ABSTRACT

RESERVOIR ARCHITECTURE AND CONNECTIVITY ANALYSIS

An interactive system and method of operating the system to define and evaluate a model of a hydrocarbon reservoir. The reservoir model is defined from extrinsic information such as seismic surveys, well logs, and the like, and is based on elements of formation regions, connections among the regions, wells, and perforations. A boundary-element method is used to determine pressure interference responses, corresponding to the pressure at a perforation in response to a single perforation producing fluid at a unit flow rate. These pressure interference responses are then convolved with measured well flow rates obtained during production to arrive at estimates of the wellbore pressure at one or more wells of interest. The estimated wellbore pressure can be compared with downhole pressure measurements to validate the reservoir model, or to provoke the user into modifying the model and repeating the evaluation of the model.

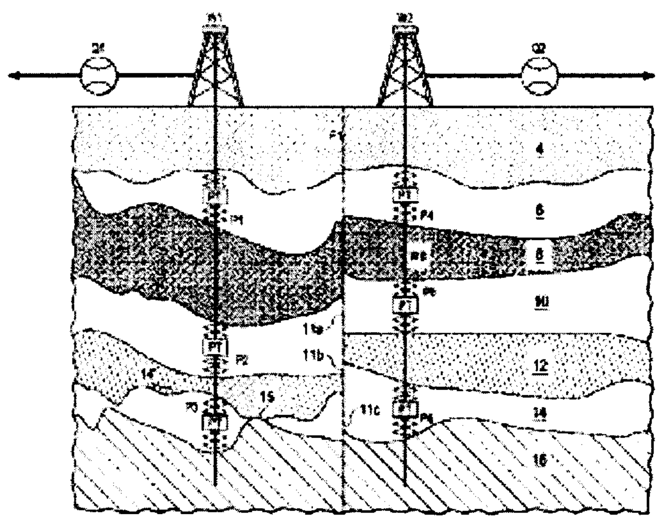

FIG. 1a

I/We claim:

1. A method of interactively deriving and validating a computerized model of a hydrocarbon reservoir with downhole measurements from one or more wells in the earth, comprising:

receiving data corresponding to downhole measurements acquired over time at a wellbore of at least one well of interest, and corresponding to flow rates from a plurality of wells including the well of interest;

receiving inputs from a user identifying attributes of a hydrocarbon reservoir, the attributes comprising shapes and properties of formation regions, connections between formation regions, and locations of wells into the formation regions;

operating a computer to evaluate pressure responses between each of a plurality of wells in the reservoir and the at least one well of interest in the reservoir by solving a fluid flow problem for a structure corresponding to the identified reservoir attributes;

operating a computer to superpose the data corresponding to measured flow rates from the plurality of wells to the evaluated pressure responses to calculate a simulated downhole pressure at the at least one well of interest over time;

comparing the simulated downhole pressure at the well of interest over time with data corresponding to downhole measurements acquired over time at the at least one well of interest;

after the comparing step, receiving inputs from a user modifying the reservoir attributes; and

then repeating the operating and comparing steps for the structure corresponding to the modified reservoir attributes.

2. The method of claim 1, wherein the identified reservoir attributes further comprise a plurality of perforations, each perforation corresponding to an intersection of one of the wells and one of the formation regions;

wherein the step of operating the computer to evaluate pressure responses comprises:

calculating a pressure interference response at each perforation in response to a unit flow rate at each perforation.

3. The method of claim 2, wherein the calculating step comprises:

defining a plurality of boundary nodes at boundaries of each of the formation regions;

for each of the perforations:

assigning a unit flow rate to the perforation and zero flow rate to others of the plurality of perforations; and

solving a system of equations to evaluate pressure at each of the boundary nodes in response to the unit flow rate at the perforation; and

then, for a selected perforation location:

selecting an interfering one of the plurality of perforations;

retrieving the pressure at each of the boundary nodes from the solving step in response to a unit flow rate at the selected interfering perforation; and

evaluating the pressure at the selected perforation location from the retrieved boundary node pressures, to arrive at a pressure interference response at the selected perforation location to unit flow rate from the interfering perforation; and

repeating the selecting, retrieving, and evaluating steps for each of the plurality of perforations as the interfering perforation.

4. The method of claim 3, wherein at least two or more of the formation regions are connected together at a common boundary;

and wherein the defined plurality of boundary nodes comprises common boundary nodes at the common boundary.

5. The method of claim 4, wherein three or more formation regions share a common point at the common boundary;

and further comprising:

defining a no-flow region at the common point, the no-flow region defining common boundary nodes that are common to no more than two of the formation regions.

6. The method of claim 2, wherein the step of operating the computer to evaluate pressure responses further comprises:

from the calculated pressure interference responses, for each of a plurality of perforations, deriving a well-level pressure interference response to a unit flow rate from each of the plurality of wells.

7. The method of claim 6, wherein the step of operating a computer to superpose the data comprises:

convolving the measured flow rates from the plurality of wells with the well-level pressure interference responses to derive a predicted pressure at the well of interest.

8. The method of claim 6, further comprising:

from the calculated pressure interference responses, for each of a plurality of perforations, deriving a well-level rate response to a unit flow rate from each of the plurality of wells; and

convolving the measured flow rates from the plurality of wells with the well-level rate responses to derive perforation flow rates for each of the perforations at the well of interest.

9. The method of claim 6, further comprising:

defining time grid points over a time period corresponding to completion times of the plurality of wells;

at each of the time grid points, solving a system of equations comprising equations expressing time-domain perforation flow rate changes caused by differences in initial pressure of formation regions corresponding to perforations in common wells;

evaluating residuals in the perforation flow rate changes from the solving step at each of the time grid points;

repeating the solving and evaluating steps until the residuals satisfy a convergence criterion;

then combining the perforation flow rate changes caused by differences in initial pressure of formation regions with the perforation flow rates corresponding to the measured flow rates; and

then evaluating perforation pressures at a well of interest responsive to the combined perforation flow rates.

10. The method of claim 2, wherein the step of operating a computer to superpose the data comprises:

defining time grid points over a time period corresponding to the measured flow rates from the plurality of wells;

at each of the time grid points, solving a system of equations comprising equations constraining time-domain perforation flow rates and pressure derivatives to a corresponding well flow rate, and equations constraining perforation pressures within a corresponding well and including a turbulence expression, to derive perforation flow rates at the time grid points;

evaluating residuals corresponding to a difference in the evaluated perforation flow rates in the system of equations;

repeating the solving and evaluating steps until the residuals satisfy a convergence criterion; and

evaluating downhole pressure over the time period for at least one of the plurality of wells.

11. A computer system, comprising:

an interface for receiving measurement data corresponding to measurements from one or more hydrocarbon wells;

an input device for receiving inputs from a user of the system;

one or more central processing units coupled to the interface and to the input device, for executing program instructions; and program memory, coupled to the one or more central processing units, for storing a computer program including program instructions that, when executed by the one or more central processing units, cause the computer system to perform a plurality of operations interactively deriving and validating a computerized model of a hydrocarbon reservoir with downhole measurements from one or more wells in the earth, the plurality of operations comprising:

receiving measurement data via the interface, the measurement data corresponding to downhole measurements acquired over time at a wellbore of at least one well of interest, and corresponding to flow rates from a plurality of wells including the well of interest;

receiving inputs from a user identifying attributes of a hydrocarbon reservoir, the attributes comprising shapes and properties of formation regions, connections between formation regions, and locations of wells into the formation regions;

evaluating pressure responses between each of a plurality of wells in the reservoir and the at least one well of interest in the reservoir by solving a fluid flow problem for a structure corresponding to the identified reservoir attributes;

superposing the data corresponding to measured flow rates from the plurality of wells to the evaluated pressure responses to calculate a simulated downhole pressure at the at least one well of interest over time;

comparing the simulated downhole pressure at the well of interest over time with data corresponding to downhole measurements acquired over time at the at least one well of interest;

after the comparing operation, receiving inputs from a user modifying the reservoir attributes; and

then repeating the evaluating, superposing, and comparing operations for the structure corresponding to the modified reservoir attributes.

12. The system of claim 11, wherein the identified reservoir attributes further comprise a plurality of perforations, each perforation corresponding to an intersection of one of the wells and one of the formation regions;

wherein the evaluating operation comprises:

calculating a pressure interference response at each perforation in response to a unit flow rate at each perforation.

13. The system of claim 12, wherein the calculating operation comprises:

receiving inputs from a user defining a plurality of boundary nodes at boundaries of each of the formation regions;

for each of the perforations:

assigning a unit flow rate to the perforation and zero flow rate to others of the plurality of perforations; and

solving a system of equations to evaluate pressure at each of the boundary nodes in response to the unit flow rate at the perforation; and

then, for a selected perforation location:

selecting an interfering one of the plurality of perforations;

retrieving the pressure at each of the boundary nodes from the solving step in response to a unit flow rate at the selected interfering perforation; and

evaluating the pressure at the selected perforation location from the retrieved boundary node pressures, to arrive at a pressure interference response at the selected perforation location to unit flow rate from the interfering perforation; and

repeating the selecting, retrieving, and evaluating operations for each of the plurality of perforations as the interfering perforation.

14. The system of claim 13, wherein at least two or more of the formation regions are connected together at a common boundary;

and wherein the defined plurality of boundary nodes comprises common boundary nodes at the common boundary.

15. The system of claim 14, wherein three or more formation regions share a common point at the common boundary;

and wherein the plurality of operations further comprises:

defining a no-flow region at the common point, the no-flow region defining common boundary nodes that are common to no more than two of the formation regions.

16. The system of claim 12, wherein the evaluating operation further comprises:

from the calculated pressure interference responses, for each of a plurality of perforations, deriving a well-level pressure interference response to a unit flow rate from each of the plurality of wells.

17. The system of claim 16, wherein the superposing operation comprises:

convolving the measured flow rates from the plurality of wells with the well-level pressure interference responses to derive a predicted pressure at the well of interest.

18. The system of claim 16, wherein the plurality of operations further comprises:

from the calculated pressure interference responses, for each of a plurality of perforations, deriving a well-level rate response to a unit flow rate from each of the plurality of wells; and

convolving the measured flow rates from the plurality of wells with the well-level rate responses to derive perforation flow rates for each of the perforations at the well of interest.

19. The system of claim 16, wherein the plurality of operations further comprises:

defining time grid points over a time period corresponding to completion times of the plurality of wells;

at each of the time grid points, solving a system of equations comprising equations expressing time-domain perforation flow rate changes caused by differences in initial pressure of formation regions corresponding to perforations in common wells;

evaluating residuals in the perforation flow rate changes from the solving step at each of the time grid points;

repeating the solving and evaluating operations until the residuals satisfy a convergence criterion;

then combining the perforation flow rate changes caused by differences in initial pressure of formation regions with the perforation flow rates corresponding to the measured flow rates; and

then evaluating perforation pressures at a well of interest responsive to the combined perforation flow rates.

20. The system of claim 12, wherein the superposing operation comprises:

defining time grid points over a time period corresponding to the measured flow rates from the plurality of wells;

at each of the time grid points, solving a system of equations comprising equations constraining time-domain perforation flow rates and pressure derivatives to a corresponding well flow rate, and equations constraining perforation pressures within a corresponding well and including a turbulence expression, to derive perforation flow rates at the time grid points;

evaluating residuals corresponding to a difference in the evaluated perforation flow rates in the system of equations;

repeating the solving and evaluating operations until the residuals satisfy a convergence criterion; and

evaluating downhole pressure over the time period for at least one of the plurality of wells.

21. A computer-readable medium storing a computer program that, when executed on a computer system, causes the computer system to perform a plurality of operations interactively deriving and validating a computerized model of a hydrocarbon reservoir with downhole measurements from one or more wells in the earth, the plurality of operations comprising:

receiving measurement data corresponding to downhole measurements acquired over time at a wellbore of at least one well of interest, and corresponding to flow rates from a plurality of wells including the well of interest;

receiving inputs from a user identifying attributes of a hydrocarbon reservoir, the attributes comprising shapes and properties of formation regions, connections between formation regions, and locations of wells into the formation regions;

evaluating pressure responses between each of a plurality of wells in the reservoir and the at least one well of interest in the reservoir by solving a fluid flow problem for a structure corresponding to the identified reservoir attributes;

superposing the data corresponding to measured flow rates from the plurality of wells to the evaluated pressure responses to calculate a simulated downhole pressure at the at least one well of interest over time;

comparing the simulated downhole pressure at the well of interest over time with data corresponding to downhole measurements acquired over time at the at least one well of interest;

after the comparing operation, receiving inputs from a user modifying the reservoir attributes; and

then repeating the evaluating, superposing, and comparing operations for the structure corresponding to the modified reservoir attributes.

22. The computer-readable medium of claim 21, wherein the identified reservoir attributes further comprise a plurality of perforations, each perforation corresponding to an intersection of one of the wells and one of the formation regions;

wherein the evaluating operation comprises:

calculating a pressure interference response at each perforation in response to a unit flow rate at each perforation.

23. The computer-readable medium of claim 22, wherein the calculating operation comprises:

receiving inputs from a user defining a plurality of boundary nodes at boundaries of each of the formation regions;

for each of the perforations:

assigning a unit flow rate to the perforation and zero flow rate to others of the plurality of perforations; and solving a system of equations to evaluate pressure at each of the boundary nodes in response to the unit flow rate at the perforation; and

then, for a selected perforation location:

selecting an interfering one of the plurality of perforations;

retrieving the pressure at each of the boundary nodes from the solving step in response to a unit flow rate at the selected interfering perforation; and

evaluating the pressure at the selected perforation location from the retrieved boundary node pressures, to arrive at a pressure interference response at the selected perforation location to unit flow rate from the interfering perforation; and

repeating the selecting, retrieving, and evaluating operations for each of the plurality of perforations as the interfering perforation.

24. The computer-readable medium of claim 23, wherein at least two or more of the formation regions are connected together at a common boundary;

and wherein the defined plurality of boundary nodes comprises common boundary nodes at the common boundary.

25. The computer-readable medium of claim 24, wherein three or more formation regions share a common point at the common boundary;

and wherein the plurality of operations further comprises:

defining a no-flow region at the common point, the no-flow region defining common boundary nodes that are common to no more than two of the formation regions.

26. The computer-readable medium of claim 22, wherein the evaluating operation further comprises:

from the calculated pressure interference responses, for each of a plurality of perforations, deriving a well-level pressure interference response to a unit flow rate from each of the plurality of wells.

27. The computer-readable medium of claim 26, wherein the superposing operation comprises:

convolving the measured flow rates from the plurality of wells with the well-level pressure interference responses to derive a predicted pressure at the well of interest.

28. The computer-readable medium of claim 26, wherein the plurality of operations further comprises:

from the calculated pressure interference responses, for each of a plurality of perforations, deriving a well-level rate response to a unit flow rate from each of the plurality of wells; and

convolving the measured flow rates from the plurality of wells with the well-level rate responses to derive perforation flow rates for each of the perforations at the well of interest.

29. The computer-readable medium of claim 26, wherein the plurality of operations further comprises:

defining time grid points over a time period corresponding to completion times of the plurality of wells;

at each of the time grid points, solving a system of equations comprising equations expressing time-domain perforation flow rate changes caused by differences in initial pressure of formation regions corresponding to perforations in common wells;

evaluating residuals in the perforation flow rate changes from the solving step at each of the time grid points;

repeating the solving and evaluating operations until the residuals satisfy a convergence criterion;

then combining the perforation flow rate changes caused by differences in initial pressure of formation regions with the perforation flow rates corresponding to the measured flow rates; and

then evaluating perforation pressures at a well of interest responsive to the combined perforation flow rates.

30. The computer-readable medium of claim 22, wherein the superposing operation comprises:

defining time grid points over a time period corresponding to the measured flow rates from the plurality of wells;

at each of the time grid points, solving a system of equations comprising equations constraining time-domain perforation flow rates and pressure derivatives to a corresponding well flow rate, and equations constraining perforation pressures within a corresponding well and including a turbulence expression, to derive perforation flow rates at the time grid points;

evaluating residuals corresponding to a difference in the evaluated perforation flow rates in the system of equations;

repeating the solving and evaluating operations until the residuals satisfy a convergence criterion; and

evaluating downhole pressure over the time period for at least one of the plurality of wells.

Dated this 13 March, 2012

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To
The Controller of Patents
The Patent Office at New Delhi

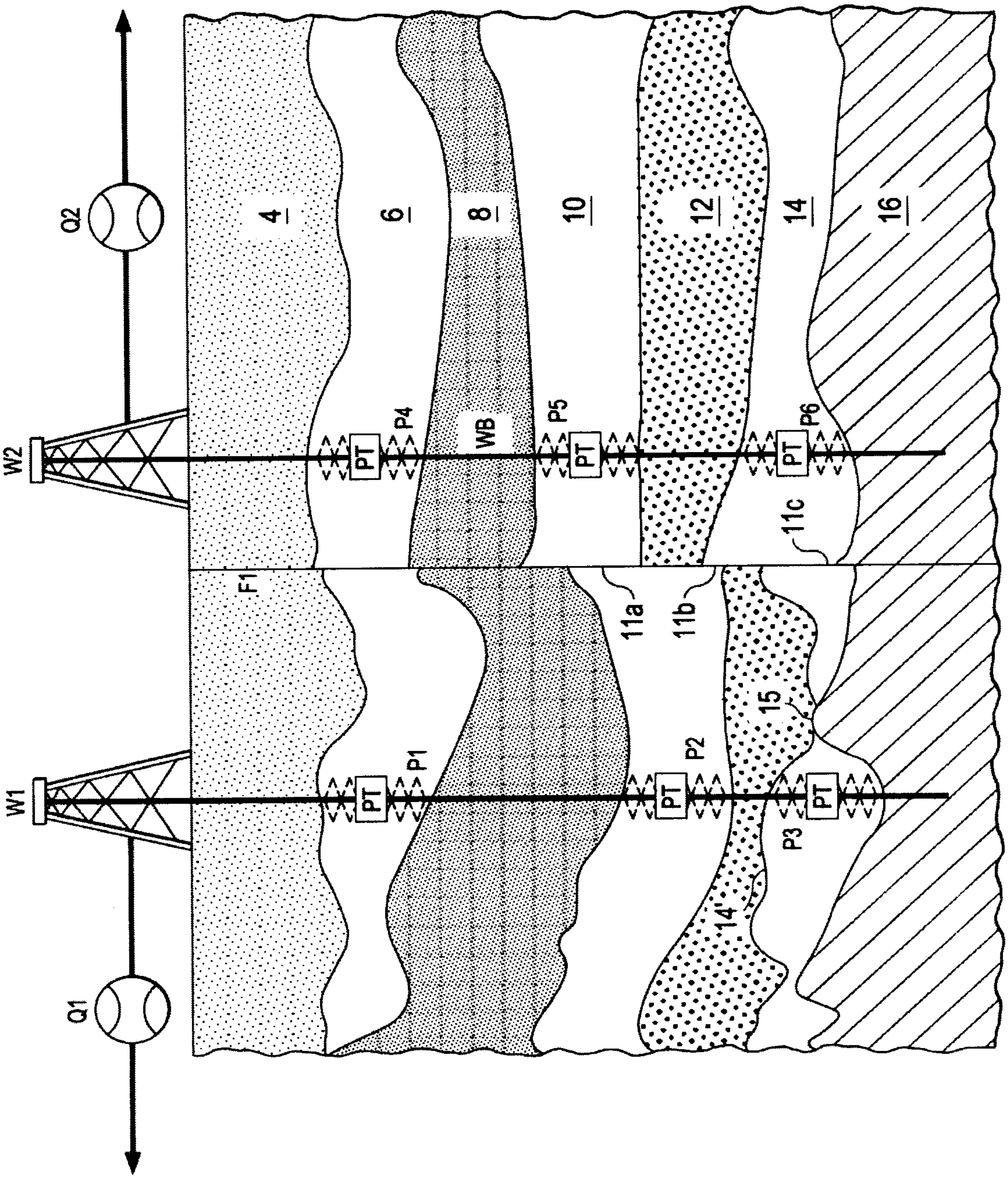
2189-DELNP-2

Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 1
Application No: Total No. of Sheets: 24

13 MAR 2012

ORIGINAL

FIG. 1a



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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 2
Application No: Total No. of Sheets: 24

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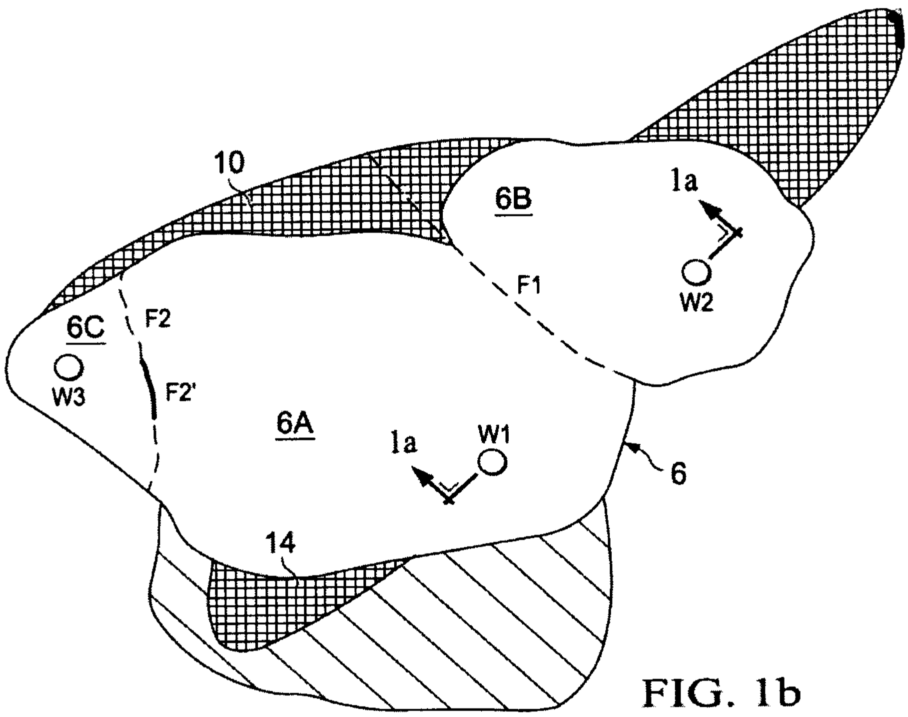

FIG. 1b

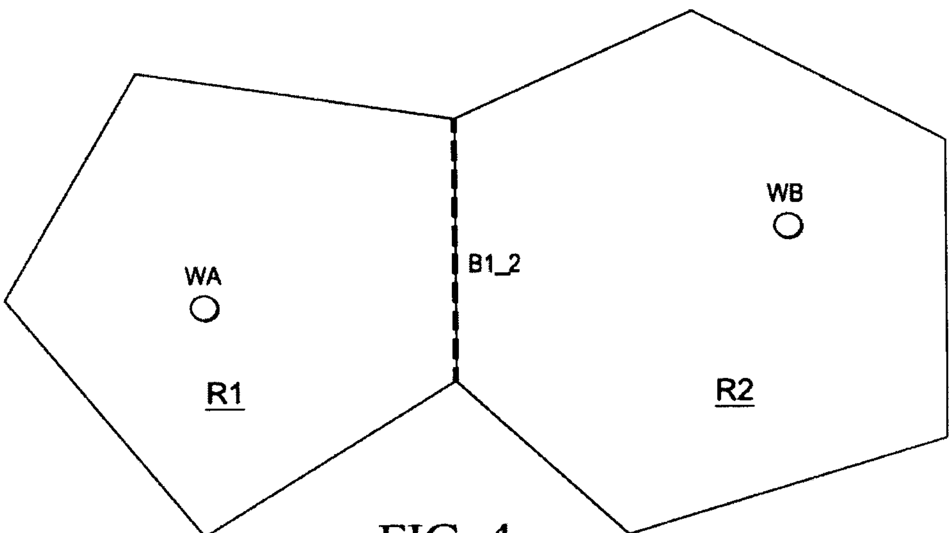

FIG. 4

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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 3
Application No: Total No. of Sheets: 24

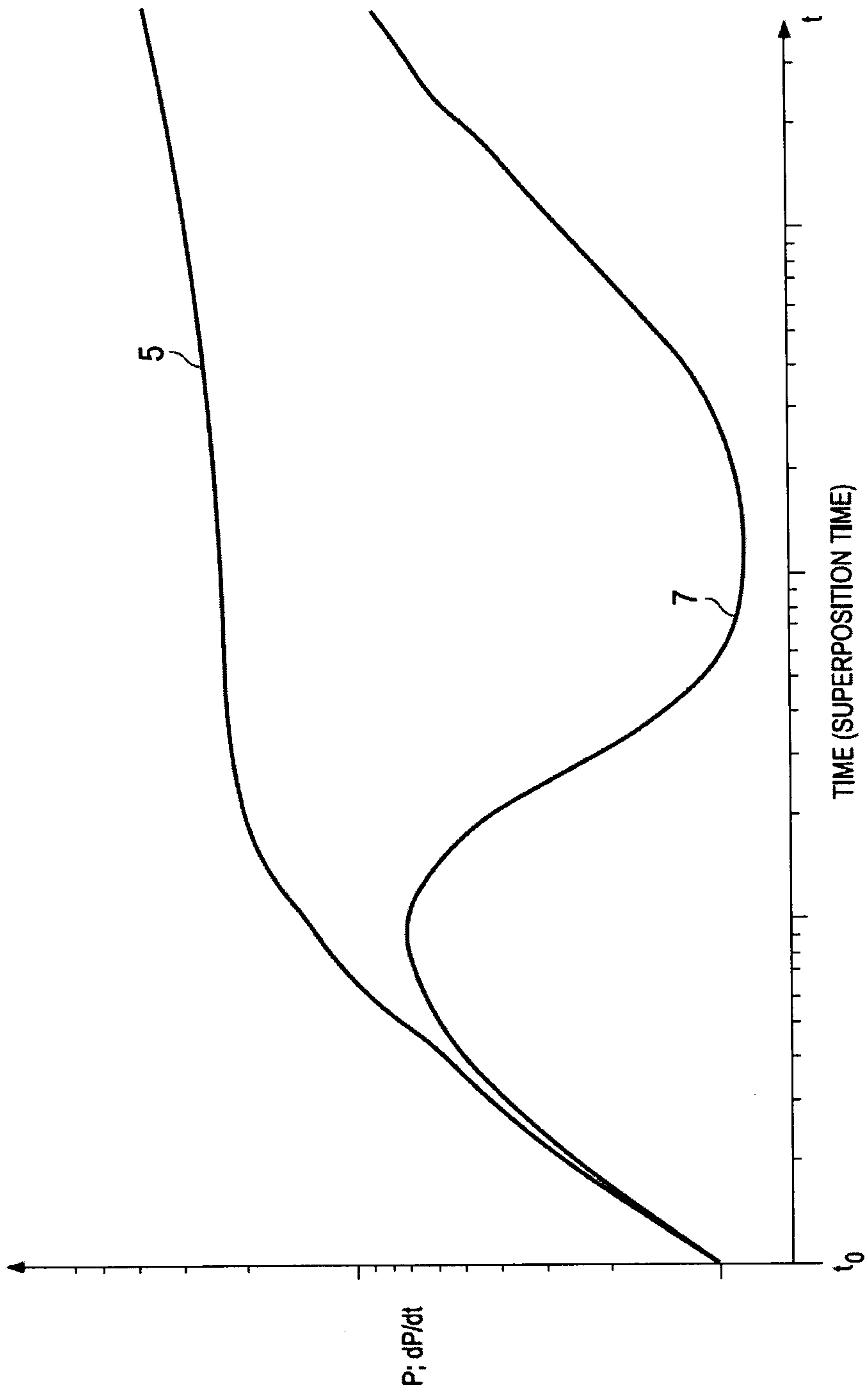

FIG. 1c

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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 4
Application No: Total No. of Sheets: 24

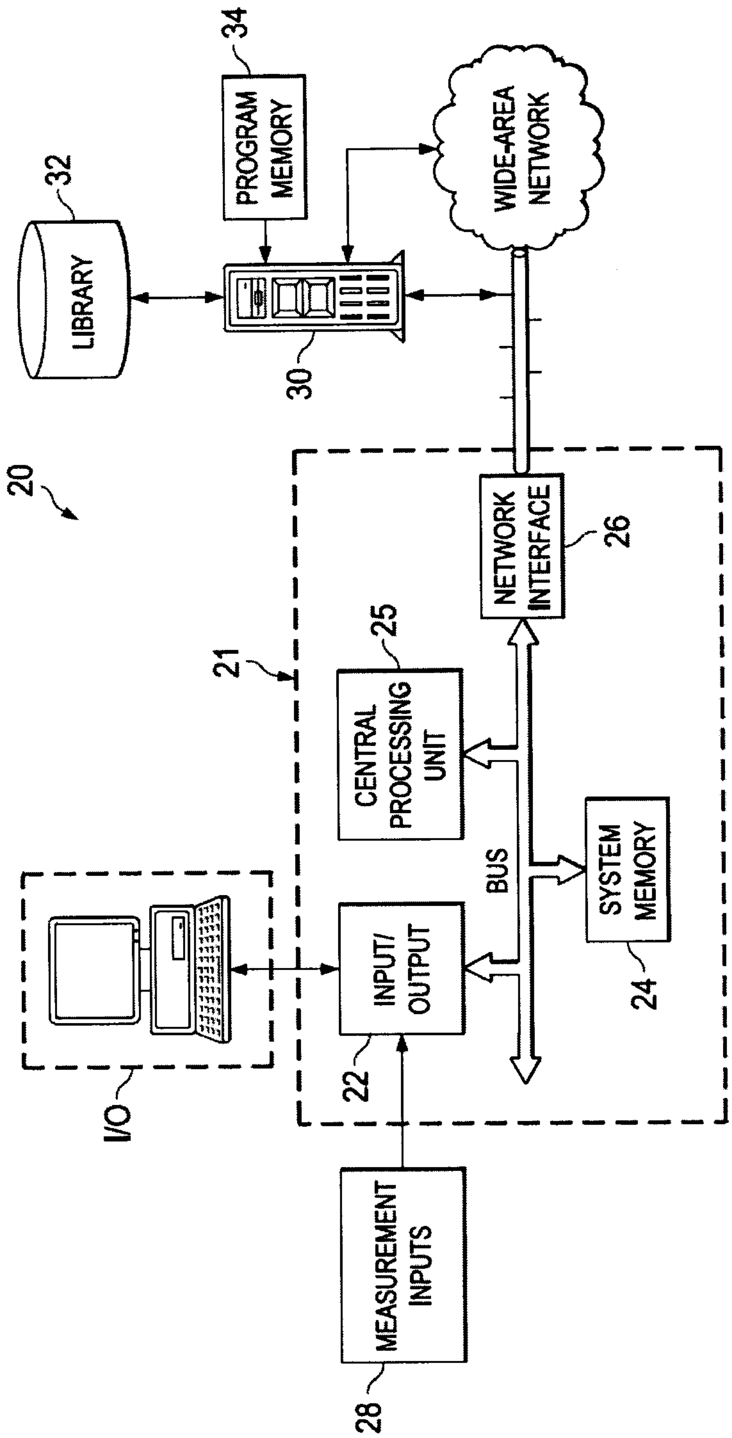

FIG. 2

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2189DELNP 12

Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 5
Application No: Total No. of Sheets: 24

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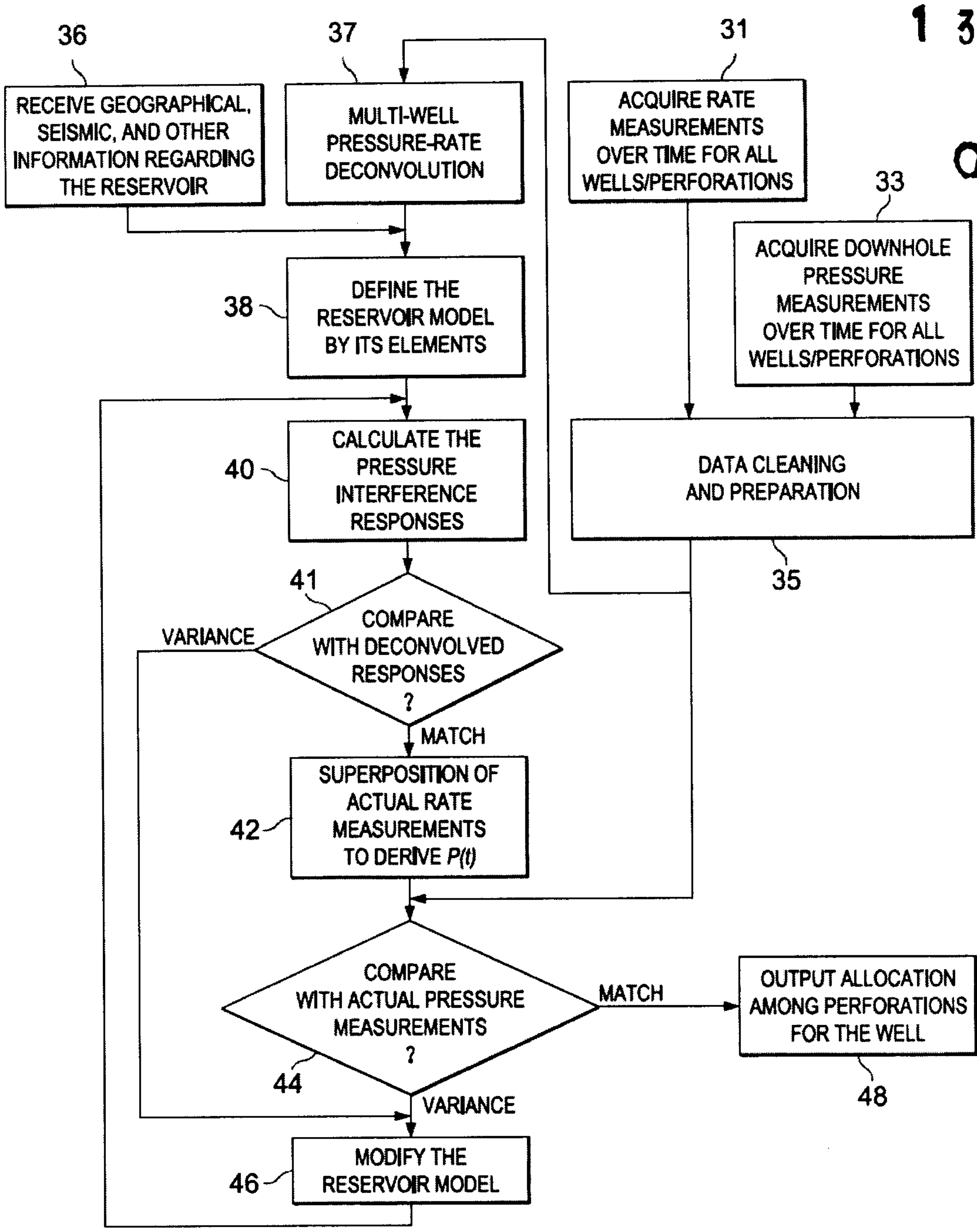

FIG. 3

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2189DELNP - 2

Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 6
Application No: Total No. of Sheets: 24

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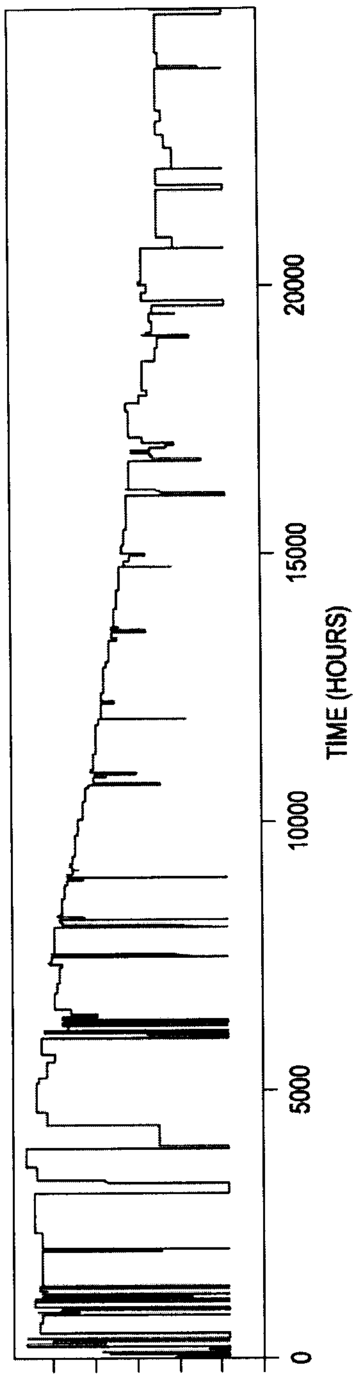

FIG. 5a

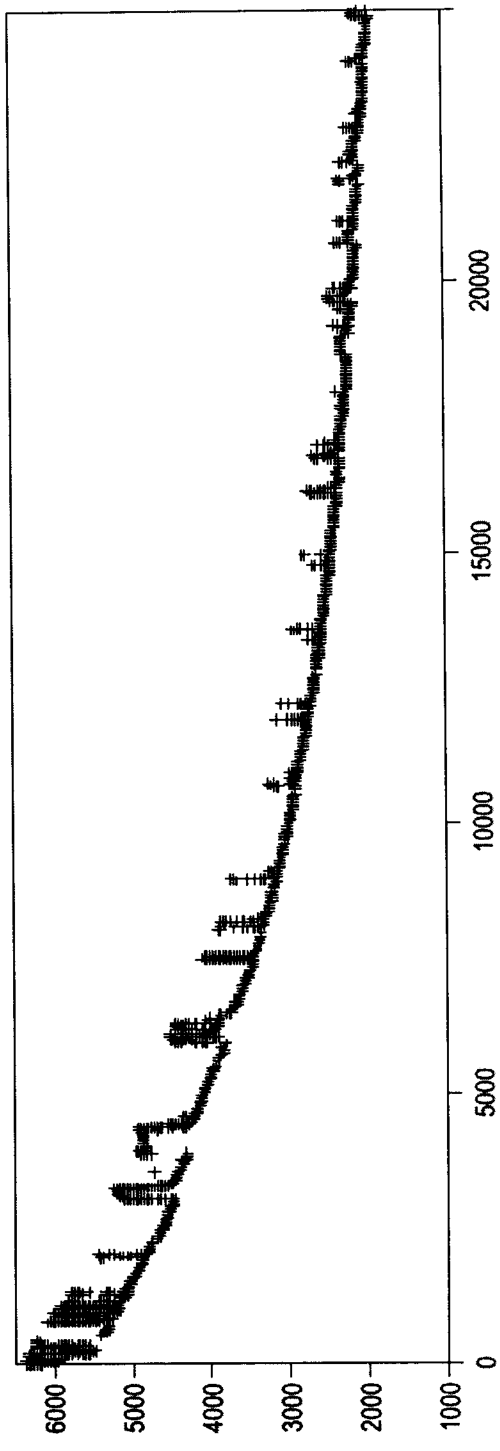

FIG. 5b

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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 7
Application No: Total No. of Sheets: 24

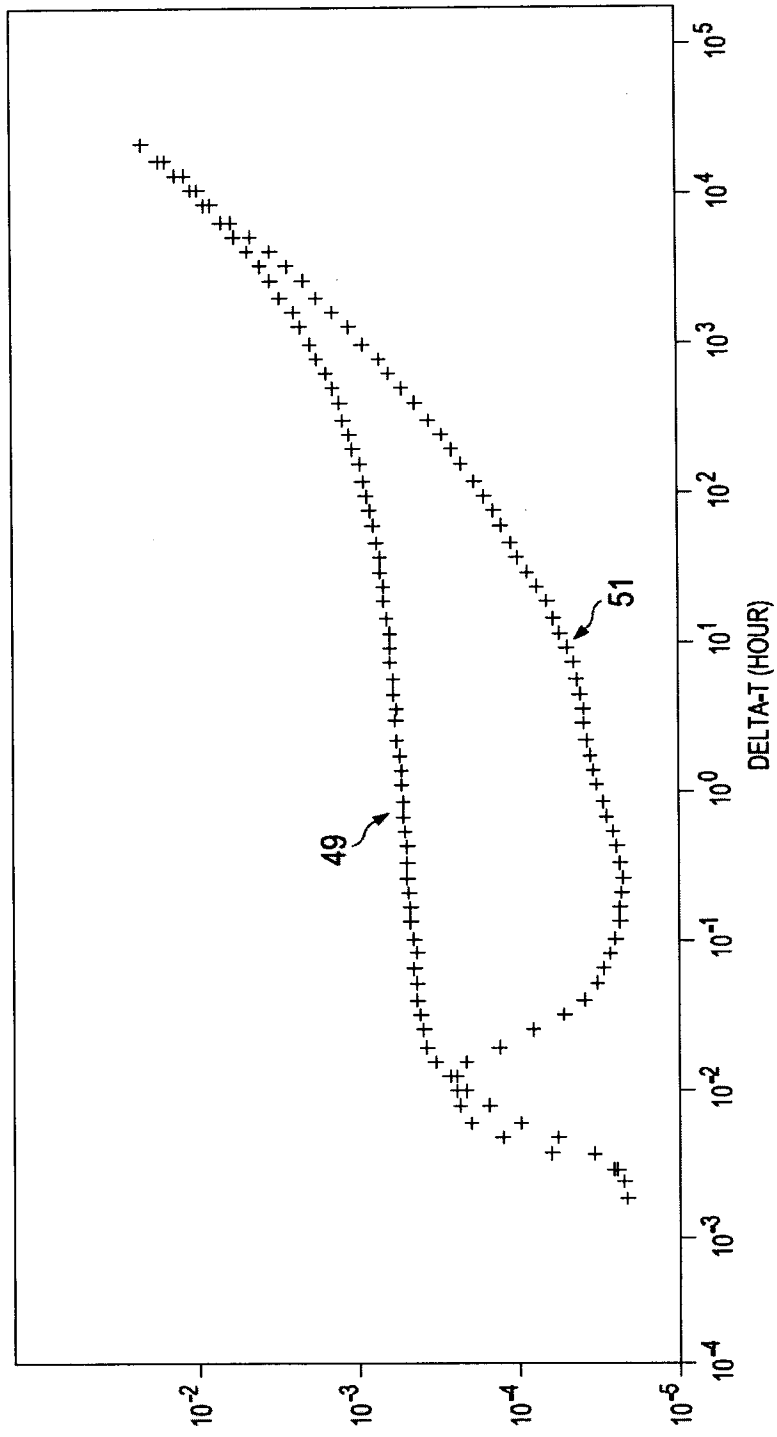

FIG. 5c

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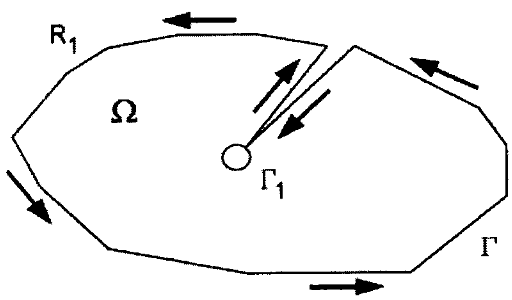

FIG. 6a

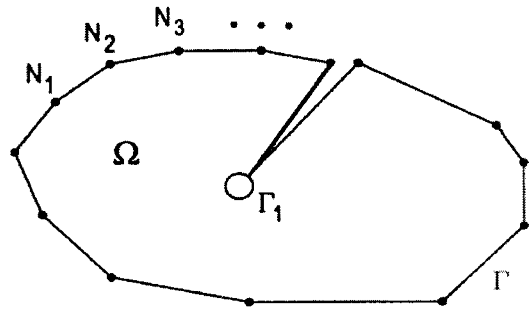

FIG. 6b

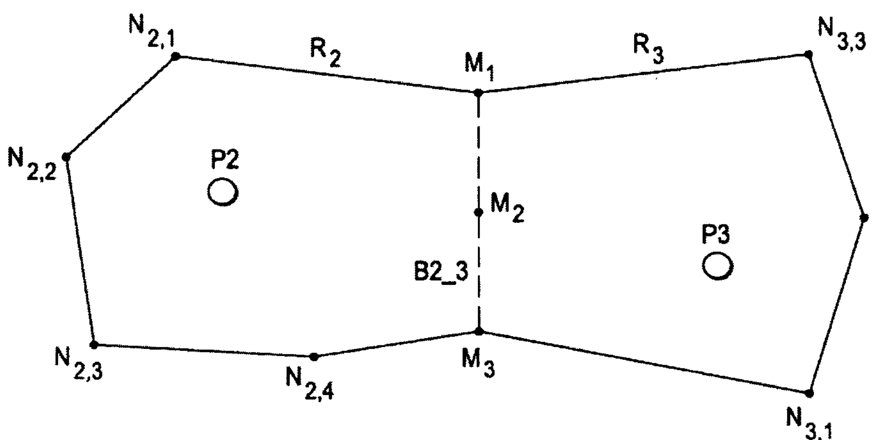

FIG. 6c

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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 9
Application No: Total No. of Sheets: 24

1 3 MAR 2012

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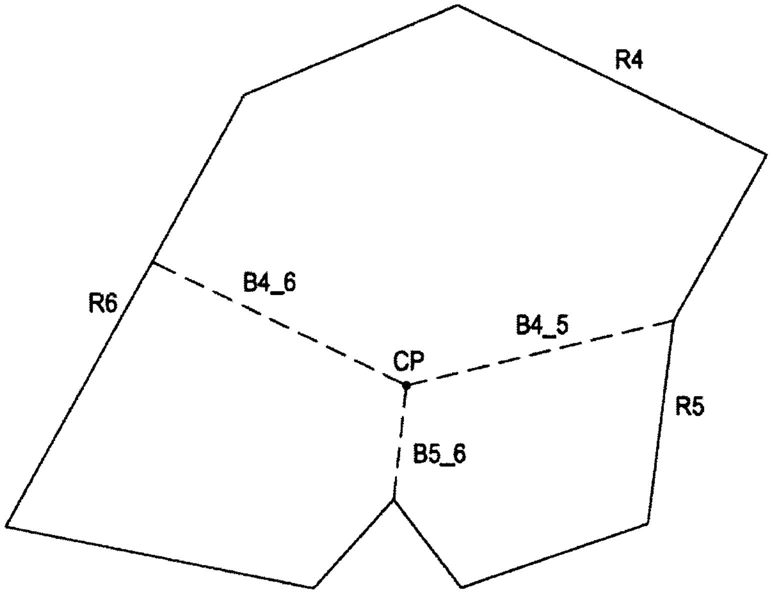

FIG. 6d

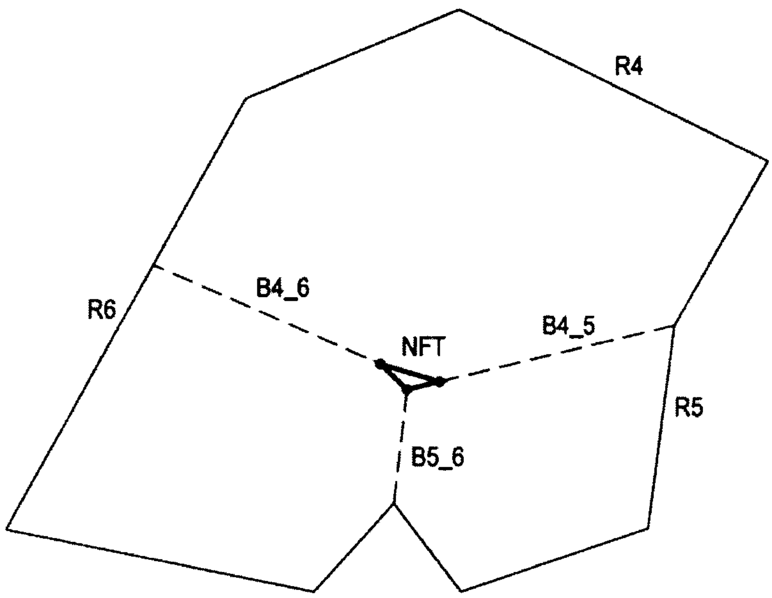

FIG. 6e

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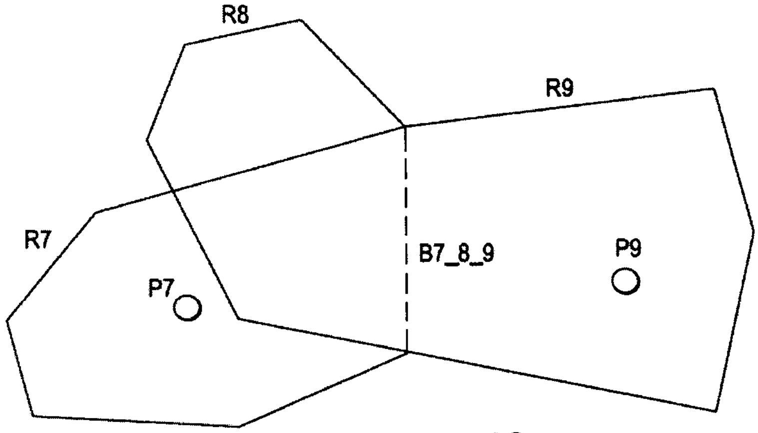

FIG. 6f

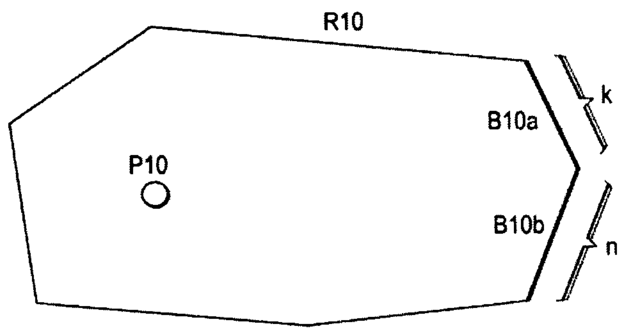

FIG. 6g

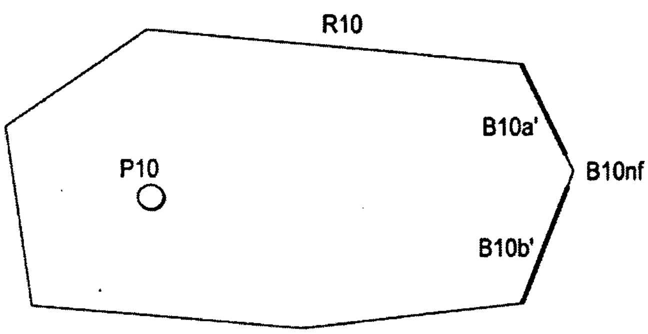

FIG. 6h

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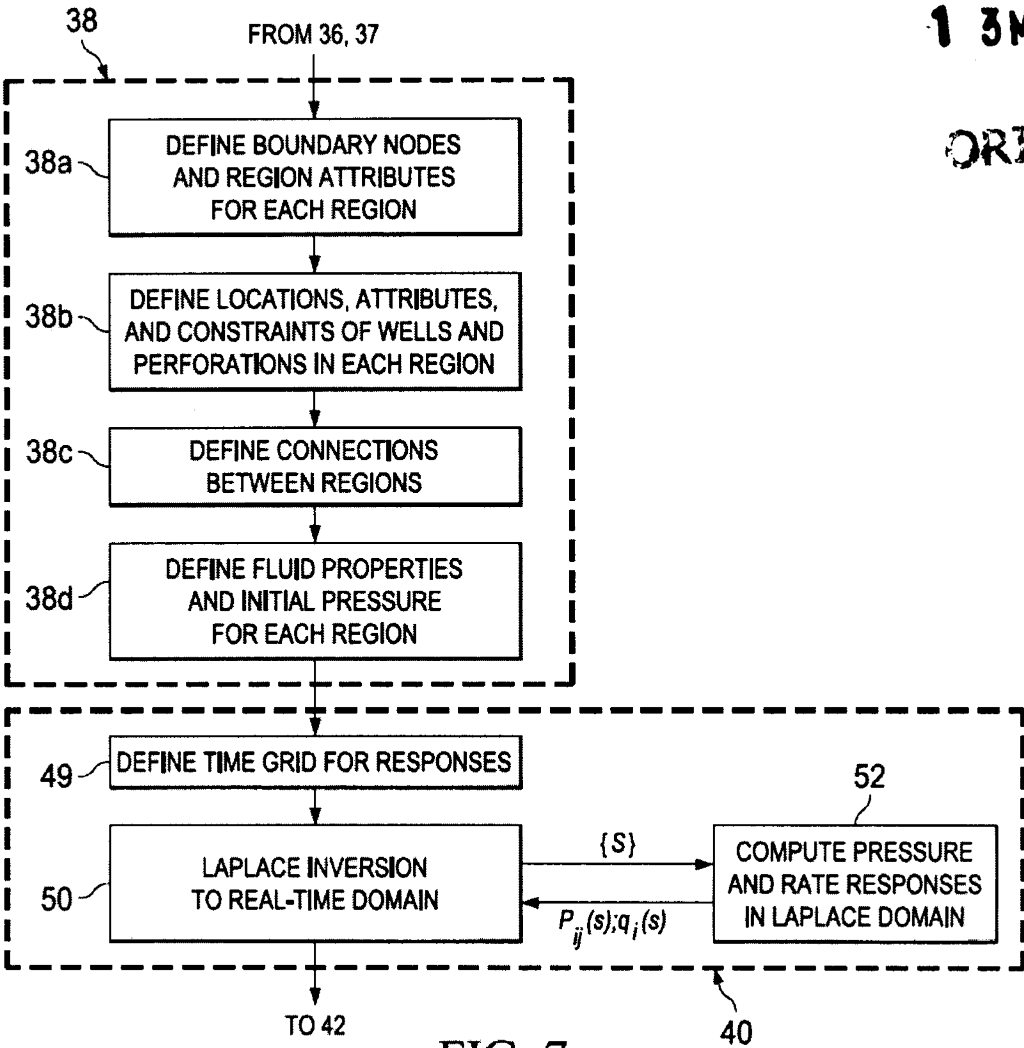

FIG. 7a

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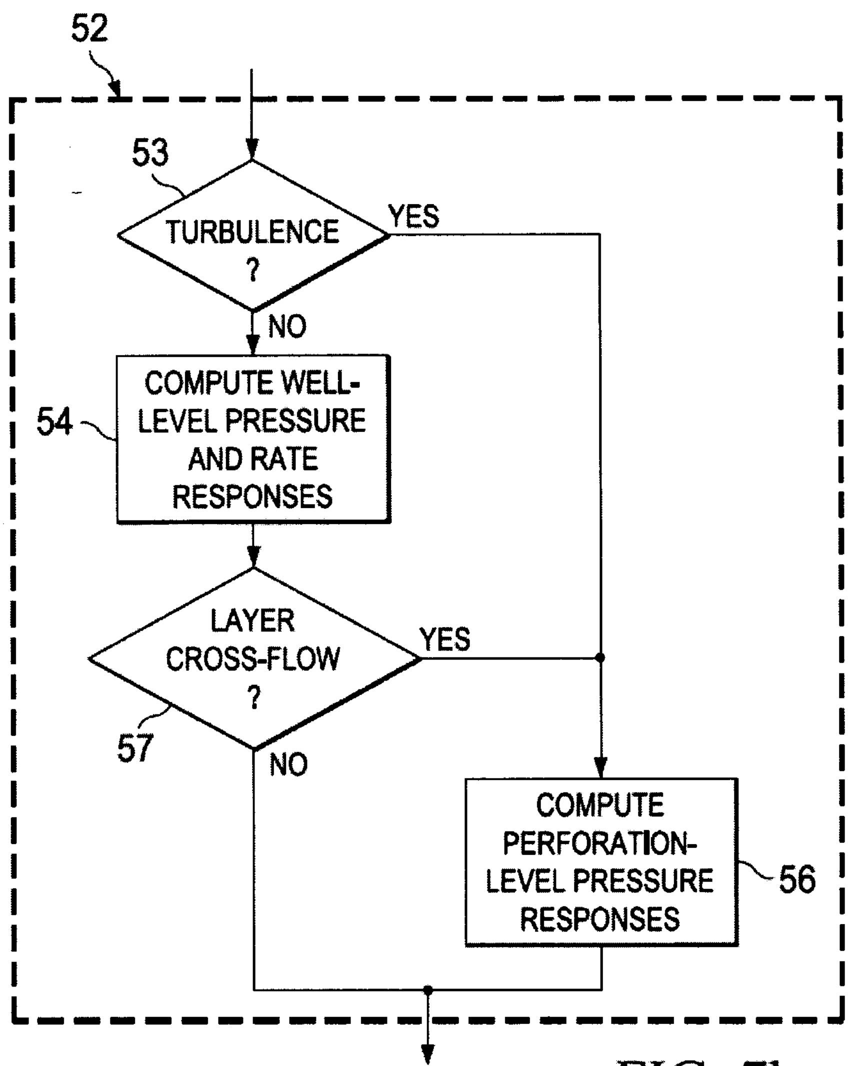

FIG. 7b

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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 13
Application No: Total No. of Sheets: 24

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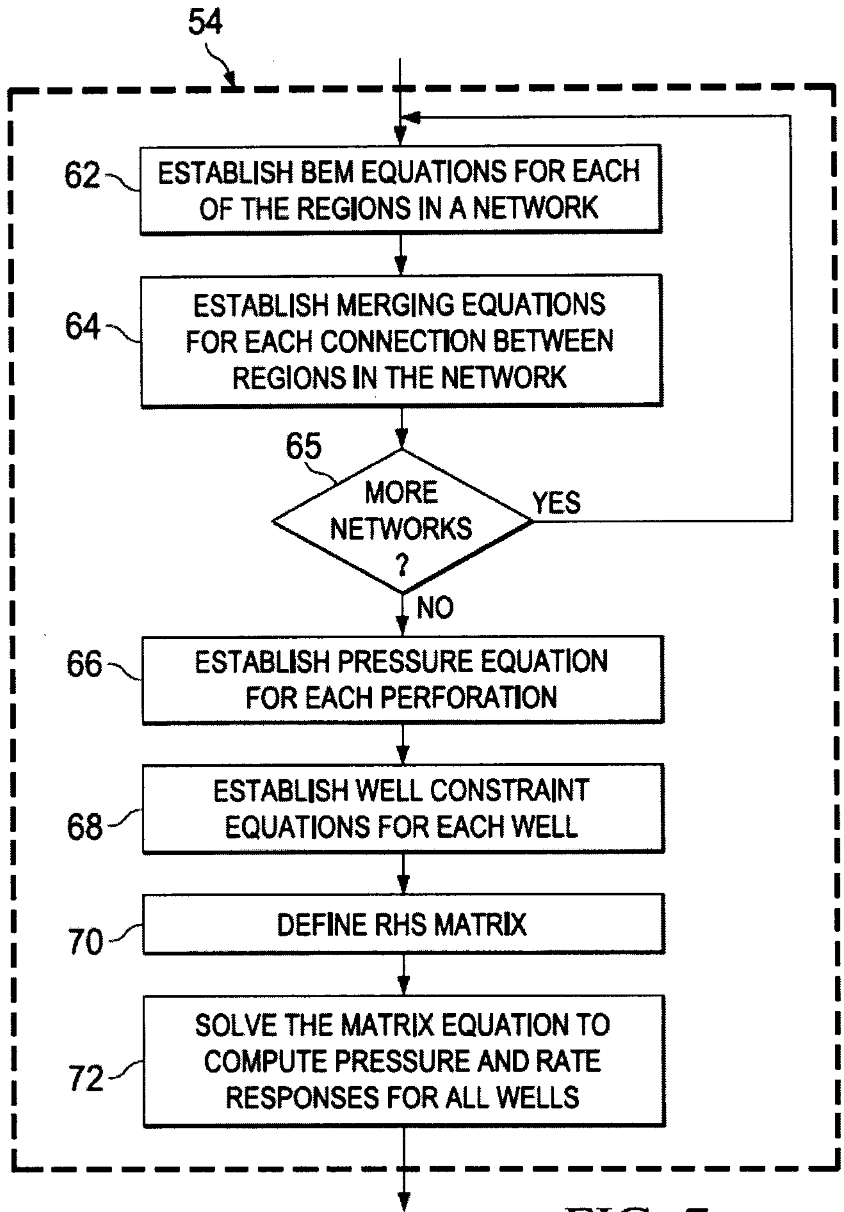

FIG. 7c

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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 14
Application No: Total No. of Sheets: 24

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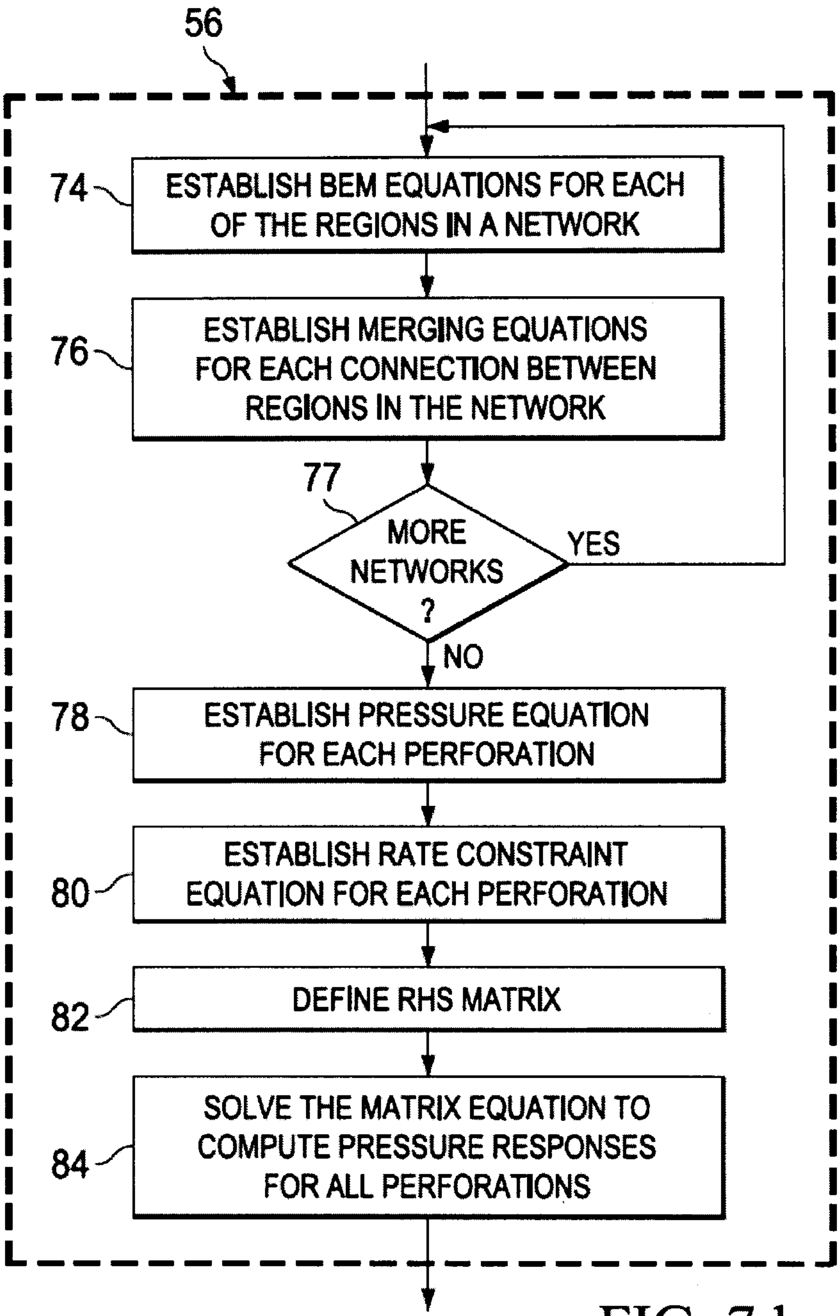

FIG. 7d

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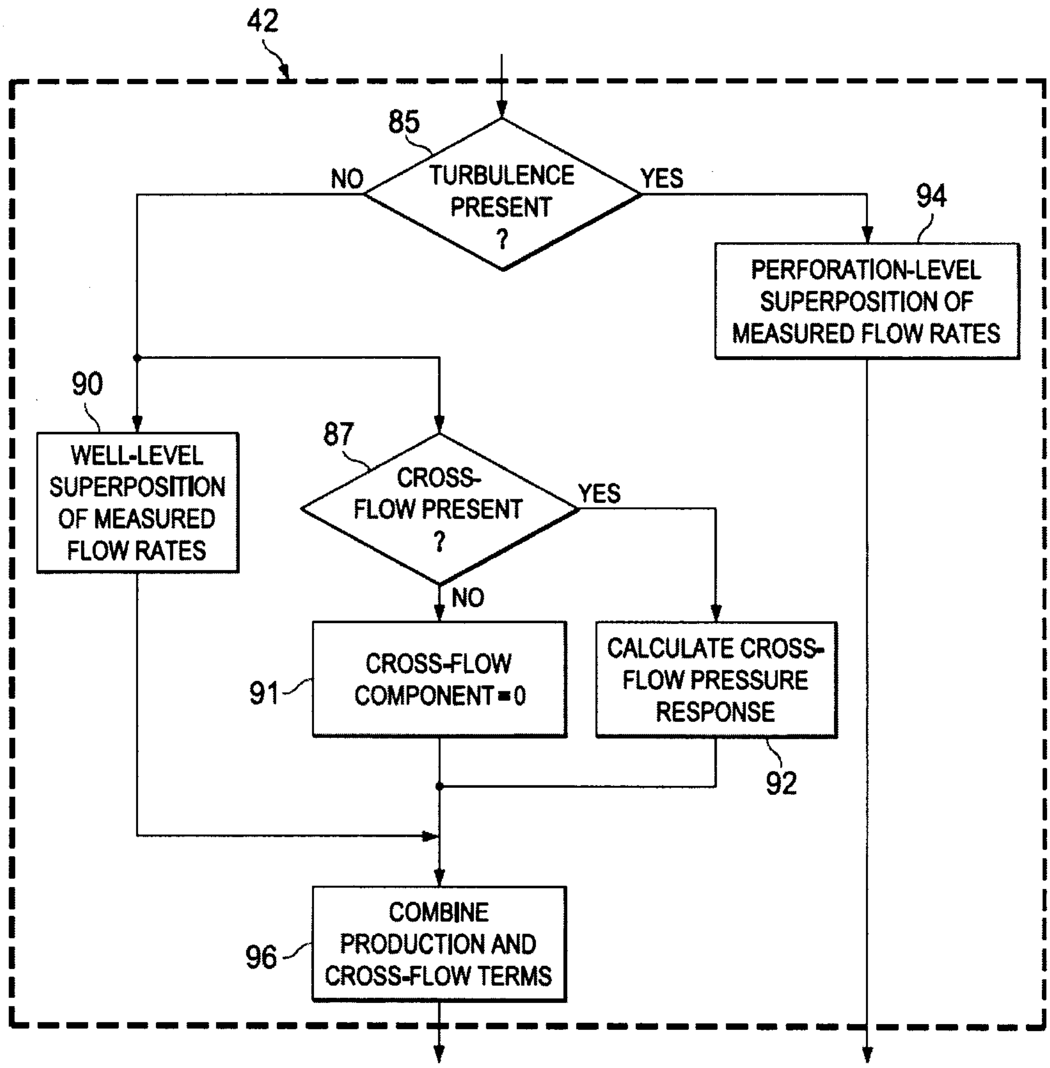

FIG. 8

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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 16
Application No: Total No. of Sheets: 24

1 3 MAR 2012

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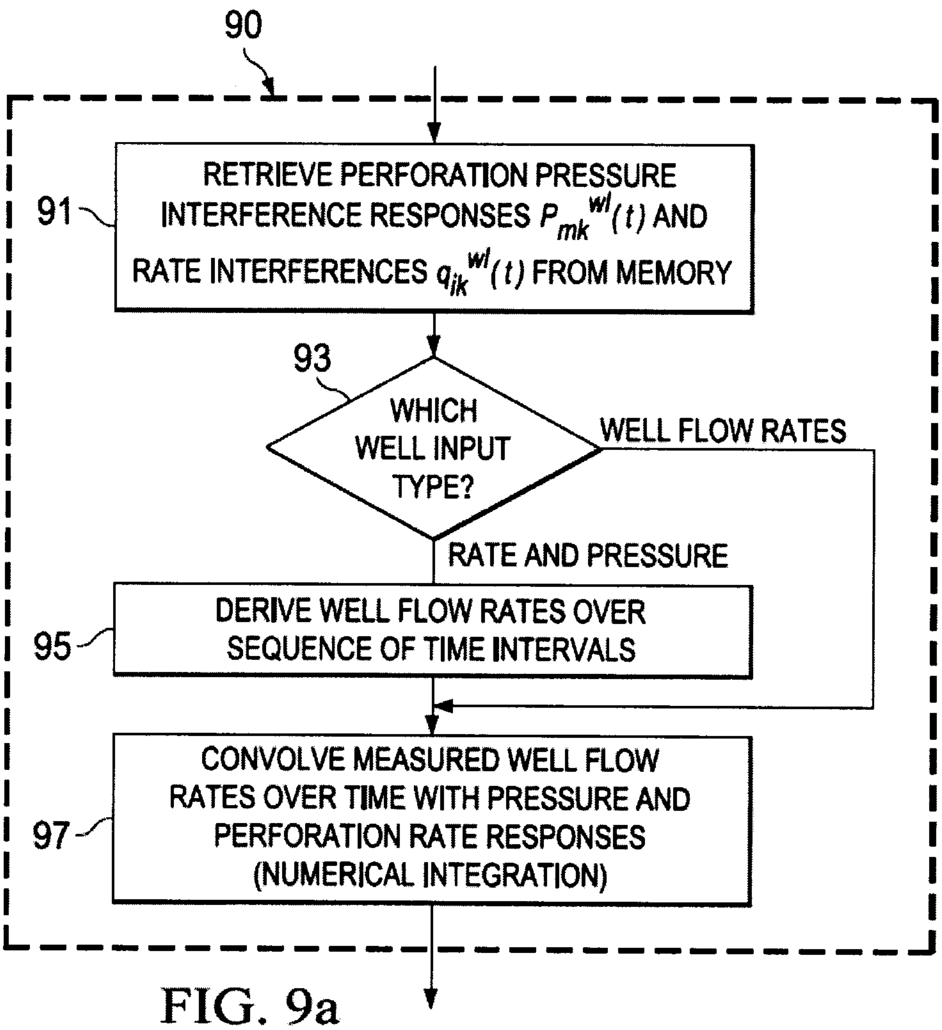

FIG. 9a

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2189 DELNP 1

Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 17
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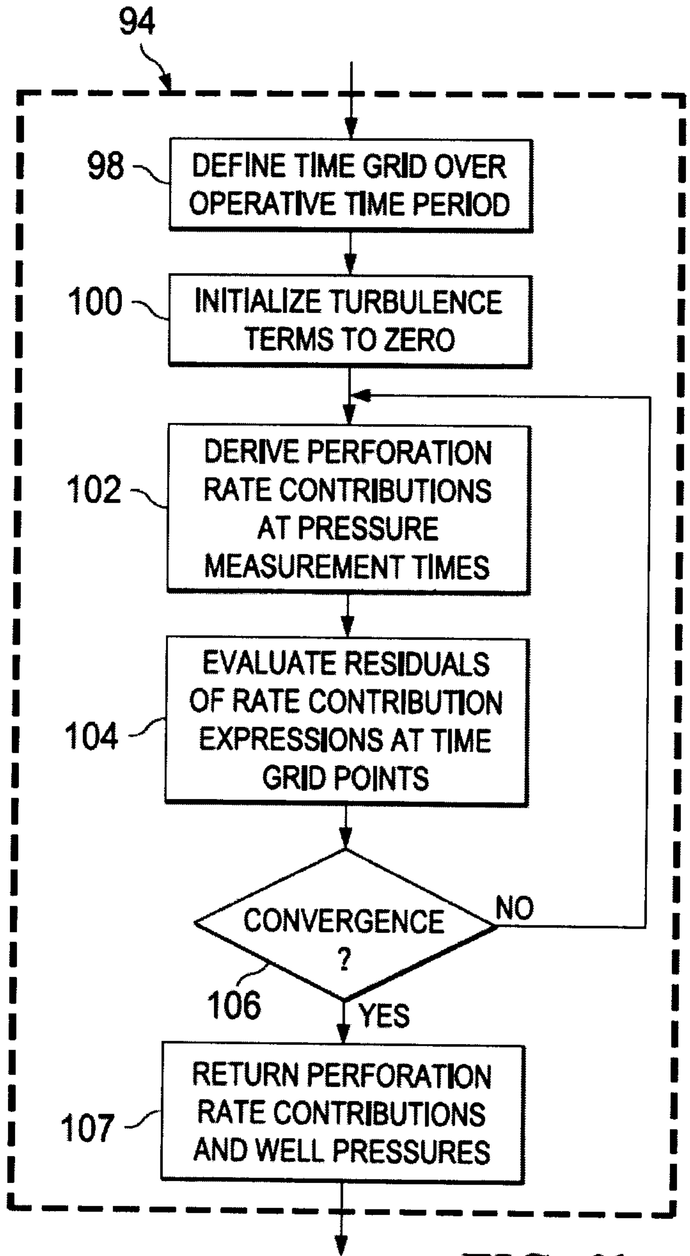

FIG. 9b

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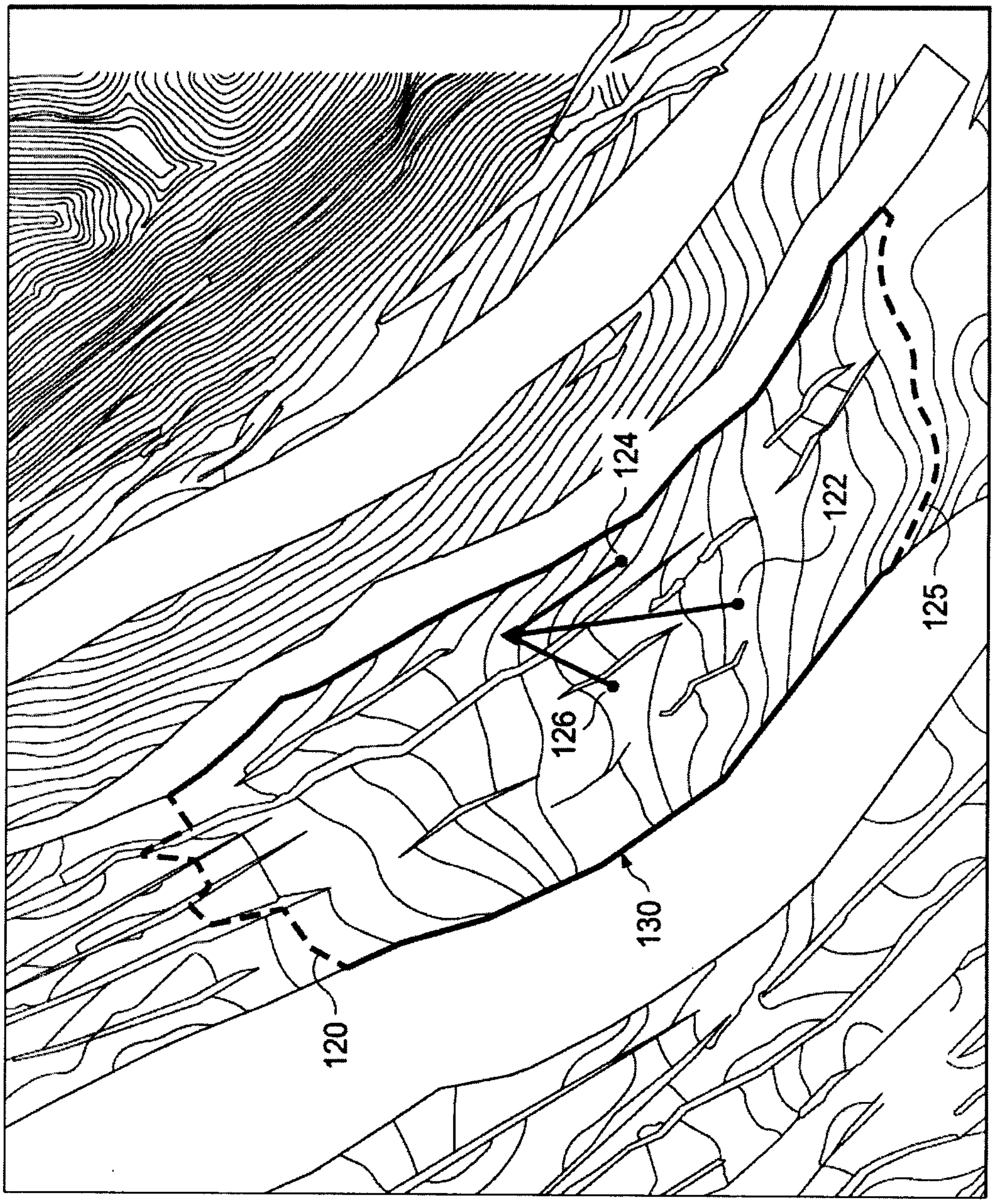

FIG. 10a

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2189DELNP12

Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 19
Application No: Total No. of Sheets: 24

1 3 MAR 2012

ORIGINAL

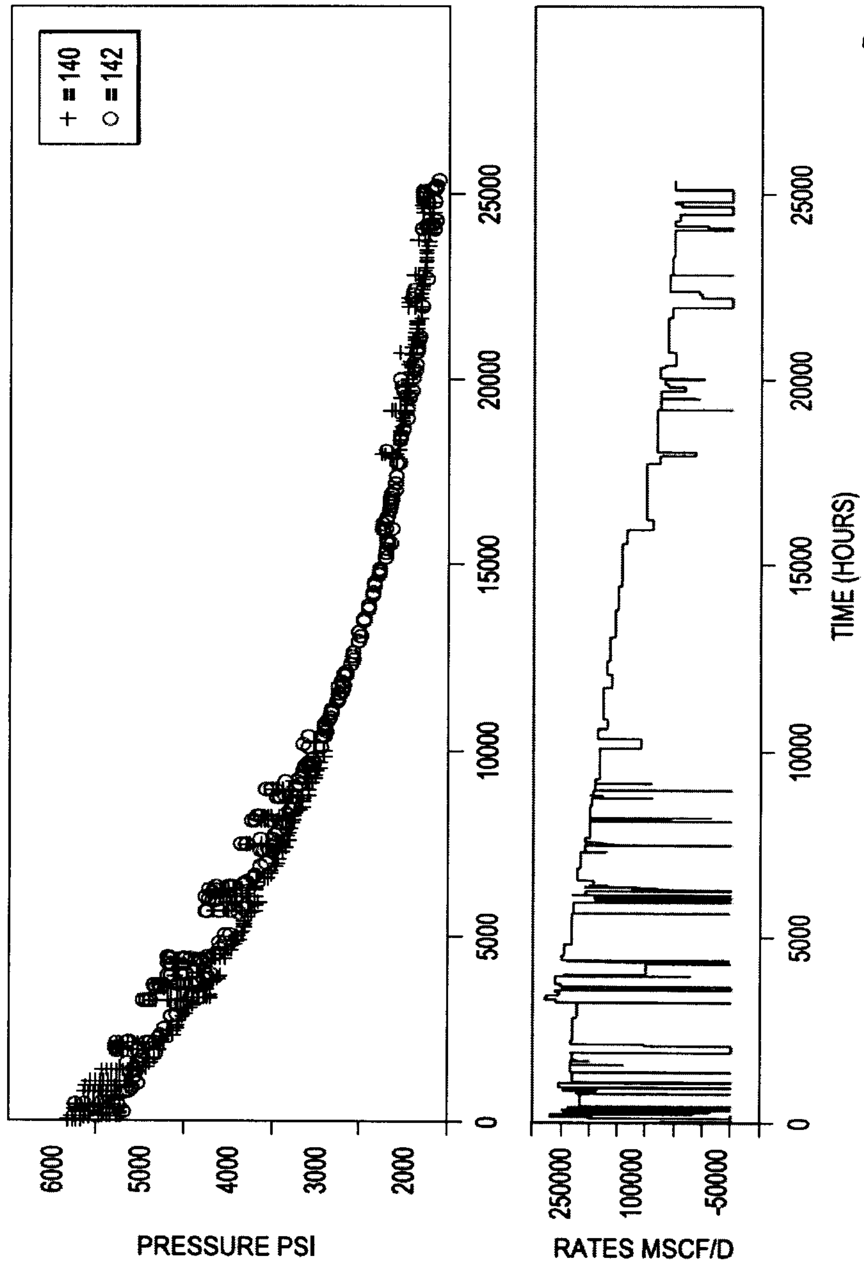

FIG. 10b

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2189 DELNP 12

Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 20
Application No: Total No. of Sheets: 24

1 3 MAR 2012

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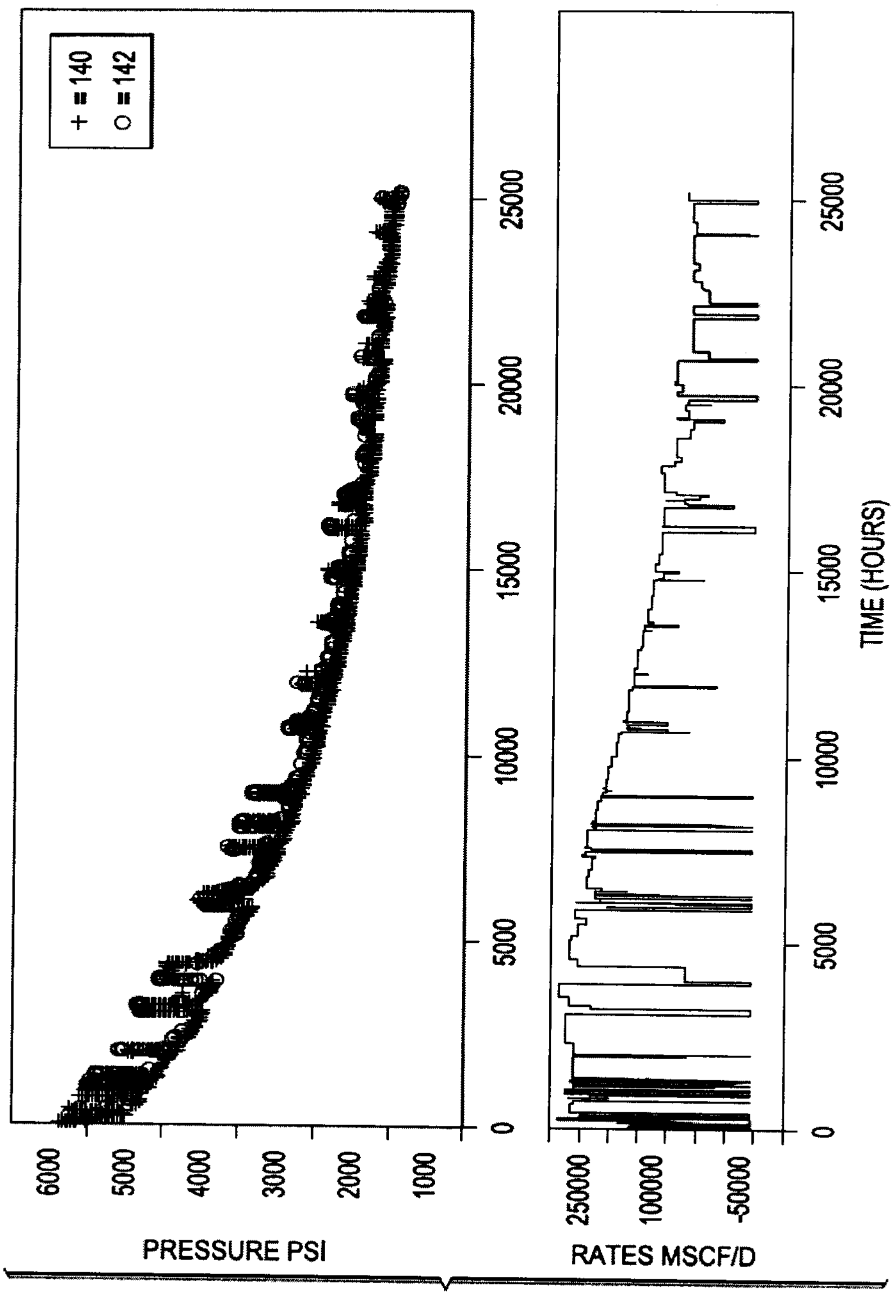

FIG. 10c

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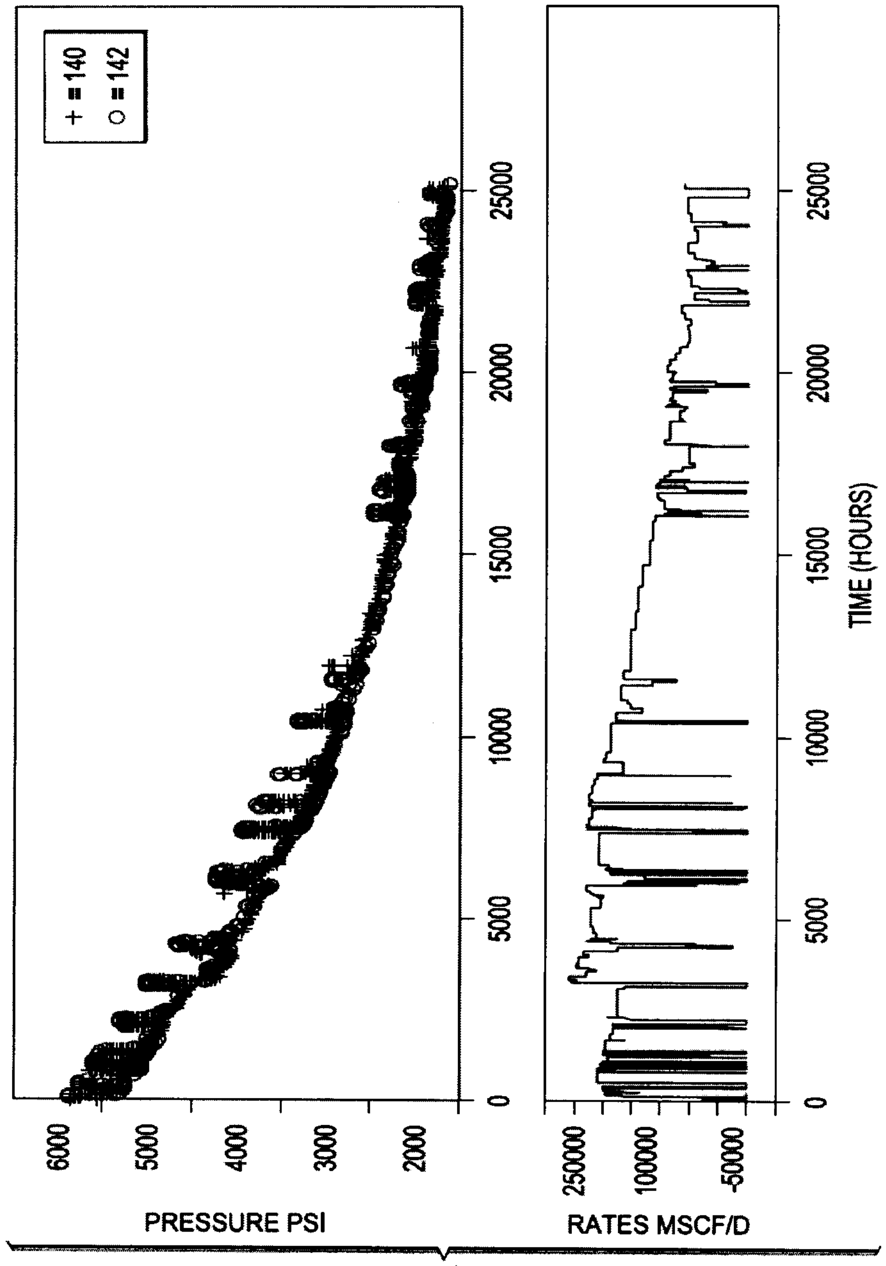

FIG. 10d

Malathi

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FIG. 10e

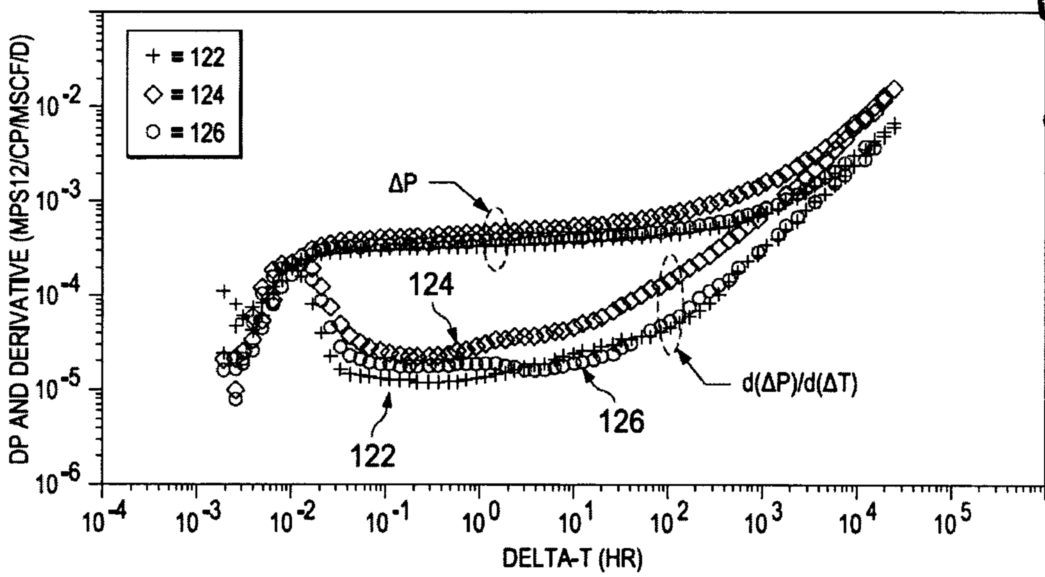
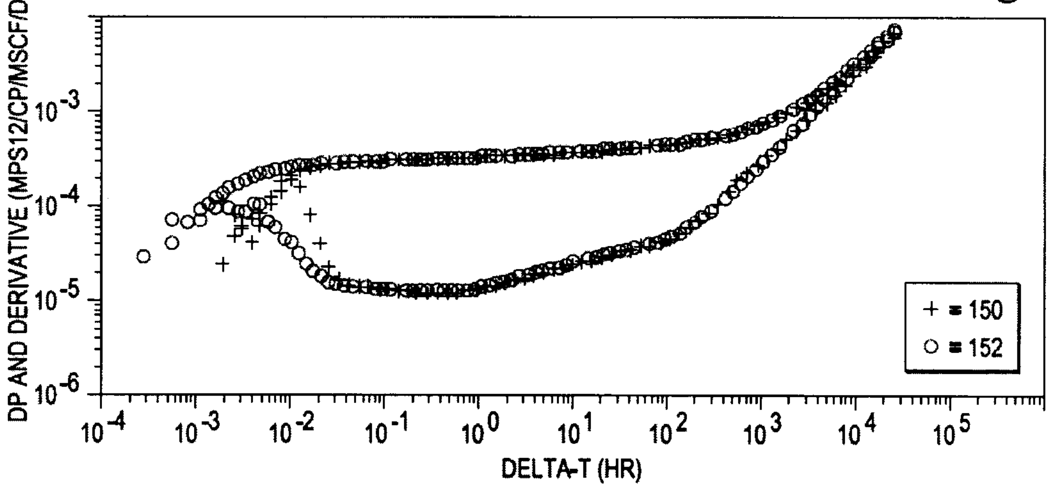


FIG. 10g



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F2189DELNP12

Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 23
Application No: Total No. of Sheets: 24

1 3 MAR 2012

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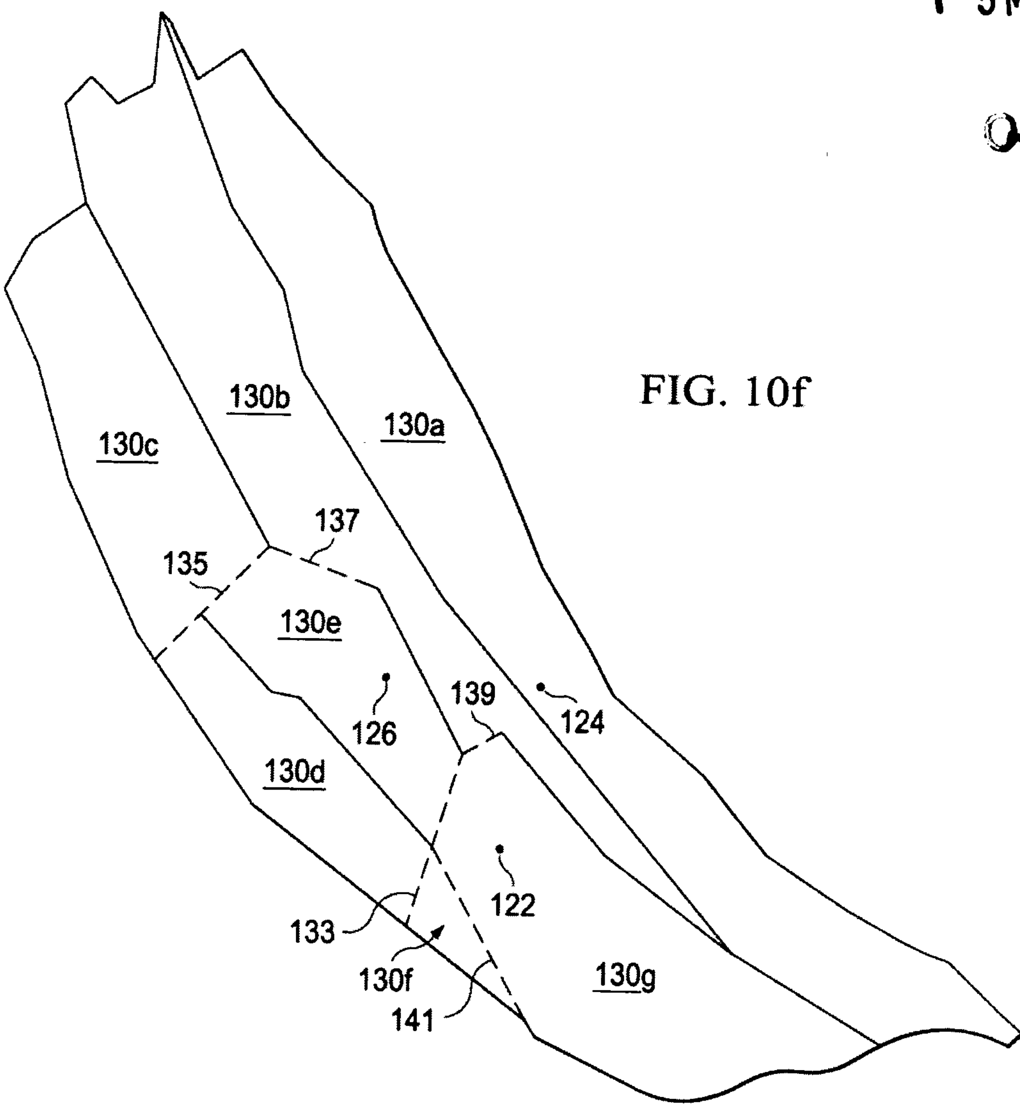

FIG. 10f

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Applicant(s) Name: **BP CORPORATION NORTH AMERICA INC.** Sheet No.: 24
Application No: Total No. of Sheets: 24

FIG. 10h 13 MAR 201

ORIGIN

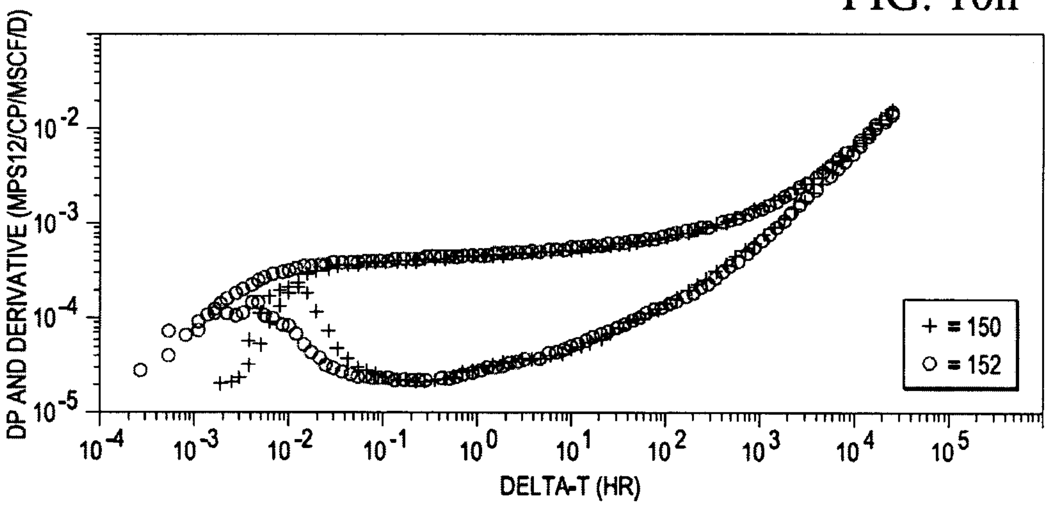
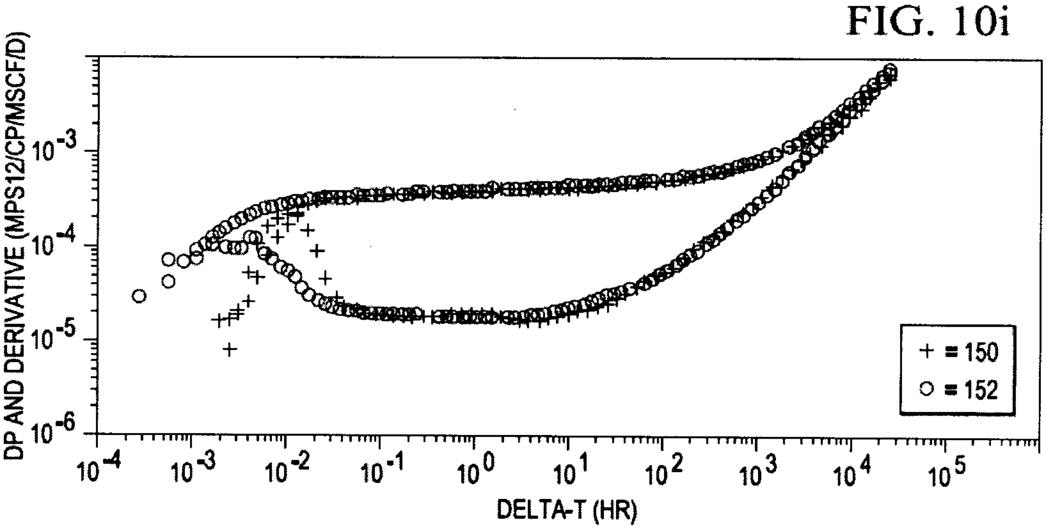


FIG. 10i



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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 61/233,897 filed on August 14, 2009, which is incorporated by reference herein in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

BACKGROUND OF THE INVENTION

[0003] This invention is in the field of oil and gas production. Embodiments of this invention are more specifically directed to the analysis of production field measurements for purposes of well and reservoir management.

[0004] The current economic climate emphasizes the need for optimizing hydrocarbon production. Such optimization is especially important considering that the costs of drilling of new wells and operating existing wells are high by historical standards, largely because of the extreme depths to which new producing wells must be drilled and because of other physical barriers to discovering and exploiting reservoirs. These high economic stakes require operators to devote substantial resources toward effective management of oil and gas reservoirs, and effective management of individual wells within production fields.

[0005] For example, the optimization of production from a given field or reservoir involves decisions regarding the number and placement of wells, including whether to add or shut-in wells. Secondary and tertiary recovery operations, for example involving the injection of water or gas into the reservoir, require decisions regarding whether to initiate or cease such operations, and also how many wells are to serve as injection wells and their locations in the field. Some wells may require well treatment, such as fracturing of the wellbore if drilling and production activity have packed the wellbore surface to the extent that production has slowed. In some cases, production may be improved by shutting-in one or more wells for an extended period of time, in which case the optimization of production may require reconfiguring the entire production field. All of these actions are performed with an eye toward maximizing production at minimum cost. As evident from these examples and as known in the art, the optimization of a production field is a complex problem, involving many variables and presenting many choices.

[0006] This problem is exacerbated by the complexity and inscrutability of the sub-surface “architecture” of today’s producing reservoirs. As mentioned above, current-day oil and gas reservoirs are often at extreme depths or in otherwise difficult geographical locations, both on land or offshore, because those reservoirs that are easy to reach have already been developed and produced. These extreme depths and relative inaccessibility limit the precision and accuracy of the necessarily indirect methods used to characterize the structure and location of the hydrocarbon-bearing reservoirs. In addition, the sub-surface structure of many reservoirs presents complexities such as variable porosity and permeability of the rock, and such as fractures and faults that compartmentalize formations in the reservoir and complicate sub-surface fluid flow. As known in the art, the ability of conventional exploration technologies of seismic prospecting, magnet surveying, and gravitational surveying to accurately portray the structure and contents of sub-surface strata becomes poorer as the depth of interest increases.

[0007] Accordingly, while seismic exploration and similar techniques provide important information from which the structure and properties of the sub-surface can be inferred, that information has, at best, a relatively coarse spatial resolution. The resolution of these surveys is even coarser for those regions in which salts and similar features or strata attenuate or distort seismic energy. As a result, the understanding of the structure and connectivity of sub-surface features provided by seismic and similar surveys is necessarily imprecise.

[0008] Conventional well logs provide important information regarding the location and properties of sub-surface strata during and after the drilling of exploratory, development, and production wells. These well logs yield direct information regarding depths, thicknesses, and material properties of sub-surface formations and strata. However, the information gained from well logs is valid only at the specific location of the well, and provides little visibility into the reservoir at any significant distance away from the well. Furthermore, as the depths of interest for newly developed formations increase, so does the cost of drilling and logging exploratory wells. For these reasons, well logs provide only limited insight into the sub-surface structure, architecture, and connectivity of many newly-developed and producing reservoirs.

[0009] In recent years, advances have been made in improving the measurement and analysis of parameters involved in oil and gas production, with the goal of improving production decisions. For example, surface pressure gauges and flow meters deployed at the wellhead, and also in surface lines interconnecting wellheads with centralized processing facilities, are now commonly monitored on virtually a continuous basis. Furthermore, reliable downhole pressure sensors are now often plumbed into the production string and left in the wellbore during production. The improved reliability of these sensors, even at elevated downhole temperatures and pressures, has enabled widespread deployment of real-time downhole pressure sensors that continuously monitor downhole pressure during production.

[0010] As known in the art, the manner in which downhole pressure and flow rate evolve over time provides insight into the reservoir pressure in the region around the well. Reservoir pressure is an important parameter in understanding the reservoir and how to optimize production, because the rate at which oil or gas will flow into the wellbore downhole (and thus out of the well at the surface) strongly depends on the difference between the reservoir pressure and the back pressure exerted by the fluid in the wellbore. Over time, the volume of oil or gas drawn out of the well will generally reduce the reservoir pressure and the rate of production will fall.

[0011] The evolution of well downhole pressure and flow rate over time depends on the rock properties (*e.g.*, permeability, porosity, etc.) throughout the reservoir, on barriers to flow within the reservoir, and on the reservoir boundaries. As such, it is possible to obtain information about these properties by analyzing the transient behavior of downhole pressure and the rates of producing wells.

[0012] While these downhole pressure measurement data are theoretically valuable in understanding reservoir behavior, the ability of conventional techniques to characterize and evaluate reservoir architecture and connectivity remains somewhat limited. As known in the art and as mentioned above, the evolution of downhole measured pressure with time is closely related to the flow rate from the well, as well as dependent on the reservoir properties of permeability, reservoir heterogeneities, faults, boundaries, and dependent on the overall shape and volume of the reservoir compartment being drained by the well, as mentioned above. Because the goal of pressure analysis is to understand the reservoir properties, it is desirable to minimize the effects of flow rate variation on the well pressure behavior, which can be done by flowing the well at a constant well rate. In this case, the response of downhole pressure to a constant flow rate is a useful characteristic because it reflects the reservoir properties and is not affected by rate changes. Unfortunately, it is difficult to maintain the flow rate of a well precisely constant for an extended period of time. Rather, well flow rates typically change over time. Furthermore, the pressure response to changes in flow rate has a very long time constant, and as such long-ago periods in the flow rate history of a well affect its current downhole pressure.

[0013] One approach to obtaining constant-rate pressure response from a well, for the purpose of characterizing the reservoir, is to carry out a "shut-in" or "pressure build-up" test, after the well has produced for some significant time. This approach of recovering reservoir properties from bottomhole measured pressure data is more generally referred to as pressure transient analysis ("PTA"). According to this approach, the well under analysis is flowed at a reasonable constant non-zero flow rate for some time, and is then shut-in for a period of time while the downhole pressure is measured. Because the well flow rate is essentially constant, at zero, during the "shut-in" period, the transient behavior of bottomhole pressure during the shut-in period primarily reflects the reservoir properties. Several shut-in and draw-down intervals are typically included within a single well test. Techniques are known in the art for recovering the pressure response from these variable-rate data. One conventional approach considers the pressure response to a sequence of flow rates as the superposition of several constant-flow conditions; the resulting pressure response is then plotted over "superposition time", and can be readily analyzed. However, PTA well tests are costly from the standpoint of lost production, and also require significant operator involvement to carry out the shut-in and operation at a constant