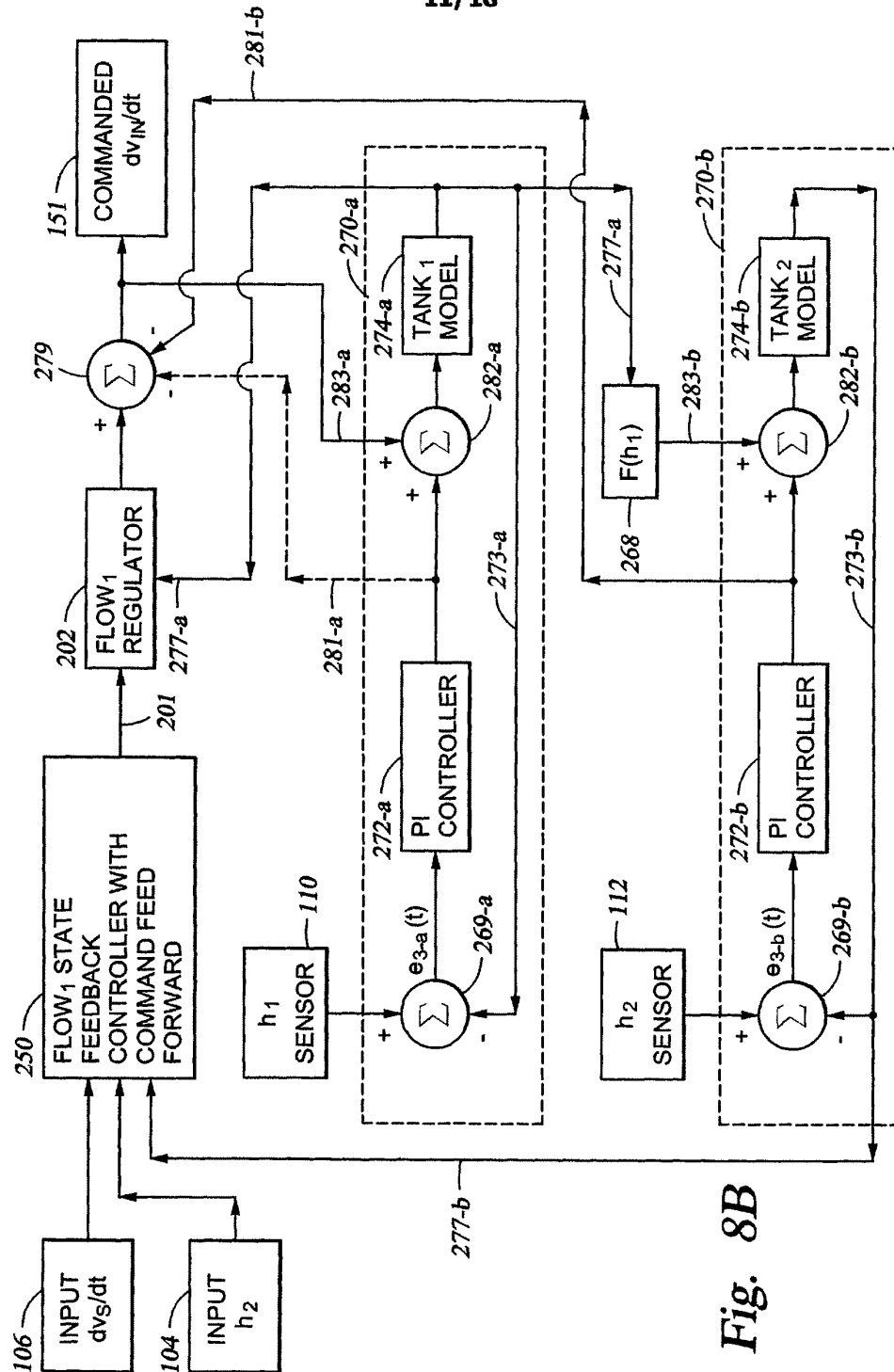


Fig. 8B

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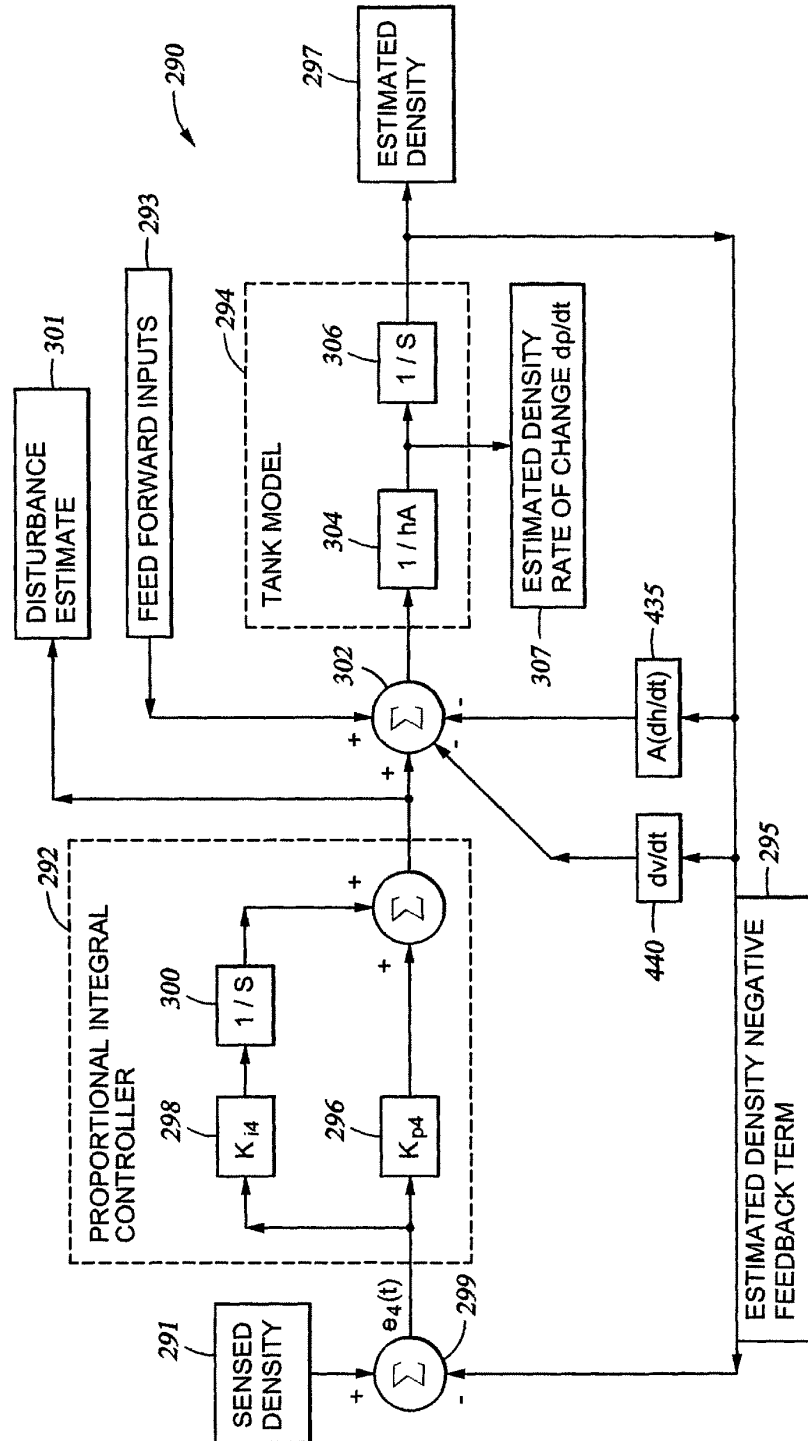


Fig. 9A

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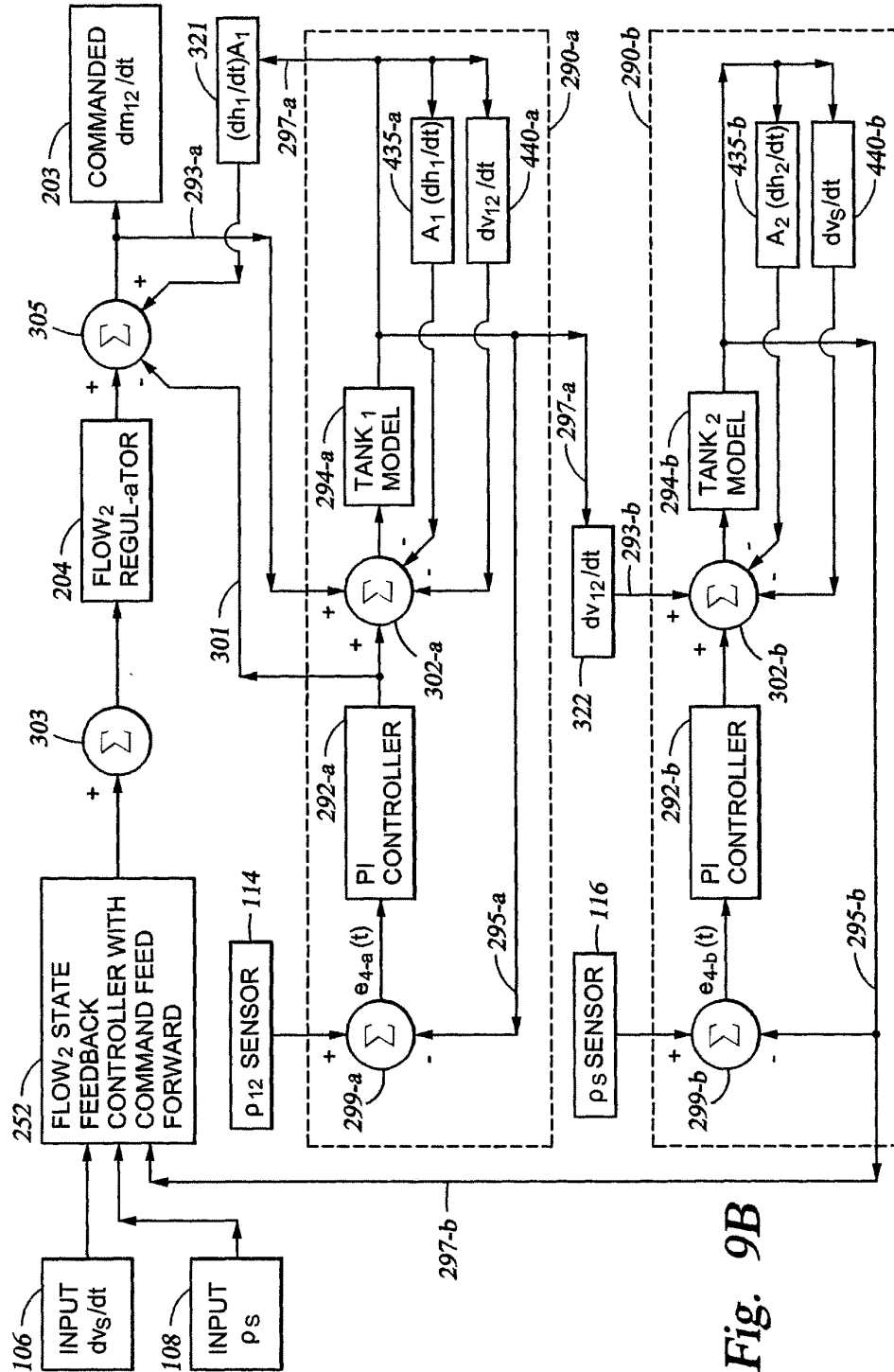


Fig. 9B

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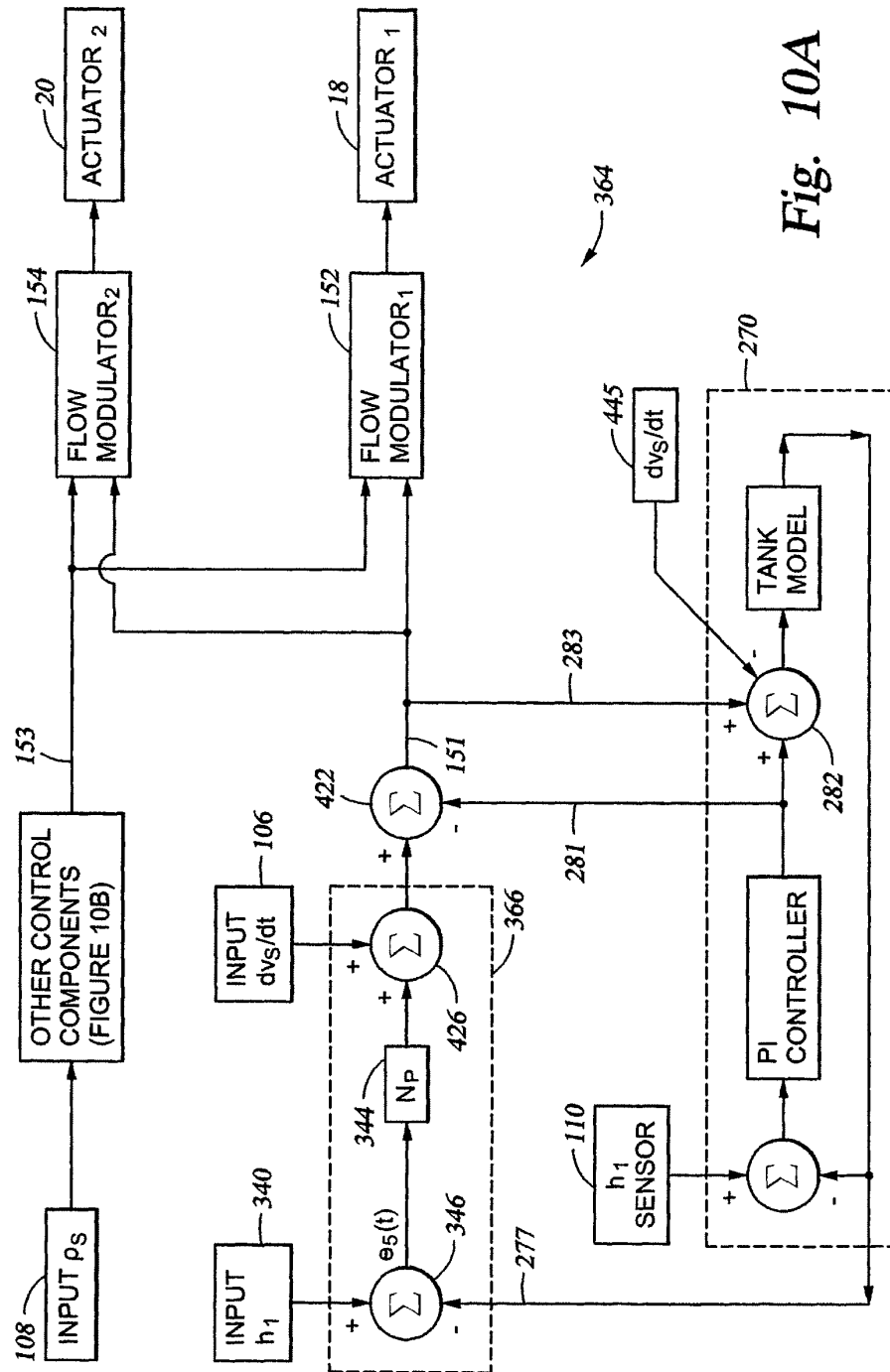


Fig. 10A

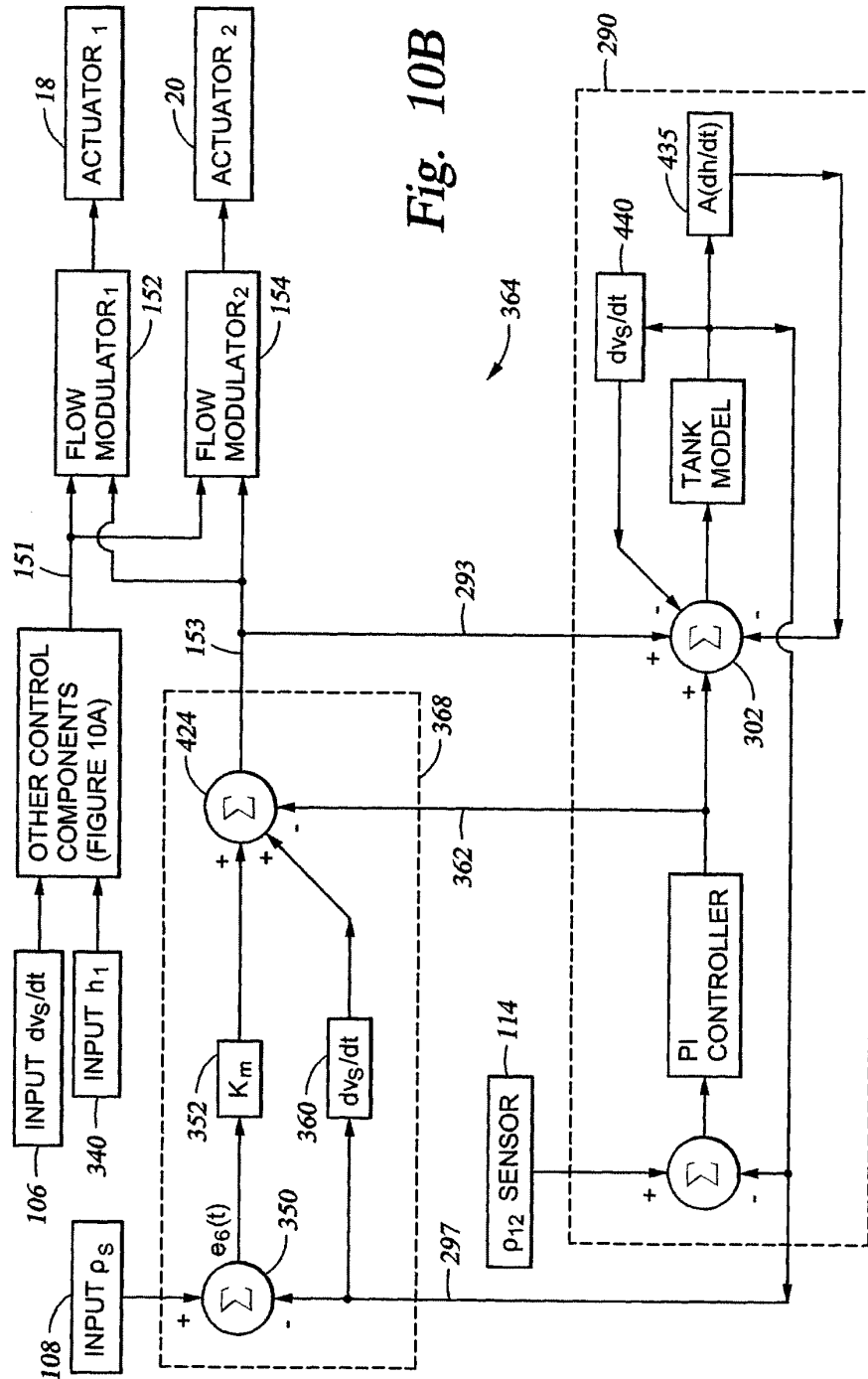
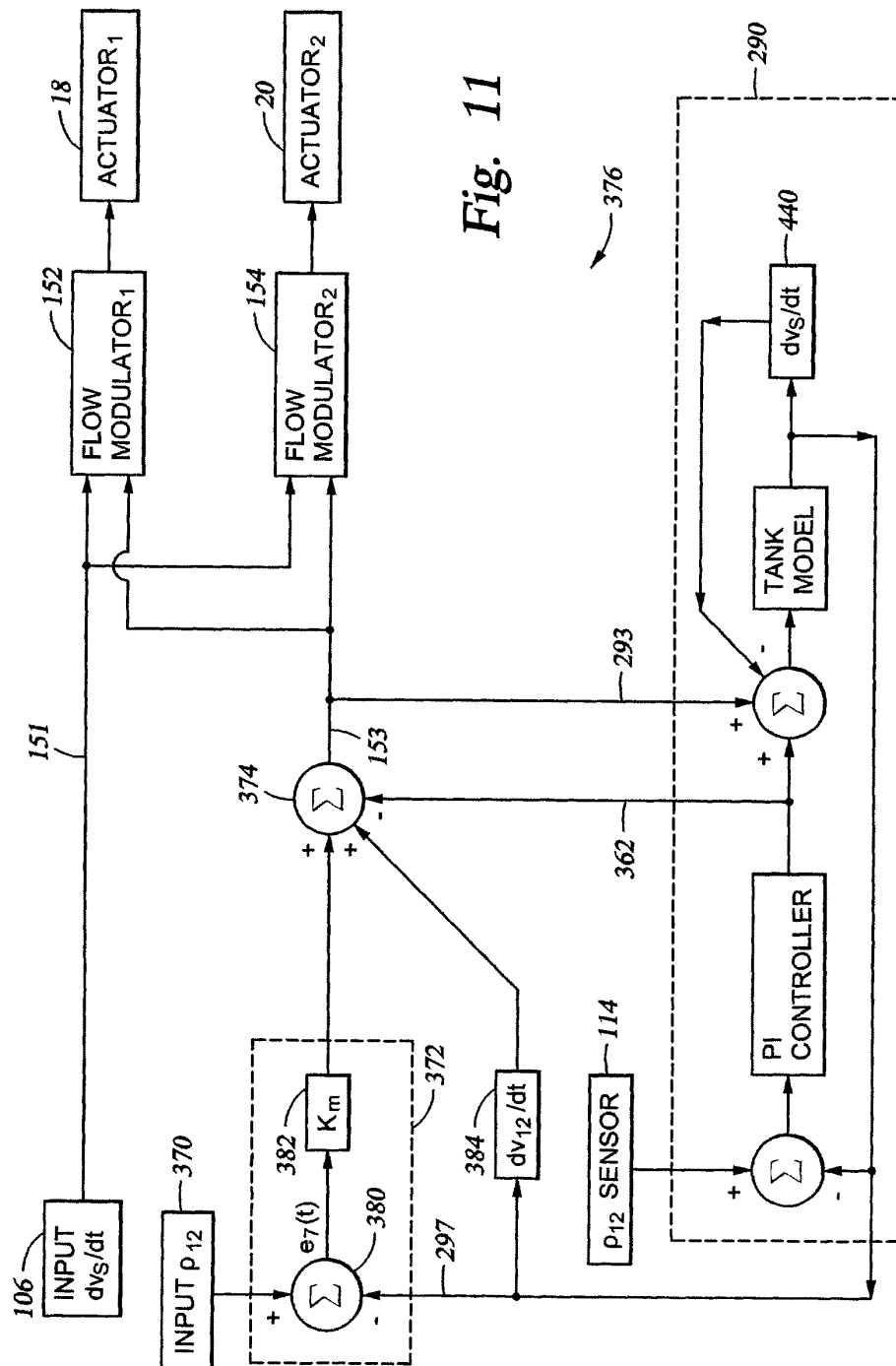


Fig. 10B

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Fig. 11



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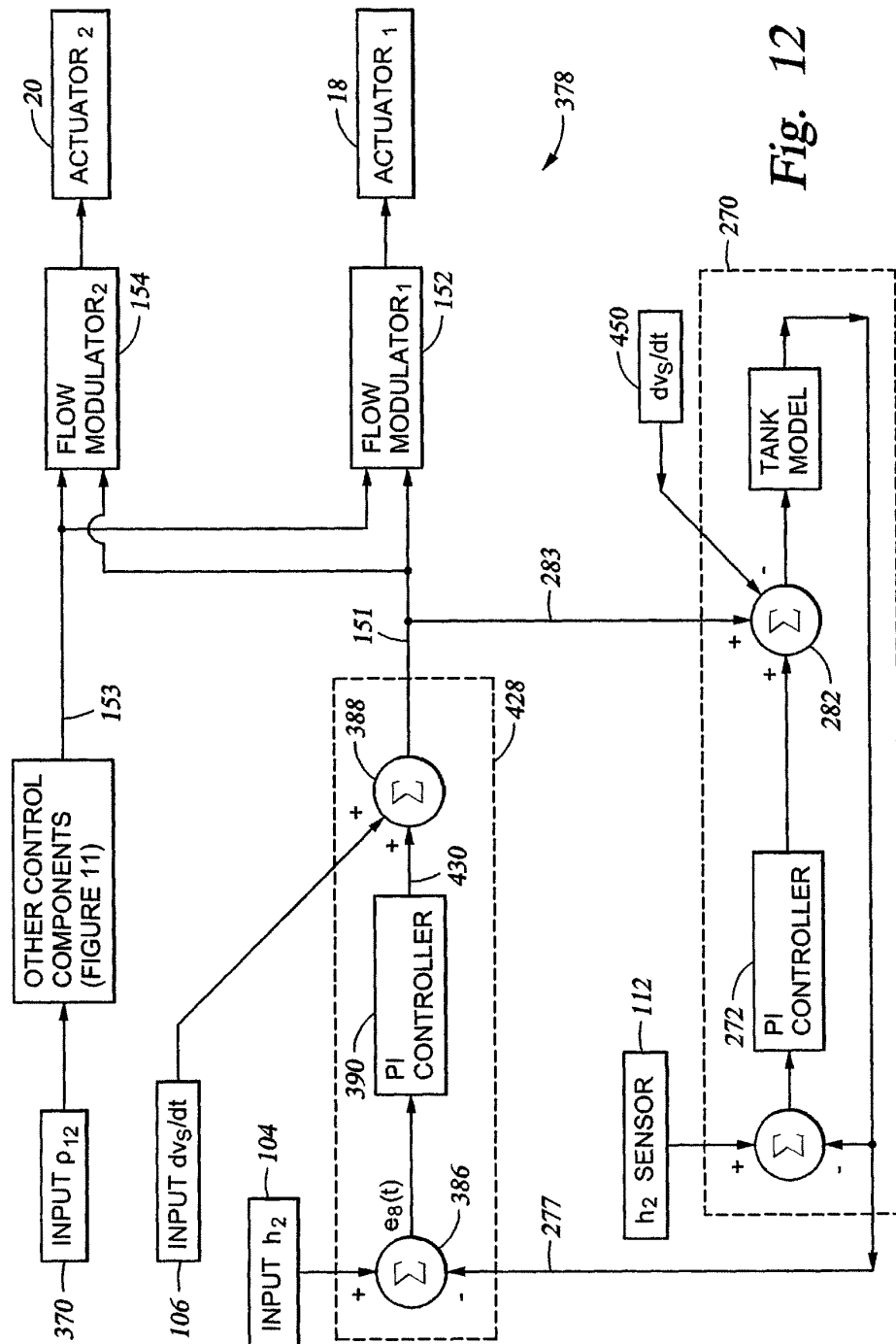


Fig. 12

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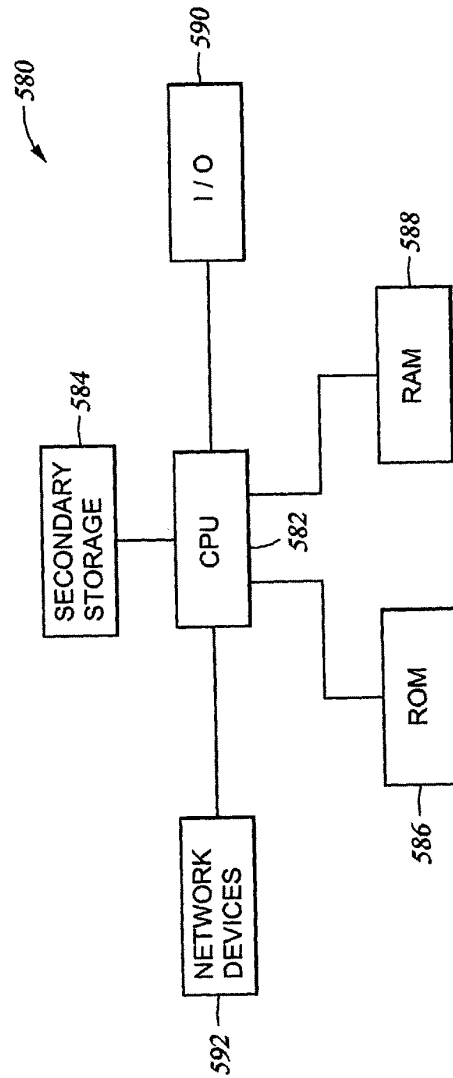


Fig. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/001302

A. CLASSIFICATION OF SUBJECT MATTER
INV. G05D11/13 B01F15/04 E21B33/13

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)
G05D B01F E21B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 289 877 A (NAEGELE ET AL) 1 March 1994 (1994-03-01)	30, 37-43, 49-51
Y	column 1, line 1 - column 5, line 20; figures 1A,1B,2	1-3, 44-48
A		4-29, 31-36, 52-57
Y	US 5 103 908 A (ALLEN ET AL) 14 April 1992 (1992-04-14)	1-3, 44-48
A	the whole document	4-43, 49-57
Y	US 5 775 803 A (MONTGOMERY ET AL) 7 July 1998 (1998-07-07)	1-3, 44-48
A	column 1, line 27 - column 7, line 27; figure 1	4-43, 49-57
	----- -/--	

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

☒ See patent family annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *Z* document member of the same patent family

Date of the actual completion of the international search

6 July 2006

Date of mailing of the international search report

17/07/2006

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Vaño Gea, J

Form PCT/ISA/210 (second sheet) (April 2005)

page 1 of 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/001302

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 397 561 A (STRONG ET AL) 9 August 1983 (1983-08-09)	30, 37-43, 49-51
Y	the whole document	1-3, 44-48
A		4-29, 31-36, 52-57

1

Form PCT/SA/210 (continuation of second sheet) (April 2005)

page 2 of 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/001302

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5289877	A	01-03-1994	CA 2102649 A1	11-05-1994
US 5103908	A	14-04-1992	NONE	
US 5775803	A	07-07-1998	NONE	
US 4397561	A	09-08-1983	NONE	

Form PCT/ISA/210 (patent family annex) (April 2005)

RECEIVED PATENT COOPERATION TREATY

10 NOV 2008

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

To: _____
A.A THORNTON & CO
Attn: Curtis, Philip Anthony
235 High Holborn
London
WC1V 7LE
GRANDE BRETAGNE

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT AND
THE WRITTEN OPINION OF THE INTERNATIONAL
SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference PAC/27054 WO	Date of mailing (day/month/year) 05/11/2008
International application No. PCT/GB2008/001730	FOR FURTHER ACTION See paragraphs 1 and 4 below
Applicant HALLIBURTON ENERGY SERVICES, INC.	International filing date (day/month/year) 21/05/2008

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

Shortly after the expiration of 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later); otherwise, the applicant must, within 20 months from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of 30 months (or later) will apply even if no demand is filed within 19 months.

See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the PCT Applicant's Guide, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the International Searching Authority  European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3018	Authorized officer Nathalie De Greef
--	---

Form PCT/ISA/220 (October 2005)

(See notes on accompanying sheet)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Volume I/A, Annexes B1 and B2).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, Volume I/A, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

- (i) the claim is unchanged;
- (ii) the claim is cancelled;
- (iii) the claim is new;
- (iv) the claim replaces one or more claims as filed;
- (v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 8 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 16 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/PEA/401).

If a demand for international preliminary examination is made, the written opinion of the International Searching Authority will, except in certain cases where the International Preliminary Examining Authority did not act as International Searching Authority and where it has notified the International Bureau under Rule 66.1 b/s(b), be considered to be a written opinion of the International Preliminary Examining Authority. If a demand is made, the applicant may submit to the International Preliminary Examining Authority a reply to the written opinion together, where appropriate, with amendments before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later (Rule 43bis.1(c)).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see the *PCT Applicant's Guide*, Volume II.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference PAC/27054 WO	FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, Item 5 below.	
International application No. PCT/GB2008/001730	International filing date (day/month/year) 21/05/2008	(Earliest) Priority Date (day/month/year) 24/05/2007
Applicant HALLIBURTON ENERGY SERVICES, INC.		

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International search report consists of a total of 5 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the language, the International search was carried out on the basis of:

- ☒ the international application in the language in which it was filed
☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

- b. ☐ This International search report has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)).
- c. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, see Box No. I.

2. ☐ Certain claims were found unsearchable (See Box No. II)

3. ☐ Unity of invention is lacking (see Box No. III)

4. With regard to the title,

- ☒ the text is approved as submitted by the applicant
☐ the text has been established by this Authority to read as follows:

5. With regard to the abstract,

- ☐ the text is approved as submitted by the applicant
☒ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the drawings,

- a. the figure of the drawings to be published with the abstract is Figure No. 2B
☐ as suggested by the applicant
☒ as selected by this Authority, because the applicant failed to suggest a figure
☐ as selected by this Authority, because this figure better characterizes the invention
- b. ☐ none of the figures is to be published with the abstract

Form PCT/ISA/210 (first sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB2008/001730

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

The present invention relates to methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly to methods and apparatus to place a first fracture(215) with a first orientation(x) in a formation(210) followed by a second fracture(220) with a second angular orientation(y) in the formation. The first and second fractures are initiated at about a fracturing location. The initiation of the first fracture is characterized by a first orientation line. The first fracture temporarily alters a stress field in the subterranean formation. The initiation of the second fracture is characterized by a second orientation line. The first orientation line and the second orientation line have an angular disposition to each other. There is a time delay between inducing the first fracture and inducing the second fracture.

Form PCT/ISA/210 (continuation of first sheet (3)) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2008/001730

A. CLASSIFICATION OF SUBJECT MATTER INV. E21B43/26		
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) E21B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 1 460 647 A (INTERCOMP RESOURCE DEV ENG INC) 6 January 1977 (1977-01-06)	1
Y	page 2, lines 11-23 page 6, lines 17-53 page 10, lines 29-46	2-25
Y	US 2006/081412 A1 (WRIGHT CHRIS [US] ET AL) 20 April 2006 (2006-04-20) paragraphs [0048], [0049]	2-25
P,X	WO 2008/041010 A (HALLIBURTON ENERGY SERV INC [US]; CURTIS PHILIP ANTHONY [GB]; SOLIMAN) 10 April 2008 (2008-04-10) claims 1-12	1, 10
A	US 6 935 424 B2 (LEHMAN LYLE V [US] ET AL) 30 August 2005 (2005-08-30) column 6, lines 17-34	1-25
-/-		
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
Special categories of cited documents: *A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art *Z* document member of the same patent family		
Date of the actual completion of the international search 29 October 2008		Date of mailing of the international search report 05/11/2008
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel: (+31-70) 340-2040 Fax: (+31-70) 340-3018		Authorized officer Garrido Garcia, M

Form PCT/ISA/210 (second sheet) (April 2005)

page 1 of 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2008/001730

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 682 246 A (CLOSMANN PHILIP JOSEPH) 8 August 1972 (1972-08-08) column 2, lines 5-22 -----	1-25
A	US 5 228 510 A (JENNINGS JR ALFRED R [US] ET AL) 20 July 1993 (1993-07-20) column 1, lines 41-62 -----	1-25
A	US 3 455 391 A (MATTHEWS CHARLES S ET AL) 15 July 1969 (1969-07-15) column 4, line 73 - column 5, line 17 -----	1-25
A	US 3 822 747 A (MAGUIRE J) 9 July 1974 (1974-07-09) abstract -----	1-25

2

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

page 2 of 2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2008/001730

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
GB 1460647	A	06-01-1977	NONE	
US 2006081412	A1	20-04-2006	NONE	
WO 2008041010	A	10-04-2008	US 2008083538 A1	10-04-2008
US 6935424	B2	30-08-2005	AU 2003244335 A1	22-04-2004
			BR 0304271 A	28-12-2004
			CA 2441537 A1	30-03-2004
			DE 60303751 T2	10-08-2006
			DK 1403465 T3	10-04-2006
			EP 1403465 A1	31-03-2004
			US 2004206495 A1	21-10-2004
US 3682246	A	08-08-1972	NONE	
US 5228510	A	20-07-1993	NONE	
US 3455391	A	15-07-1969	NONE	
US 3822747	A	09-07-1974	CA 997675 A1	28-09-1976

Form PCT/ISA/210 (patent family annex) (April 2005)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: see form PCT/ISA/220		PCT WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY (PCT Rule 43bis.1)	
Date of mailing (day/month/year) see form PCT/ISA/210 (second sheet)		Applicant's or agent's file reference see form PCT/ISA/220	
International application No. PCT/GB2008/001730		International filing date (day/month/year) 21.05.2008	
International Patent Classification (IPC) or both national classification and IPC INV. E21B43/26		Priority date (day/month/year) 24.05.2007	
Applicant HALLIBURTON ENERGY SERVICES, INC.			
1. This opinion contains indications relating to the following items: ☒ Box No. I Basis of the opinion ☐ Box No. II Priority ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability ☐ Box No. IV Lack of unity of invention ☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement ☒ Box No. VI Certain documents cited ☐ Box No. VII Certain defects in the international application ☐ Box No. VIII Certain observations on the international application 2. FURTHER ACTION If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered. If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later. For further options, see Form PCT/ISA/220. 3. For further details, see notes to Form PCT/ISA/220.			
Name and mailing address of the ISA: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3018		Date of completion of this opinion see form PCT/ISA/210 Authorized Officer Garrido Garcia, M Telephone No. +31 70 340-4468	

Form PCT/ISA/237 (Cover Sheet) (April 2005)

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/GB2008/001730

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:
 - ☒ the international application in the language in which it was filed
 - ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).
2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material:
 - ☐ a sequence listing
 - ☐ table(s) related to the sequence listing
 - b. format of material:
 - ☐ on paper
 - ☐ in electronic form
 - c. time of filing/furnishing:
 - ☐ contained in the international application as filed.
 - ☐ filed together with the international application in electronic form.
 - ☐ furnished subsequently to this Authority for the purposes of search.
4. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/GB2008/001730

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	<u>2-25</u>
	No: Claims	<u>1</u>
Inventive step (IS)	Yes: Claims	
	No: Claims	<u>1-25</u>
Industrial applicability (IA)	Yes: Claims	<u>1-25</u>
	No: Claims	

2. Citations and explanations

see separate sheet

Box No. VI Certain documents cited

1. Certain published documents (Rules 43bis.1 and 70.10)

and / or

2. Non-written disclosures (Rules 43bis.1 and 70.9)

see form 210

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING
AUTHORITY (SEPARATE SHEET)**

International application No.

PCT/GB2008/001730

Reference is made to the following documents:

D1 : GB 1 460 647 A

D2 : US 2006/081412 A1

Re Item V

**Reasoned statement with regard to novelty, inventive step or industrial applicability;
citations and explanations supporting such statement**

The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of claim 1 is not new in the sense of Article 33(2) PCT.

Document D1 discloses (the references in parentheses applying to this document) a method for fracturing a subterranean formation, wherein the subterranean formation comprises a wellbore (21) having an axis, the method comprising:
inducing a first fracture (73) in the subterranean formation, wherein:
the first fracture is initiated at about a fracturing location;
the initiation of the first fracture is characterized by a first orientation line; and
the first fracture (73) temporarily alters a stress field in the subterranean formation;
determining a time delay between inducing the first fracture and inducing a second fracture (see page 10, lines 29-47);
wherein the time delay is determined based, at least in part, on one or more stress fields of one or more affected layers during opening or closing of the first fracture; and
after the time delay, inducing the second fracture in the subterranean formation, wherein:
the second fracture (75, 77) is initiated at about the fracturing location;
the initiation of the second fracture is characterized by a second orientation line; and
the first orientation line and the second orientation line have an angular disposition to each other.

Independent claims 10 and 19 correspond to the subject-matter of claim 1, and incorporate additionally a computer. D1 was published in 1977, and it does not contain any computing means, but the teachings of D2, which discloses precisely such a computer, would be adopted in combination with the system of D1, arriving at a system with all the features of claims 10 and 19, without the exercise of any inventive skills.

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING
AUTHORITY (SEPARATE SHEET)**

International application No.

PCT/GB2008/001730

The subject-matter of claims 10 and 19 does therefore not involve an inventive step in the sense of Article 33(3) PCT.

Dependent claims 2-9, 11-18, 20-25 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step (Article 33(2) and (3) PCT).

Re Item VI

Certain documents cited

Application No Patent No	Publication date (day/month/year)	Filing date (day/month/year)	Priority date (valid claim) (day/month/year)
PCT/ GB2007/ 003809	10.04.2008	05.10.2007	06.10.2006

Electronic Patent Application Fee Transmittal				
Application Number:		11873186		
Filing Date:		16-Oct-2007		
Title of Invention:		Method and System for Centralized Well Treatment		
First Named Inventor/Applicant Name:		Jim B. Surjaatmadja		
Filer:		Carey Christine Jordan./Debbie Allen		
Attorney Docket Number:		2006-IP-021186U1		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
Total in USD (\$)				180

Electronic Acknowledgement Receipt	
EFS ID:	8191656
Application Number:	11873186
International Application Number:	
Confirmation Number:	1172
Title of Invention:	Method and System for Centralized Well Treatment
First Named Inventor/Applicant Name:	Jim B. Surjaatmadja
Customer Number:	29920
Filer:	Carey Christine Jordan./Debbie Allen
Filer Authorized By:	Carey Christine Jordan.
Attorney Docket Number:	2006-IP-021186U1
Receipt Date:	10-AUG-2010
Filing Date:	16-OCT-2007
Time Stamp:	17:06:40
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$180
RAM confirmation Number	3619
Deposit Account	500417
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees) Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		0861080099IDS.PDF	2215947 924625795374d8185446b5765168cd640a6361bb	yes	87

Multipart Description/PDF files in .zip description

Document Description	Start	End
Information Disclosure Statement (IDS) Filed (SB/08)	1	2
Foreign Reference	3	70
NPL Documents	71	83
NPL Documents	84	87

Warnings:

The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing

Information:

2	Fee Worksheet (PTO-875)	fee-info.pdf	30111 48e7d30d2338510ee15d9557989682b719c91016	no	2
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Warnings:

Information:

Total Files Size (in bytes): 2246058

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/873,186	10/16/2007	Jim B. Surjaatmadja	2006-IP-021186U1	1172
29920 7590 09/30/2010 JOHN W. WUSTENBERG P.O. BOX 1431 DUNCAN, OK 73536			EXAMINER BATES, ZAKIYA W	
			ART UNIT 3676	PAPER NUMBER
			NOTIFICATION DATE 09/30/2010	DELIVERY MODE ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

JOHN.WUSTENBERG@HALLIBURTON.COM
TIFFANY.KYLE@HALLIBURTON.COM

Office Action Summary	Application No.		Applicant(s)	
	11/873,186		SURJAATMADJA, JIM B.	
	Examiner		Art Unit	
	/Zakiya W. Bates/		3676	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) ☒ Responsive to communication(s) filed on 16 March 2010.

2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.

3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4) ☒ Claim(s) 1-31 is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5) ☐ Claim(s) _____ is/are allowed.

6) ☒ Claim(s) 1-31 is/are rejected.

7) ☐ Claim(s) _____ is/are objected to.

8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9) ☐ The specification is objected to by the Examiner.

10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a) ☐ All b) ☐ Some * c) ☐ None of:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. _____.

3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO/SB/08)
Paper No(s)/Mail Date _____.

4) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. _____.

5) ☐ Notice of Informal Patent Application

6) ☐ Other: _____.

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

2. Claims 1-31 are rejected under 35 U.S.C. 102(e) as being anticipated by Tolman et al. (US 2009/0114382).

Tolman et al. discloses, with respect to claim 17, a system for centralized distributing, receiving, and treating fluids for a plurality of wells, the system comprising: a centralized well treatment fluid center 100; one or more centralized service factories 106, 206; a plurality of distribution lines (from 202) coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of distribution lines are adapted to flow one or more well development task fluids; and a plurality of return lines 228 coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of return lines are adapted to flow one or more recovered well treatment fluids. With respect to the depending claims, the reference teaches the limitations as claimed. See

the entire document, especially Figs. 1-2, and pars. [0027-0031], [0037]. With respect to method claims 1-16, the reference teaches the associated method

Response to Arguments

3. Applicant's arguments with respect to the claims have been considered but are moot in view of the new ground(s) of rejection.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to /Zakiya W. Bates/ whose telephone number is (571) 272-7039. The examiner can normally be reached on Monday-Friday, 8:30 AM-5 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Shane Bomar can be reached on (571) 272-7026. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Application/Control Number: 11/873,186
Art Unit: 3676

Page 4

/Zakiya W. Bates/
Primary Examiner
Art Unit 3676

zb
9/24/10

Notice of References Cited	Application/Control No. 11/873,186		Applicant(s)/Patent Under Reexamination SURJAATMADJA, JIM B.	
	Examiner /Zakiya W. Bates/		Art Unit 3676	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2009/0114392	05-2009	Tolman et al.	166/305.1
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.



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BIB DATA SHEET

CONFIRMATION NO. 1172

SERIAL NUMBER 11/873,186	FILING or 371(c) DATE 10/16/2007 RULE	CLASS 166	GROUP ART UNIT 3676	ATTORNEY DOCKET NO. 2006-IP-021186U1	
APPLICANTS Jim B. Surjaatmadja, Duncan, OK; ** CONTINUING DATA ***** ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 11/02/2007					
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☒ No Verified and Acknowledged <u>/ZAKIYA W BATES/</u> Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY OK	SHEETS DRAWINGS 7	TOTAL CLAIMS 31 INDEPENDENT CLAIMS 2
ADDRESS JOHN W. WUSTENBERG P.O. BOX 1431 DUNCAN, OK 73536 UNITED STATES					
TITLE Method and System for Centralized Well Treatment					
FILING FEE RECEIVED 1710	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

BIB (Rev. 05/07).

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	20	("20080083531" "3455391" "3682246" "3822747" "5228510" "6935424" "7711487").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2010/09/24 21:27
L2	8	("20020125011" "4845981" "5417283" "7243728").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2010/09/24 21:28
L3	4	("20020125011" "20060081412").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2010/09/24 21:29
L4	45	("20060161358" "20070153622" "20070153623" "20070153624" "20070201305" "4137970" "4209278" "4265266" "4353482" "4409927" "4724905" "4830106" "5014218" "5659480" "6193402" "7036587" "7143842").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2010/09/24 21:31
L5	487	((plural\$3 multiple) with (wells wellbore\$1 borehole\$1) with central\$7) same ((distribut\$3 inject\$3) (receiv\$3 return\$3 produc\$4) treat\$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2010/09/24 21:35

S1	2900	(166/52,75.12,268,279,310,305.1,369).CCLS.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/09/21 16:14
S2	8	((plural\$3 multiple) with (wells wellbore\$1 borehole\$1) with central\$7) same ((distribut\$3 inject\$3) and (receiv\$3 return\$3 produc\$4) and treat\$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/09/21 16:19
S3	4	((("5,515,920") or ("4,305,463")).PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/09/21 18:02
S5	426	((plural\$3 multiple) with (wells wellbore\$1 borehole\$1) with central\$7) same ((distribut\$3 inject\$3) (receiv\$3 return\$3 produc\$4) treat\$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/09/21 18:03

9/24/10 9:36:51 PM

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186	
	Filing Date		2007-10-16	
	First Named Inventor	Jim Surjaatmadja		
	Art Unit	3676		
	Examiner Name	Zakiya Bates		
	Attorney Docket Number	2006-IP-021186U1		

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1	20020125011	A1	2002-09-12	Snider et al.	
	2	20060081412	A1	2006-04-20	Wright et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1	WO2008/041010		A1	2008-04-10	Halliburton Energy Services, Inc.		☐
	2	WO2008/142406		A3	2008-11-27	Halliburton Energy Services, Inc.		☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186	
	Filing Date		2007-10-16	
	First Named Inventor	Jim Surjaatmadja		
	Art Unit	3676		
	Examiner Name	Zakiya Bates		
Attorney Docket Number		2006-IP-021186U1		

	3	1460647	GB	A	1977-01-06	Intercomp Resource Dev Eng Inc.	☐
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NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵
	1	SURJAATMADJA et al., "Consideration for Future Stimulation Options is Vital in Deciding Horizontal Well Drilling and Completion Schemes for Production Optimization," Society of Petroleum Engineers, 2006, SPE 103774	☐
	2	~~Office Action for U.S. Patent Application No. 11/545,740 dated January 27, 2010~~	☐
	3	~~Notice of Allowance and Notice of Allowability for U.S. Patent Application No. 11/753,314 dated December 17, 2009~~	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Zakiya Bates/ (09/24/2010)	Date Considered	
--------------------	-----------------------------	-----------------	--

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	11873186
Filing Date	2007-10-16
First Named Inventor	Jim Surjaatmadja
Art Unit	3676
Examiner Name	Zakiya Bates
Attorney Docket Number	2006-IP-021186U1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

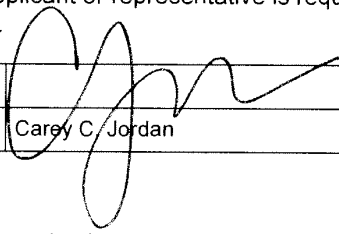
☐ See attached certification statement.

☒ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

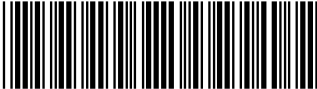
☐ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature		Date (YYYY-MM-DD)	2010-2-9
Name/Print	Carey C. Jordan	Registration Number	47,646

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Search Notes 	Application/Control No. 11/873,186 Examiner /Zakiya W. Bates/	Applicant(s)/Patent under Reexamination SURJAATMADJA, JIM B. Art Unit 3676
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SEARCHED			
Class	Subclass	Date	Examiner

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
East attached	9/24/2010	ZB

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)

Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	11873186
	Filing Date	2007-10-16
	First Named Inventor	Jim B. Surjaatmadja
	Art Unit	3676
	Examiner Name	BATES, ZAKIYA W
	Attorney Docket Number	2006-IP-021186U1 (063718.1162)

U.S.PATENTS								
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1	4845981		1989-07-11	Pearson			
	2	5417283		1995-05-23	Ejiogu et al.			
	3	7243726		2007-07-17	Ohmer			
If you wish to add additional U.S. Patent citation information please click the Add button.								
U.S.PATENT APPLICATION PUBLICATIONS								
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1	20020125011		2002-09-12	Snider et al.			
If you wish to add additional U.S. Published Application citation information please click the Add button.								
FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							☐

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /Z.B./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186
	Filing Date		2007-10-16
	First Named Inventor	Jim B. Surjaatmadja	
	Art Unit	3676	
	Examiner Name	BATES, ZAKIYA W	
Attorney Docket Number		2006-IP-021186U1	

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NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵
	1	~~Notice of Allowance for U.S. Patent Application Serial No. 11/753,014, dated Dec 17, 2009.~~	☐
	2	~~Office Action for U.S. Patent Application Serial No. 11/990,018, dated Dec 1, 2009.~~	☐
	3	~~Office Action for U.S. Patent Application Serial No. 11/545,719, dated Jan 27, 2010.~~	☐
If you wish to add additional non-patent literature document citation information please click the Add button			
EXAMINER SIGNATURE			
Examiner Signature	/Zakiya Bates/ (09/24/2010)		Date Considered
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Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (07-09)

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11873186	
	Filing Date		2007-10-16	
	First Named Inventor	Jim Surjaatmadja		
	Art Unit	3676		
	Examiner Name	Zakiya Bates		
	Attorney Docket Number	2006-IP-021186U1		

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
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U.S.PATENT APPLICATION PUBLICATIONS

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	1					

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FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵

**INFORMATION DISCLOSURE
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NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵
	1	Notice of Allowance for U.S. Patent Application No. 11/001,628 dated February 18, 2010	☐
	2	Notice of Allowance for U.S. Patent Application No. 11/545,740 dated April 6, 2010	☐

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	Examiner Name	Bates, Zakiya W.	
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	11873186
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	Art Unit	3676
	Examiner Name	Bates, Zakiya W.
	Attorney Docket Number	2006-IP-021186U1

		Office Action from U.S. Application Serial No. 11873186 dated May 24, 2010	☐
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U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1	20060243437	A1	2006-11-02	Albers et al.	

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FOREIGN PATENT DOCUMENTS

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵
	1	~~Office Action for U.S. Patent Application No. 11/291,490 dated May 13, 2010~~	☐

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	11/873,186
	Filing Date	10/16/2007
	First Named Inventor	Surjaatmadja
	Confirmation Number	1172
	Client Number	86108
Page 1 of 2	Matter Number	99

U.S. PATENT DOCUMENTS				
Initials	Cite No.	Document Number	Issue/Publication Date	First Named Inventor
	1	7711487	5/4/2010	Surjaatmadja
	2	20080083531	4/10/2008	Surjaatmadja
	3	3455391	7/15/1969	Matthews
	4	3682246	8/8/1972	Closmann
	5	3822747	7/9/1974	Maguire
	6	5228510	7/20/1993	Jennings#s#Jr
	7	6935424	8/30/2005	Lehman

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Initials	Cite No.	Document Number	Publication Date	Country
	1	2006109035		WO

OTHER DOCUMENTS		
Initials	Cite No.	Author, Title, Date, Pages, etc.
	1	Search Report and Written Opinion for International Application No. PCT/GB2008/001730 dated May 21, 2008.
	2	Notice of Allowance for U.S. Patent No. 11/601,623 dated July 26, 2010.

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	Filing Date	10/16/2007
	First Named Inventor	Surjaatmadja
	Confirmation Number	1172
	Client Number	86108
Page 2 of 2	Matter Number	99

TIMING
In accordance with 37 CFR 1.97(c), this Information Disclosure Statement is being filed after the period specified in 37 CFR 1.97(b) and before the mailing date of a Final Action under 37 CFR 1.113, a Notice of Allowance under 37 CFR 1.311, or an Action that otherwise closes prosecution in the application.

CERTIFICATION STATEMENT
No certification statement is required.
This Information Disclosure Statement is being filed in accordance with 37 CFR 1.97(c) and is accompanied by the fee set forth in 37 CFR 1.17(p).

FEE
The Director is hereby authorized to charge \$180 to deposit account number 500417. Please reference attorney docket number 86108-99 for this transaction.
This Information Disclosure Statement is being filed in accordance with 37 CFR 1.97(c), and is not accompanied by one of the certification statements of 37 CFR 1.97(e). Therefore, this Information Disclosure Statement is subject to the fee set forth in 37 CFR 1.17(p).

SIGNATURE			
Signature	/ Melody Wirz /	Date	8/10/2010
Name	Melody Wirz	Registration Number	53783

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /Z.B./

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

SURJAATMADJA

Serial No.: 11/873,186

Filed: OCTOBER 16, 2007

Title: "METHOD AND SYSTEM FOR
CENTRALIZED WELL TREATMENT"

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Group Art Unit: 3676

Confirmation No.: 1172

Examiner: BATES, ZAKIYA W.

Atty. Docket No:

HES 2006-IP-021186U1 (063718.1162)

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**RESPONSE UNDER 37 C.F.R. § 1.111 TO
OFFICE ACTION, MAILED SEPTEMBER 30, 2010**

Dear Honorable Commissioner:

In response to the Office Action mailed on September 30, 2010 (the "Office
Action"), Applicant submits the following:

- **Listing of the Claims**, which begin on page 2 of this paper; and
- **Remarks / Arguments** which begin on page 14 of this paper.

LISTING OF THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

Claims:

1. (Original) A method of providing centralized well development services to a plurality of wells, comprising the steps of:

flowing from a centralized well treatment fluid center to one or more centralized service factories one or more well development task fluids, wherein the one or more centralized service factories are selectively configurable to receive the one or more well development task fluids;

preparing, at the one or more centralized service factories, one or more well treatment fluids from the one or more well development task fluids, wherein the one or more centralized service factories are selectively configurable to prepare the one or more well treatment fluids;

flowing from the one or more centralized service factories to at least one of the plurality of wells the one or more well treatment fluids, wherein the one or more centralized service factories are selectively configurable to flow the one or more well treatment fluids;

recovering from the at least one of the plurality of wells the one or more well treatment fluids at the one or more centralized service factories, wherein the one or more centralized service factories are selectively configurable to receive the one or more recovered well treatment fluids; and

flowing from the one or more centralized service factories to the centralized well treatment fluid center the one or more recovered well treatment fluids, wherein the one or more centralized service factories are selectively configurable to flow the one or more recovered well treatment fluids, and wherein the centralized well treatment fluid center is selectively configurable to receive the one or more recovered well treatment fluids.

2. (Previously Presented) The method of claim 1, wherein at least two well development task fluids are provided and they comprise different compositions.

3. (Previously Presented) The method of claim 1, further comprising the step of:
disposing of at least one of the one or more recovered well treatment fluids at the centralized well treatment fluid center, wherein the centralized well treatment fluid center is configurable to dispose of the at least one of the one or more recovered well treatment fluids.

4. (Previously Presented) The method of claim 1, further comprising the step of:
reconditioning at least one of the one or more recovered well treatment fluids at the centralized well treatment fluid center, wherein the centralized well treatment fluid center is configurable to recondition the at least one of the one or more recovered well treatment fluids.

5. (Original) The method of claim 1, wherein at least one of the one or more well treatment fluids comprises a compound selected from the group consisting of drilling fluid, HMP, cement, gas, oil, water, proppant, fracturing fluid, gelling agents, friction reducers, acidizers, conformance fluids, cleaning fluids, brine, cutting abrasives and combinations thereof.

6. (Original) The method of claim 1, further comprising the steps of:
receiving a production fluid at one or more of the one or more centralized service factories from the at least one of the plurality of wells, wherein the one or more of the one or more centralized service factories is configurable to receive the production fluid; and

receiving the production fluid at the centralized well treatment fluid center from the one or more of the one or more centralized service factories, wherein the centralized well treatment fluid center is configurable to receive the production fluid from the one or more of the one or more centralized service factories.

7. (Previously Presented) The method of claim 6, further comprising the step of:

separating the production fluid into at least two or more second production fluids, wherein the centralized well treatment fluid center is configurable to separate the production fluid into at least two or more second production fluids.

8. (Original) The method of claim 7, further comprising the steps of:

conditioning the at least two or more second production fluids, wherein the centralized well treatment fluid center is configurable to condition the at least two or more second production fluids; and

disposing of at least one of the at least two or more second production fluids, wherein the centralized well treatment fluid center is configurable to dispose of the at least one of the at least two or more second production fluids.

9. (Original) The method of claim 7, further comprising:

flowing the at least two or more second production fluids to a distribution center, wherein the centralized well treatment fluid center is configurable to flow the at least two or more second production fluids to the distribution center.

10. (Original) The method of claim 1, further comprising the steps of:

flowing from the centralized well treatment fluid center to the one or more centralized service factories one or more other well development task fluids, wherein the one or more centralized service factories are selectively configurable to receive the one or more other well development task fluids;

flowing from the one or more centralized service factories to the at least one of the plurality of wells the one or more other well treatment fluids, wherein the one or more centralized service factories is selectively configurable to flow the one or more other well treatment fluids;

recovering from the at least one of the plurality of wells the one or more other well treatment fluids at the one or more centralized service factories, wherein the one or more centralized service factories are selectively configurable to receive the one or more recovered other well treatment fluids; and

flowing from the one or more centralized service factories to the centralized well treatment fluid center the one or more other recovered well treatment fluids, wherein the one or more centralized service factories are selectively configurable to flow the one or more other recovered well treatment fluids, and wherein the centralized well treat fluid center is selectively configurable to receive the one or more other recovered well treatment fluids.

11. (Previously Presented) The method of claim 1, further comprising the step of:

storing the one or more recovered well treatment fluids at the centralized well treatment fluid center, wherein the centralized well treatment fluid center is configurable to store the one or more recovered well treatment fluids.

12. (Previously Presented) The method of claim 1, further comprising the step of:

flowing from the centralized well treatment fluid center substantially simultaneously two or more well development task fluids to at least one of the one or more centralized service factories, wherein the centralized well treatment fluid center is configurable to flow substantially simultaneously the two or more well development task fluids, and wherein the at least one of the one or more centralized service factories are configurable to receive substantially simultaneously the two or more well development task fluids.

13. (Previously Presented) The method of claim 12, further comprising the step of:

flowing to a first well of the plurality of wells from the at least one of the one or more centralized service factories any of the one or more well treatment fluids prepared from the two or more well development task fluids substantially simultaneously with flowing to a second well of the plurality of wells from the at least one of the one or more centralized service factories any of the one or more well treatment fluids prepared from the two or more well development task fluids, wherein the at least one of the one or more centralized service factories is configurable to flow substantially simultaneously at least two of the one or more well treatment fluids.

14. (Previously Presented) The method of claim 1, further comprising the step of:

flowing from the centralized well treatment fluid center to the one or more centralized service factories the one or more well treatment fluids, wherein the one or more centralized service factories are selectively configurable to receive the one or more well treatment fluids.

15. (Previously Presented) The method of claim 1, further comprising the steps of:

flowing to two or more wells of the plurality of wells substantially simultaneously the one or more well treatment fluids from at least one of the one or more centralized service factories, wherein the at least one of the one or more centralized service factories is configurable to flow substantially simultaneously the one or more well treatment fluids to the two or more wells of the plurality of wells; and

recovering from the two or more wells of the plurality of wells substantially simultaneously the one or more well treatment fluids at the at least one of the one or more centralized service factories, wherein the at least one of the one or more centralized service factories is configured to recover substantially simultaneously the one or more well treatment fluids.

16. (Original) The method of claim 1, further comprising the steps of:

providing a first plurality of fluid lines from the centralized well treatment fluid center to a first centralized service factory, wherein the first plurality of fluid lines are adapted to flow the one or more well treatment fluids;

providing a second plurality of fluid lines from the centralized well treatment fluid center to the first centralized service factory, wherein the second plurality of fluid lines are adapted to flow the one or more recovered well treatment fluids;

providing a third plurality of fluid lines from the centralized well treatment fluid center to a second centralized service factory, wherein the third plurality of fluid lines are adapted to flow the one or more well treatment fluids; and

providing a fourth plurality of fluid lines from the centralized well treatment fluid center to the second centralized service factory, wherein the fourth plurality of fluid lines are adapted to flow the one or more recovered well treatment fluids.

17. (Previously Presented) A system for centralized distributing, receiving, and treating fluids for a plurality of wells, the system comprising:

a centralized well treatment fluid center;

one or more centralized service factories;

a plurality of distribution lines coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of distribution lines are adapted to flow one or more well development task fluids; and

a plurality of return lines coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of return lines are adapted to flow one or more recovered well treatment fluids.

18. (Previously Presented) The system of claim 17, further comprising:

a plurality of modules disposed about each of the one or more centralized service factories;

a first fluid flow line coupled between the at least one of the plurality of wells and any of the plurality of modules, wherein the first fluid flow line is adapted to flow one or more well treatment fluids to the at least one of the plurality of wells; and

a second fluid flow line coupled between the at least one of the plurality of wells and one or more of the plurality of modules, wherein the second fluid flow line is adapted to recover the one or more well treatment fluids from the at least one of the plurality of wells;

wherein a first configuration of the plurality of modules is operable to flow a first well treatment fluid to the at least one of the plurality of wells; and

wherein a second configuration of the plurality of modules is operable to flow a second well treatment fluid to the at least one of the plurality of wells.

19. (Original) The system of claim 17, wherein each of the plurality of distribution lines are adapted to flow one or more well treatment fluids.

20. (Original) The system of claim 17, wherein the centralized well treatment center is configurable to:

flow the one or more well development task fluids;

receive the one or more recovered well treatment fluids;

recondition the one or more recovered well treatment fluids; and

receive production fluids.

21. (Original) The system of claim 17, wherein the one or more centralized service factories is configurable to:

receive the one or more well development task fluids from the centralized well treatment fluid center;

prepare the one or more well treatment fluids from the one or more well development task fluids;

flow the one or more well treatment fluids to the plurality of wells;

receive the one or more recovered well treatment fluids from the plurality of wells; and

receive production fluids from the plurality of wells.

22. (Original) The system of claim 17, wherein the plurality of modules comprise:

- one or more blending modules;
- one or more additive storage modules, wherein the one or more additive storage modules are operable to connect to the one or more blending modules;
- one or more liquid additive pumps, wherein the one or more liquid additive pumps are operable to connect to the one or more blending modules;
- one or more pumping grids, wherein the one or more pumping grids are operable to connect to the one or more blending modules;
- one or more manifolds, wherein the one or more manifolds are operable to connect to the one or more blending modules; and
- a power grid, wherein the power grid is operable to connect to the one or more blending modules, the one or more additive storage modules, the one or more liquid additive pumps, the one or more pumping grids, and the one or more manifolds.

23. (Original) The system of claim 22, further comprising:

- a third fluid flow line between at least one of a second plurality of wells and the one or more manifolds, wherein the third fluid flow line is directed to delivering at least one of the one or more well treatment fluids;
- wherein the one or more manifolds is operable to deliver substantially simultaneously any of the one or more well treatment fluids through the third fluid flow line and any of the one or more well treatment fluids through the second fluid flow line; and
- a fourth fluid flow line between the second plurality of wells and the one or more manifolds, wherein the fourth fluid flow line is directed to recovering the one or more well treatment fluids from the at least one of the second plurality of wells.

24. (Original) The system of claim 18, wherein at least one of the one or more modules is directed to reconditioning the one or more well treatment fluids substantially simultaneously with recovering the one or more well treatment fluids.

25. (Currently Amended) The system of claim ~~18~~ 23, further comprising:

a fluid reconditioning module disposed about the centralized well treatment fluid center, wherein the fluid reconditioning module is operable to recondition at least one of the one or more recovered well treatment fluids; and

a fifth fluid flow line between the fluid reconditioning module and the third fluid flow line so as to receive the one or more recovered well treatment fluids from the at least one of the one or more centralized service factories.

26. (Original) The system of claim 25, further comprising:

a sixth fluid flow line between the fluid reconditioning module and any of the one or more modules so as to flow the reconditioned well treatment fluids to the one or more centralized service factories.

27. (Original) The system of claim 26, further comprising:

a seventh fluid flow line between the fluid reconditioning module and an additive storage module, wherein the additive storage module is operable to store the reconditioned well treatment fluids.

28. (Original) The system of claim 18, further comprising a disposal module coupled to at least one of the one or more modules, wherein the disposal module is operable to dispose of the recovered well treatment fluids.

29. (Original) The system of claim 18, further comprising a base coupled to at least one of the one or more modules, wherein the base is operable to move the at least one of the one or more modules.

30. (Original) The system of claim 18, further comprising a cleaning module coupled to at least one of the one or more modules, wherein the cleaning module is operable to clean any fluid flow line.

31. (Original) The system of claim 18, further comprising a production fluid module, wherein the production fluid module is operable to receive production fluid from at least one of the one or more centralized service factories.

REMARKS / ARGUMENTS

I. Disposition of the Claims.

Please consider the application in view of the following remarks. Applicant thanks the Examiner for the careful consideration of this application including the references that Applicant has submitted in this case.

At the time of the Office Action, claims 1-31 were pending in this application. Claims 1-31 stand rejected. Applicant respectfully requests that the above amendments be entered and further request reconsideration in light of the amendments and remarks contained herein.

III. Remarks Regarding Claim Rejections Under 35 U.S.C. § 102

Claims 1-31 are rejected under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent Publication No. 2009/0114382 (*sic.*) to Tolman et al. (hereinafter “Tolman”). With respect to this rejection, the Office Action states:

Tolman et al. discloses, with respect to claim 17, a system for centralized distributing, receiving, and treating fluids for a plurality of wells, the system comprising: a centralized well treatment fluid center 100; one or more centralized service factories 106, 206; a plurality of distribution lines (from 202) coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of distribution lines are adapted to flow one or more well development task fluids; and a plurality of return lines 228 coupled between the centralized well treatment fluid center and the one or more centralized service factories, wherein the plurality of return lines are adapted to flow one or more recovered well treatment fluids. With respect to the depending claims, the reference teaches the limitations as claimed. See the entire document, especially Figs. 1-2, and pars. [0027-0031], [0037]. With respect to method claims 1-16, the reference teaches the associated method

(Office Action at 2-3). Applicant respectfully disagrees.

The present invention relates generally to methods and systems for simultaneously treating multiple wells from a centralized location and simultaneously connecting multiple wells to a single manifold. Specification, paragraph [0001]. Specifically, distribution lines 108 couple the centralized well treatment fluid center 102 to centralized service factories

104. Specification, paragraph [0019]. The centralized service factories 104 are coupled to one or more of the plurality of wells 106 through first and second fluid flow lines 110, 114. Specification, paragraph [0020]. Accordingly, well development task fluid may flow between the centralized well treatment fluid center 102 and the centralized service factories 104 through the distribution lines 108 and return lines 112. Specification, paragraph [0019]. Additionally, first fluid flow lines 110 may be adapted to flow fluids from the centralized service factories 104 to the plurality of wells 106 and second fluid flow lines 114 may be adapted to flow fluids from the plurality of wells 106. Specification, paragraph [0022].

Accordingly, independent claim 1 recites (1) flowing from a centralized well treatment fluid center to one or more centralized service factories one or more well development task fluids; (2) preparing, at the one or more centralized service factories, one or more well treatment fluids from the one or more well development task fluids; (3) flowing from the one or more centralized service factories to at least one of the plurality of wells the one or more well treatment fluids; (4) recovering from the at least one of the plurality of wells the one or more well treatment fluids at the one or more centralized service factories; and (5) flowing from the one or more centralized service factories to the centralized well treatment fluid center the one or more recovered well treatment fluids.

Similarly, independent claim 17 recites (1) a centralized well treatment fluid center; (2) one or more centralized service factories; (3) distribution lines coupled between the centralized well treatment fluid center and the one or more centralized service factories to flow one or more well development task fluids; and (4) return lines coupled between the centralized well treatment fluid center and the one or more centralized service factories to flow one or more recovered well treatment fluids.

In contrast, Tolman merely discloses connecting multiple wells to a stimulation fluid pumping system via a pumping system manifold. Tolman, paragraph [0020]. This pumping system manifold contains multiple valves to enable stimulation fluid to be pumped into any selected well, while the other remaining wells are hydraulically isolated from the pressure and energy created by the stimulation fluid pumping system. Tolman, paragraph [0020].

The Office Action identifies item 100 of Tolman as the centralized well treatment fluid center; items 106 and 206 as the centralized service factories, item 202 as the distribution

line and item 228 as the return line. (Office Action, at 2). Applicants respectfully disagree with this characterization of Tolman.

Specifically, with respect to items 100 and 106, Tolman states:

Turning now to the drawings, and referring initially to FIG. 1, an exemplary production system 100 having multiple wells located at a single surface pad in accordance with certain aspects of the present techniques is illustrated. In the production system 100, a surface pad 102 has two or more wells 104a-104n. Each of the wells 104a-104n has an oil field tree 106a-106n located over the wellbore 108a-108n and are positioned in a specific configuration.

Tolman, paragraph [0021] (emphasis added). Similarly, with respect to item 206, Tolman states:

To couple the stimulation fluid pumping system 202 to the trees 106a-106c, the pumping system manifold 206 is utilized.

Tolman, paragraph [0030].

Accordingly, Tolman merely discloses a production system 100 with a single pad. Moreover, both the oil field tree 106 and the pumping system manifold 206 which couples the stimulation fluid pumping system 202 to the oil field tree 106 are located in, and are part of the production system 100. Accordingly, assuming *arguendo*, that as the Office Action suggests, the production system 100 is analogous to the centralized well treatment fluid center of the present application, then Tolman does not disclose a centralized service factory as recited in independent claims 1 and 17. Specifically, the oil field tree 106 and the pumping system manifold 206 of Tolman are part of the production system 100 and there are no distribution lines or return lines coupled between the production system 100 (identified in the Office Action as the centralized well treatment fluid center) and the oil field tree 106 or the pumping system manifold 206 (identified in the Office Action as the centralized service factory) as recited in independent claim 1. Similarly, Tolman at least fails to disclose flowing from a centralized well treatment fluid center (identified as item 100 in the Office Action) to one or more centralized service factories (identified as item 106 or item 206 in the Office Action) one or more well development task fluids and flowing from the one or more centralized service factories to the centralized well treatment fluid center the one or more recovered well treatment fluids, as recited in independent claim 17.

Therefore, Applicant respectfully asserts that independent claims 1 and 17 and their dependent claims are not anticipated by Tolman, nor does Tolman. Claims 2-16 and 18-31 are dependent on independent claims 1 and 17 and are therefore allowable for at least the same reasons. Accordingly, Applicant respectfully requests withdrawal of this rejection with respect to claims 1-31.

V. No Waiver

All of Applicant's arguments and amendments are without prejudice or disclaimer. Additionally, Applicant has merely discussed example distinctions from the cited references. Other distinctions may exist, and Applicant reserves the right to discuss these additional distinctions in a later Response or on Appeal, if appropriate. By not responding to additional statements made by the Examiner, Applicant does not acquiesce to the Examiner's additional statements, such as, for example, any statements relating to what would be obvious to a person of ordinary skill in the art.

SUMMARY

In light of the above remarks, Applicant respectfully requests reconsideration and withdrawal of the outstanding rejections. Applicant further submits that the application is now in condition for allowance, and earnestly solicits timely notice of the same. Should the Examiner have any questions, comments or suggestions in furtherance of the prosecution of this application, the Examiner is invited to contact the attorney of record by telephone, facsimile, or electronic mail.

Applicant believes that no fees are due in association with the filing of this Response. However, should the Commissioner deem that any fees are due, including any fees for extensions of time, the Commissioner is authorized to debit Baker Botts L.L.P. Deposit Account No. 02-0383, Order Number 063718.1162, for any underpayment of fees that may be due in association with this filing.

Respectfully submitted,

Date: November 4, 2010

By: 
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ATTORNEY FOR APPLICANT

Electronic Acknowledgement Receipt	
EFS ID:	8767581
Application Number:	11873186
International Application Number:	
Confirmation Number:	1172
Title of Invention:	Method and System for Centralized Well Treatment
First Named Inventor/Applicant Name:	Jim B. Surjaatmadja
Customer Number:	29920
Filer:	Elizabeth L. Durham/Nicci Fowler
Filer Authorized By:	Elizabeth L. Durham
Attorney Docket Number:	2006-IP-021186U1
Receipt Date:	04-NOV-2010
Filing Date:	16-OCT-2007
Time Stamp:	11:49:31
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		063718-1162-ROA.PDF	730030	yes	20
			5b298c9945f863a9646169a379bf8ab38e534d0b		

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Transmittal Letter	1	2
	Amendment/Req. Reconsideration-After Non-Final Reject	3	3
	Claims	4	15
	Applicant Arguments/Remarks Made in an Amendment	16	20
Warnings:			
Information:			
Total Files Size (in bytes):		730030	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

In re Application of:		§	
	SURJAATMADJA	§	Group Art Unit: 3676
Serial No.:	11/873,186	§	
		§	Confirmation No.: 1172
Filed:	OCTOBER 16, 2007	§	
		§	Examiner: BATES, ZAKIYA W.
Title:	“METHOD AND SYSTEM FOR	§	
	CENTRALIZED WELL TREATMENT”	§	Atty. Docket No:
		§	HES 2006-IP-021186U1 (063718.1162)

Respectfully submitted,

Date: November 4, 2010

By: _____



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ATTORNEY FOR APPLICANT

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 11/873,186		Filing Date 10/16/2007		☐ To be Mailed	
APPLICATION AS FILED – PART I										
(Column 1)			(Column 2)			SMALL ENTITY ☐ OR		OTHER THAN SMALL ENTITY		
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	OR	RATE (\$)	FEE (\$)			
☒ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	310			
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A				
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A				
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$ =		OR	X \$ =				
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$ =			X \$ =				
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL		310		
APPLICATION AS AMENDED – PART II										
(Column 1)			(Column 2)			SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT	11/04/2010	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 31	Minus	** 31	= 0	X \$ =		OR	X \$2=	0
	Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X \$ =		OR	X \$220=	0
	☐ Application Size Fee (37 CFR 1.16(s))							OR		
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)		
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =		OR	X \$ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =		OR	X \$ =	
	☐ Application Size Fee (37 CFR 1.16(s))							OR		
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

Legal Instrument Examiner:
/GWENDOLYN MYERS/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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NOTICE OF ALLOWANCE AND FEE(S) DUE

29920 7590 01/27/2011

JOHN W. WUSTENBERG
P.O. BOX 1431
DUNCAN, OK 73536

EXAMINER

BATES, ZAKIYA W

ART UNIT

PAPER NUMBER

3676

DATE MAILED: 01/27/2011

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/873,186	10/16/2007	Jim B. Surjaatmadja	2006-IP-021186U1	1172
TITLE OF INVENTION: METHOD AND SYSTEM FOR CENTRALIZED WELL TREATMENT				

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1510	\$300	\$0	\$1810	04/27/2011

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

29920 7590 01/27/2011

JOHN W. WUSTENBERG
P.O. BOX 1431
DUNCAN, OK 73536

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/873,186	10/16/2007	Jim B. Surjaatmadja	2006-IP-021186U1	1172
TITLE OF INVENTION: METHOD AND SYSTEM FOR CENTRALIZED WELL TREATMENT				

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1510	\$300	\$0	\$1810	04/27/2011

EXAMINER	ART UNIT	CLASS-SUBCLASS
BATES, ZAKIYA W	3676	166-268000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363). ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached. ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.	2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, 1 _____ (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 _____ 3 _____
---	---

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.111. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☐ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____

Date _____

Typed or printed name _____

Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/873,186	10/16/2007	Jim B. Surjaatmadja	2006-IP-021186U1	1172
29920	7590	01/27/2011	EXAMINER	
JOHN W. WUSTENBERG P.O. BOX 1431 DUNCAN, OK 73536			BATES, ZAKIYA W	
			ART UNIT	PAPER NUMBER
			3676	
DATE MAILED: 01/27/2011				

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.



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BIB DATA SHEET

CONFIRMATION NO. 1172

SERIAL NUMBER 11/873,186	FILING or 371(c) DATE 10/16/2007 RULE	CLASS 166	GROUP ART UNIT 3676	ATTORNEY DOCKET NO. 2006-IP-021186U1	
APPLICANTS Jim B. Surjaatmadja, Duncan, OK; ** CONTINUING DATA ***** ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 11/02/2007					
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☒ No Verified and Acknowledged <u>/ZAKIYA W BATES/</u> Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY OK	SHEETS DRAWINGS 7	TOTAL CLAIMS 31 INDEPENDENT CLAIMS 2
ADDRESS JOHN W. WUSTENBERG P.O. BOX 1431 DUNCAN, OK 73536 UNITED STATES					
TITLE Method and System for Centralized Well Treatment					
FILING FEE RECEIVED 1710	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

BIB (Rev. 05/07).

Search Notes 	Application/Control No.	Applicant(s)/Patent under Reexamination	
	11/873,186	SURJAATMADJA, JIM B.	
	Examiner	Art Unit	
	/Zakiya W. Bates/	3676	

SEARCHED			
Class	Subclass	Date	Examiner

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
attached		1/17/2011	ZB

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
East attached	1/17/2011	ZB

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L4	16	((plural\$3 multiple) with (wells wellbore\$1 borehole\$1) with central\$7) same ((distribut\$3 inject\$3) (receiv\$3 return\$3 produc\$4) treat\$3) and (factories factory)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2011/01/17 19:47
L5	3849	(166/52,75.12,268,279,310,305.1,369,90.1).CCLS.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2011/01/17 19:48
L6	287	((plural\$3 multiple) with (wells wellbore\$1 borehole\$1)) same ((distribut\$3 inject\$3) (receiv\$3 return\$3 produc\$4) treat\$3) and (factories factory)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2011/01/17 19:57
L7	4	((((plural\$3 multiple) with (wells wellbore\$1 borehole\$1)) same ((distribut\$3 inject\$3) (receiv\$3 return\$3 produc\$4) treat\$3) and (factories factory)).clm.	US-PGPUB	OR	OFF	2011/01/17 19:57

1/17/11 8:00:57 PM

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PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail** Mail Stop ISSUE FEE
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Tiffany Kyle (Depositor's name)
 (Signature)
 1/28/2011 (Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/873,186	10/16/2007	Jim B. Surjaatmadja	2006-IP-021186U1	1172

TITLE OF INVENTION: METHOD AND SYSTEM FOR CENTRALIZED WELL TREATMENT

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1510	\$300	\$0	\$1810	04/27/2011

EXAMINER	ART UNIT	CLASS-SUBCLASS
BATES, ZAKIYA W	3676	166-268000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

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(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

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1 John W. Wustenberg

2 Baker Botts LLP

3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

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(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Halliburton Energy Services Inc., Duncan, OK, USA

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

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Date 28 JAN 11

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