Title: DOWNHOLE FORMATION TESTING WITH AUTOMATION AND OPTIMIZATION

(57) Abstract: A method, and corresponding system, for formation testing includes establishing a control parameter and a test criterion for testing a formation, providing a formation tester equipped with the control parameter and the test criterion in a well bore at a test location, performing a first formation test, controlling the first formation test using the control parameter and the test criterion, collecting test data from the first formation test, adjusting the control parameter using the test data, performing a second formation test, controlling the second formation test using the adjusted control parameter and the test criterion.
DOWNHOLE FORMATION TESTING
WITH AUTOMATION AND OPTIMIZATION

BACKGROUND
[0001] During the drilling and completion of oil and gas wells, it may be necessary to engage in ancillary operations, such as evaluating the production capabilities of formations intersected by the wellbore. For example, after a well or well interval has been drilled, zones of interest are often tested or sampled to determine various formation properties such as permeability, fluid type, fluid quality, formation temperature, formation pressure, bubblepoint and formation pressure gradient. These tests are performed in order to determine whether commercial exploitation of the intersected formations is viable and how to optimize production. The acquisition of accurate data from the wellbore is critical to the optimization of hydrocarbon wells. This wellbore data can be used to determine the location and quality of hydrocarbon reserves, whether the reserves can be produced through the wellbore, and for well control during drilling operations.

[0002] Downhole formation testing often involves a complex set of procedures to draw formation fluids into the formation tester and properly analyze the fluid sample. For example, a probe must be properly extended and engaged with the formation. Internal pistons and pumps must be properly adjusted and actuated to induce the proper fluid flow rate from the formation and into the formation tester. Pressure buildup times must be properly set to obtain the best possible test results. Formation testers also have operational limitations which must be considered in the testing control parameters. These are but some of the features of formation testing, and to perform a successful formation test requires a highly trained operator. Such training can be rare and costly, and inevitably includes manual error. Even with a highly trained and experienced operator, the numerous variables that are part of the formation testing process must be considered and managed. Failure to do so is common and leads to sub-optimal testing. The principles of the present disclosure overcome these and other limitations of the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS
[0003] For a detailed description of exemplary embodiments, reference will now be made to the accompanying drawings in which:

[0004] Figure 1 is a schematic view, partly in cross-section, of a drilling apparatus with a formation tester;

[0005] Figure 2 is a schematic view, partly in cross-section, of a formation tester conveyed by wireline;
[0006] Figure 3 is a schematic view, partly in cross-section, of a formation tester disposed on a wired drill pipe connected to a telemetry network;

[0007] Figure 4 is a cross-section view of a section of wired drill pipe including a wired tool;

[0008] Figure 5 is a side view, partly in cross-section, of a drill collar including a formation probe assembly;

[0009] Figure 6 is a schematic view of a single probe formation tester;

[0010] Figure 7 is a schematic view of a dual probe formation tester;

[0011] Figure 8 is a flow diagram of an embodiment of a formation testing method in accordance with the principles described herein;

[0012] Figure 9 is a flow diagram of another embodiment of a formation testing method in accordance with the principles described herein;

[0013] Figure 10 is a flow diagram of still another embodiment of a formation testing method in accordance with the principles described herein; and


DETAILED DESCRIPTION

[0015] In the drawings and description that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals. The drawing figures are not necessarily to scale. Certain features of the disclosure may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. The present disclosure is susceptible to embodiments of different forms. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the disclosure, and is not intended to limit the disclosure to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results.

[0016] In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to ...". Unless otherwise specified, any use of any form of the terms "connect", "engage", "couple", "attach", or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described. Reference to up or down will be made for purposes of description with "up", "upper", "upwardly" or "upstream" meaning toward the surface of the well and with "down", "lower", "downwardly" or "downstream"
meaning toward the terminal end of the well, regardless of the well bore orientation. In
addition, in the discussion and claims that follow, it may be sometimes stated that certain
components or elements are in fluid communication. By this it is meant that the components
are constructed and interrelated such that a fluid could be communicated between them, as via a
passageway, tube, or conduit. Also, the designation "MWD" or "LWD" are used to mean all
generic measurement while drilling or logging while drilling apparatus and systems. The
various characteristics mentioned above, as well as other features and characteristics described
in more detail below, will be readily apparent to those skilled in the art upon reading the
following detailed description of the embodiments, and by referring to the accompanying
drawings.

[0017] Referring initially to Figure 1, a drilling apparatus including a formation tester is
shown. A formation tester 10 is shown enlarged and schematically as a part of a bottom hole
assembly 6 including a sub 13 and a drill bit 7 at its distal most end. The bottom hole assembly
6 is lowered from a drilling platform 2, such as a ship or other conventional land platform, via a
drill string 5. The drill string 5 is disposed through a riser 3 and a well head 4. Conventional
drilling equipment (not shown) is supported within a derrick 1 and rotates the drill string 5 and
the drill bit 7, causing the bit 7 to form a borehole 8 through formation material 9. The drill
bit 7 may also be rotated using other means, such as a downhole motor. The borehole 8
penetrates subterranean zones or reservoirs, such as reservoir 11, that are believed to contain
hydrocarbons in a commercially viable quantity. An annulus 15 is formed thereby. In addition
to the formation tester 10, the bottom hole assembly 6 contains various conventional apparatus
and systems, such as a down hole drill motor, a rotary steerable tool, a mud pulse telemetry
system, MWD or LWD sensors and systems, downhole memory and processor, and others
known in the art.

[0018] In some embodiments, and with reference to Figure 2, a formation testing tool 60 is
disposed on a tool string 50 conveyed into the borehole 8 by a cable 52 and a winch 54. The
testing tool includes a body 62, a sampling assembly 64, a backup assembly 66, analysis
modules 68, 84 including electronic devices, a flowline 82, a battery module 65, and an
electronics module 67. The formation tester 60 is coupled to a surface unit 70 that may include
an electrical control system 72 having an electronic storage medium or memory 74 and a
control processor 76. In other embodiments, the tool 60 may alternatively or additionally
include an electrical control system, an electronic storage medium and a processor.

[0019] Referring to Figure 3, a telemetry network 100 is shown. A formation tester 120 is
coupled to a drill string 101 formed by a series of wired drill pipes 103 connected for
communication across junctions using communication elements. It will be appreciated that work string 101 can be other forms of conveyance, such as wired coiled tubing. The downhole drilling and control operations are interfaced with the rest of the world in the network 100 via a top-hole repeater unit 102, a kelly 104 or top-hole drive (or, a transition sub with two communication elements), a computer 106 in the rig control center, and an uplink 108. The computer 106 can act as a server, controlling access to network 100 transmissions, sending control and command signals downhole, and receiving and processing information sent up-hole. The software running the server can control access to the network 100 and can communicate this information via dedicated land lines, satellite uplink 108), Internet, or other means to a central server accessible from anywhere in the world. The formation tester 120 is shown linked into the network 100 just above the drill bit 110 for communication along its conductor path and along the wired drill string 101.

[0020] The formation tester 120 may include a plurality of transducers 115 disposed on the formation tester 120 to relay downhole information to the operator at surface or to a remote site. The transducers 115 may include any conventional source/sensor (e.g., pressure, temperature, gravity, etc.) to provide the operator with formation and/or borehole parameters, as well as diagnostics or position indication relating to the tool. The telemetry network 100 may combine multiple signal conveyance formats (e.g., mud pulse, fiber-optics, acoustic, EM hops, etc.). It will also be appreciated that software/firmware may be configured into the formation tester 120 and/or the network 100 (e.g., at surface, downhole, in combination, and/or remotely via wireless links tied to the network).

[0021] Referring briefly to Figure 4, sections of wired drill pipe 103 are enlarged for clarity. The wired drill pipe 103 includes conductors 150 that traverse the entire length of the pipe sections. Communication elements 155 allow the transfer of power and/or data between the pipe sections 103. A data/power signal may be transmitted along a pipe section of the wired drill string, such as the pipe section with formation tester 120 (Figure 3), from one end through the conductor(s) 150 to the other end across the communication elements 155. In some embodiments, the conductor(s) 150 comprise coaxial cables, copper wires, optical fiber cables, triaxial cables, and twisted pairs of wire. The conductor(s) 150 may be disposed through a hole formed in the walls of the outer tubular members of the pipes 103. The communication elements 155 may comprise inductive couplers, direct electrical contacts, optical couplers, and combinations thereof. Portions of the wired drill pipes 103 may be subs or other connections means. The ends of subs or connections means of the wired subs 103 are configured to communicate within the downhole telemetry network 100.
Referring next to Figure 5, an embodiment of an MWD formation probe collar section 200 is shown in detail, which may be used as the tool 10 in Figure 1 or the tool 120 in Figure 3. A drill collar 202 houses the formation tester or probe assembly 210. The probe assembly 210 includes various components for operation of the probe assembly 210 to receive and analyze formation fluids from the earth formation 9 and the reservoir 11. An extendable probe member 220 is disposed in an aperture 222 in the drill collar 202 and extendable beyond the drill collar 202 outer surface, as shown. The probe member 220 is retractable to a position recessed beneath the drill collar 202 outer surface. The probe assembly 210 may include a recessed outer portion 203 of the drill collar 202 outer surface adjacent the probe member 220. The probe assembly 210 includes a drawdown or piston accumulator assembly 208, a sensor 206, a valve assembly 212 having a flow line shutoff valve 214 and equalizer valve 216, and a drilling fluid flow bore 204. At one end of the probe collar 200, generally the lower end when the tool 10 is disposed in the borehole, is an optional stabilizer 230, and at the other end is an assembly 240 including a hydraulic system 242 and a manifold 244.

The piston assembly 208 includes a piston chamber 252 containing a piston 254 and a manifold 256 including various fluid and electrical conduits and control devices. The piston assembly 208, the probe 220, the sensor 206 (e.g., a pressure gauge) and the valve assembly 212 communicate with each other and various other components of the probe collar 200, such as the manifold 244 and hydraulic system 242, as well as the tool 10 via conduits 224a, 224b, 224c and 224d. The conduits 224a, 224b, 224c, 224d include various fluid flow lines and electrical conduits for operation of the probe assembly 210 and probe collar 200.

Referring now to Figures 6 and 7, schematic representations of a single probe formation tester 300 and a dual probe formation tester 400 are shown with internal details. In Figure 6, the formation tester 300 includes a tool body or collar 302 supporting an extendable probe 304. In some embodiments, the body 302 also supports backup pistons 306. A primary tool flowline 308 extends longitudinally through the tool body 302 and fluidically couples to a formation fluid sample flowline 310 through an isolation valve 318. The probe 304 is coupled to the formation fluid sample flowline 310. Also coupled into the formation fluid sample flowline 310 is an equalization valve 312 that vents to the borehole annulus through a port 324, a pretest piston 316 and a strain gauge 314, and a quartz gauge 320.

In Figure 7, the formation tester 400 includes a tool body or collar 402 supporting a pair of extendable probes 404. In some embodiments, the body 402 also supports backup pistons 406. A primary tool flowline 408 extends longitudinally through the tool body 402 and fluidically couples to a formation fluid sample flowline 410 through an isolation valve 418. The
probes 404 are coupled to the formation fluid sample flowline 410. Also coupled into the
formation fluid sample flowline 310 are probe valves 422, an equalization valve 412 that vents
to the borehole annulus through a port 424, a pretest piston 416 and a strain gauge 414, and a
quartz gauge 420.

[0026] Formation testing using the various formation testers described above, as well as other
similar formation testers known in the industry, requires highly trained operators to manually
set formation testing parameters and controls in an attempt to obtain the best results possible.
For example, a skilled operator must set appropriate flow rates and buildup times for the
components of the formation testers described herein such that the formation fluids can be
properly measured for useable results. As will be described below, the principles of the present
disclosure are embodied in various methods and systems for optimizing the testing mode,
parameters, and controls for a formation tester. In some embodiments, the method is partially
optimized by automating the testing mode and procedure and the adjustability of the parameters
and controls. In some embodiments, the testing modes for the single and dual probe formation
testers 300, 400 of Figures 6 and 7 are optimized.

[0027] In some embodiments, an automated and optimized formation testing method includes
controlling the testing procedure based on multiple criteria and parameters as will be further
detailed below. In some embodiments, the method is based on a set of test criteria and/or
control parameters used to target a test objective. In further embodiments, a set of formation
tester tool parameters or specifications based on the operating range and limitations of the
formation tester supplements the method. For purposes of the following description, the
formation testers of Figures 5-7 will be referred to, including the drawdown piston 208 and the
pretest pistons 316, 416; but, it is understood that other types of formation testers and
measurements are contemplated and consistent with the teachings herein.

[0028] Upon a first drawdown using the drawdown piston 208 and the corresponding probe
assembly 210 of Figure 5, or a first pretest using the pretest pistons 316, 416 and the
corresponding probes 304, 404, little formation information is available but certain initial
control parameters and/or test criteria may be determined, set, and used. Based on such an
initial test, the resulting new information is used to further refine the control parameters for the
subsequent or next pressure test. Referring now to Figure 8, an embodiment of an adjustable
and optimized formation testing method includes establishing control parameters for testing a
formation at 502, performing a first formation test using the control parameters at 504,
determining optimum control parameters for a next formation test based on results from the
immediately preceding formation test at 506, performing the next formation test using the
optimum control parameters, and then returning the process back to just before the step 506 and determining optimum control parameters based on the immediately preceding formation test.  

[0029] In some further embodiments, a control parameter as well as a test criterion are established prior to a first formation test. Referring now to Figure 9, an embodiment of an adjustable and optimized formation testing method 600 includes establishing a control parameter (or parameters) and a test criterion (or criteria) for testing a formation at 602, providing a formation tester in a well bore at a test location at 604, wherein the formation tester includes or is equipped with the control parameter and the test criterion, performing a first formation test at 606, controlling the first formation test using the control parameter and the test criterion at 608, collecting test data from the first formation test at 610, adjusting the control parameter using the test data at 612, performing a second formation test at 614, and controlling the second formation test using the adjusted control parameter and the test criterion. In some embodiments, the method may further include collecting additional test data from the second formation test, and re-adjusting the control parameter using the additional test data. In certain embodiments, the method may further include controlling a subsequent formation test using the test criterion, the test data, and the adjusted control parameter. In still further embodiments, the method may include re-adjusting the control parameter after each subsequent formation test and based on test data of each immediately preceding formation test, and using the re-adjusted control parameter for each subsequent formation test.  

[0030] In some embodiments, the collecting 610 and adjusting 612 steps, as well as the determining 506 and the performing 508 steps, occur while downhole. In certain embodiments, the collecting 610 and adjusting 612 steps occur in close temporal proximity, such that they occur during the same trip into the well bore or during the same formation testing run or sequence. Similarly, the determining 506 and the performing 508 steps occur in close temporal proximity such that the resulting formation tests can be optimized during a single trip or testing sequence. In some embodiments, the noted methods include automatically executing the optimized formation test while downhole.  

[0031] Referring next to Figure 10, an embodiment of an adjustable and optimized formation testing method 700 includes establishing a set of control parameters and test criteria for testing a formation at 702, providing a formation tester in a well bore at a test location at 704, performing a first pressure test that is controlled by the set of control parameters and test criteria at 706, adjusting the set of control parameters and test criteria based on the results of the first pressure test at 708, using the adjusted set to control a second pressure test subsequent to the first pressure test at 710, adjusting the set of control parameters and test criteria after the
second pressure test and each subsequent pressure test at 712, and using the adjusted set of
control parameters and test criteria for each subsequent pressure test at 714.

[0032] In some embodiments, the previously described methods can be used to optimize
testing for a formation tester with multiple probes. For example, for the dual probe formation
tester 400 of Figure 7, a first formation test is performed using both probes 404. Then, one or
more control parameters are adjusted and another formation test is performed using one of the
probes 404. Additional information is obtained and combined with the information learned
from the first formation test to determine new control parameters for performing a formation
test with the other probe 404. The information from the latest formation test can be used to
determine whether to use the first or second probe 404 to verify the initial tests or improve the
formation test results.

[0033] The control parameters described above are input parameters including test control
objectives, formation tester specifications, or combinations thereof. In some embodiments, the
control parameter is a test flow rate or initial drawdown rate, or a drawdown volume. In further
embodiments, the control parameters may include those parameters listed in Table 1 appended
to this disclosure. Table 1 includes control parameters that are specified by the engineer or the
client or customer, for example. In some embodiments, the parameters can be stored in the
formation testing tool, while in other embodiments parameters can be selected for downloading
while testing. With reference to Table 1, the listed control parameters are exemplary control
parameters that may be used, adjusted, and optimized in the various embodiments disclosed
herein. For example, each drawdown pressure can be controlled to a minimum pressure.
Previously obtained drawdown/buildup data can be used to optimize the next
drawdown/buildup. In some embodiments, a maximum pretest volume that is available is used.
In some embodiments, a desired drawdown pressure and time is maintained during testing. In
other embodiments, a buildup time is limited based on pressure stability, or a buildup time is
limited to no less than a minimum specified or predetermined buildup time. In further
embodiments, a buildup time is limited to no greater than a maximum specified or
predetermined buildup time.

[0034] In some embodiments, when a variable rate control is selected (see Table 1), the
initial rate is increased or decreased during the test to maintain a drawdown control pressure. If
the formation tester tool parameters do not allow for variable rate control, other control
parameters can be used such as a minimum control drawdown pressure to cause the drawdown
to terminate. In some embodiments, the primary parameters that are adjusted and or optimized
after a formation test include initial drawdown rate, drawdown volume, and minimum drawdown pressure (see Table 1).

[0035] The embodiments herein also incorporate or take into account formation tester tool parameters or specifications. With reference to Table 2, appended, exemplary tool parameters include probe size, number of probes, flow rate control range (maximum and minimum), total pretest volume available, minimum control volume, drawdown pressure limits (maximum and minimum), flowline volume, system response time and maximum number of drawdowns possible. However, the listed parameters are not limiting and other exemplary control parameters are provided and contemplated throughout this disclosure. Further, these parameters and their associated objectives can change based on various factors. For example, normally it is desirable to use the maximum pretest volume; however, if the objective is to minimize total testing time, then a large volume is not helpful. Thus, the method and it’s optimization algorithms would need to be revised for this alternative objective. In some embodiments, a maximum volume is chosen because it is normally assumed that the best test results are obtained when moving the largest volume of formation fluids as possible from the formation.

[0036] In some embodiments, the formation tester parameters or specifications are stored in downhole memory, as described with reference to Figures 1-5. The test control parameters can be similarly stored and accessed. While the control parameters can be varied while testing, in some embodiments it is desirable to store both sets of parameters in the testing database records for each test sequence, to document how each test was performed.

[0037] Referring now to Table 3, appended, the embodiments here include test criteria. The test criteria are listed in Table 3, and include maximum drawdown rate, drawdown differential desired, drawdown limit (bubble point), buildup pressure stability, buildup temperature stability, and stability time period. As illustrated by Tables 1-3, some embodiments herein include a control parameter that is a characteristic or value of the formation test or tool that can be directly controlled, while a test criterion is a passive baseline, limit, or boundary that can be used to trigger an action or step in the formation testing process when met.

[0038] In certain embodiments, before control parameters can be adjusted and optimized, calculations must be made based on the information gathered and the known control parameters and test criteria. Referring to Table 4, appended, a list of optimization calculation variables is provided, as will be described in more detail below. In some embodiments, controlling each drawdown pressure to a minimum pressure is a significant objective, particularly for the first pretest drawdown. If the first pretest drawdown cannot be controlled above a pressure cutoff.
point, then any subsequent test optimization may not be possible using traditional
drawdown/buildup testing methods. However, controlling to a minimum pressure, in some
embodiments, allows calculations to be performed resulting in test adjustment and/or
optimization, as will be described below.

[0039] In exemplary embodiments, a method for formation testing includes establishing a set
of control parameters for testing a formation, performing a first formation test using the testing
control parameters, determining optimum control parameters for a next formation test based on
results from the previous formation test, performing the next formation test using the optimum
control parameters, and then repeating the determining optimum control parameters and
performing the next formation test for each subsequent formation test. In further exemplary
embodiments, a method for formation testing includes establishing a control parameter and a
test criterion for testing a formation, providing a formation tester equipped with the control
parameter and the test criterion in a well bore at a test location, performing a first formation
test, controlling the first formation test using the control parameter and the test criterion,
collecting test data from the first formation test, and adjusting the control parameter using the
test data.

[0040] In certain embodiments described herein, pressure tests are referred to when
describing the methods and processes that exemplify the disclosure. However, it is understood
that formation tests other than pressure tests are contemplated. As described, the testing control
parameters may include formation tester specifications. In some embodiments, the control
parameters may be associated with test control objectives. In some embodiments, the testing
control parameter includes test control objectives including at least one parameter that controls
a formation test in progress and formation test initial parameters. The formation test initial
parameters may include at least one of a flow rate, a drawdown volume, a drawdown time, and
a buildup time range. In other embodiments, the test control objectives include controlling
each drawdown pressure of the formation tests to a minimum pressure. In still other
embodiments, the test control objectives include controlling each drawdown of the formation
tests using a predetermined range of flow rates. In certain embodiments, the test control
objectives include controlling each drawdown of the formation tests to a maximum drawdown
time. In some embodiments, the test control objectives include controlling each buildup of the
formation tests to a minimum buildup time. In some embodiments, the test control objectives
include controlling each buildup of the formation tests to a maximum buildup time. In further
embodiments, the method includes controlling a buildup time based on an objective to
terminate the buildup before the maximum buildup time is reached, and wherein the objective
can be supplemented with test criteria including a pressure stability, a temperature stability, or a combination thereof. As used in some embodiments herein, a control parameter is a characteristic or value of the formation test or tool that can be directly controlled, while a test criteria is a passive baseline, limit, or boundary that can be used to trigger an action or step in the formation testing process when met.

[0041] In some embodiments, the method includes moving a drawdown device to flow a formation fluid at a flow rate into the formation tester for a pretest, thereby producing a drawdown pressure, and automatically controlling the drawdown pressure to a minimum pressure criterion $P_{\text{min}}$ by controlling the flow rate or terminating the drawdown device movement. The method may include a minimum pressure $P_{\text{min}}$ that is determined by an absolute pressure limit determined using a hydrostatic well bore pressure and tool specification, wherein the absolute pressure limit defines the lowest pressure the formation tester can reduce a pressure from the hydrostatic well bore pressure when performing a drawdown. The method may include terminating the pretest drawdown substantially at the minimum pressure $P_{\text{min}}$. Further, the tool specification includes a system response time $\Delta t_{\text{sys}}$, and the method further includes predicting a pressure within the system response time $\Delta t_{\text{sys}}$, and, when the predicted pressure at $\Delta t_{\text{sys}}$ is at or below the minimum pressure $P_{\text{min}}$, then terminating the pretest drawdown. Also, the predicting step and the step of terminating when the predicted pressure at $\Delta t_{\text{sys}}$ is at or below the minimum pressure $P_{\text{min}}$ further includes performing a regression of recorded drawdown pressure data using a predictive function which estimates when the minimum pressure $P_{\text{min}}$ will occur.

[0042] In some embodiments, one or more of the formation tests includes controlling a buildup time of a pretest. In some embodiments, the buildup time is controlled by not terminating the buildup until at least a minimum buildup time has passed. In some embodiments, the buildup time is controlled by terminating the buildup when the change in pressure or temperature over a time range meets the control parameter or the test criteria. In some embodiments, the buildup time is controlled by terminating the buildup when a predetermined maximum buildup time has been reached.

[0043] In some embodiments, the method includes, after the initial drawdown and pretest, determining an optimized drawdown rate $q_{d0}$ and a volume. The method may include determining estimated formation parameters from the initial pretest. Then, an optimal drawdown pressure differential $AP_{d0}$ is determined based on the previous pretest, test control objectives of Table 1, and formation tester specifications of Table 2. Further, the method includes calculating an initial estimate of the optimized drawdown rate $q_{d0}$ using the estimated
formation parameters determined from the initial pretest, the optimal drawdown pressure differential \( \Delta P_{dd} \) based on the previous pretest, the test control objectives of Table 1, and the formation tester specifications of Table 2. Next, it is determined whether the optimized drawdown rate \( q_{do} \), a drawdown time \( t_{do} \), and a volume \( V_{do} \) are within predetermined limits. In some embodiments, the optimized drawdown rate \( q_{do} \) includes:

formation parameters from the preceding drawdown including (see also Graph 1 of Appendix A):

\[
M_{Exact} \approx M_{dd} = \frac{14,696}{2\pi \cdot 2.54} \left( \frac{q_i}{(P_{stop} - P_{dd\_end})} \left( \frac{r_p}{\tau_p} \right) \right)
\]

\[
P_{Exact} = P_{dd\_end} + \beta
\]

an optimal drawdown pressure estimate including (see also Graph 2 of Appendix A):

\[
M_{Exact} = \frac{14,696}{2\pi} \left( \frac{q_o}{\beta} \left( \frac{r_p}{\tau_p} \right) \left( 1 - e^{\frac{-M_o}{\alpha}} \right) \right);
\]

adjusting the optimal drawdown rate to be within the formation tester limits, including:

\[
q_{dn} = \Delta P_{dd} M_{Exact} \left( \frac{r_p}{\tau_p} \right) \frac{2\pi}{14,696}
\]

adjusting the drawdown time and the drawdown volume to practical limits, including:

\[
if \ q_{do} > Q_{max} \ then \ q_{do} = Q_{max}
\]

[0044] In some embodiments, the pretest is continued for at least a specified minimum buildup time \( \frac{1}{3} t_{u\_min} \). The method may include various combinations of determining when to terminate the pretest using a buildup stability \( \sigma_{bu} \) (p.s.i/sec), determining the buildup stability \( \sigma_{bu} \) using a linear regression of a pressure data recorded over a specified stability time period \( \Delta t_{bu} \), replacing a previous buildup stability \( \sigma \) with the new buildup stability \( \sigma_{bu} \), and transmitting
the new buildup stability $\sigma_{bu}$ in real time. In some embodiments, the buildup stability $\sigma_{bu}$ is determined by performing a linear regression over a predetermined period of time in the control parameter or the test criteria set to determine the slope (p.s.i./sec), and updating the buildup stability $\sigma_{bu}$ as the buildup progresses. The method may further include terminating the pretest if stability $\sigma < \sigma_{bu}$ is reached after the minimum buildup time $t_{bu_{\text{min}}}$ and/or continuing the buildup until either stability $\sigma < \sigma_{bu}$ or the maximum buildup time $t_{bu_{\text{max}}}$ is reached, then terminating the pretest. In some embodiments, the method includes signaling the pretest termination using an uplink command during a mud pumps-on mode or continuing the buildup to the maximum buildup time $t_{bu_{\text{max}}}$ according to: if the minimum buildup time $t_{bu_{\text{min}}}$ is reached, and the buildup stability is less than the buildup stability of the test criteria set, then the buildup is terminated and either a new formation test can start or the formation testing is completed.

[0045] In some embodiments, the method includes signal pulsing the buildup stability $\sigma_{bu}$ to the surface of a well. In some embodiments, the method includes indicating supercharging with a negative value of the buildup stability $\sigma_{bu}$ and changing a testing procedure in response to the negative buildup stability $\sigma_{bu}$. In other embodiments, the method includes indicating that a mudcake thickness has substantially stabilized if the buildup stability $\sigma_{bu}$ indicates a pressure is increasing, and estimating a supercharge pressure using a stable mudcake model. In still other embodiments, the method includes indicating that a mudcake thickness is increasing or unstable if the buildup stability $\sigma_{bu}$ is negative or a pressure is decreasing, and estimating a supercharge pressure using a dynamic mudcake model.

[0046] In some embodiments, the method includes maintaining a drawdown pressure differential $\Delta P_{d0}$ during the second or subsequent formation test.

[0047] In some embodiments, the control parameter comprises the test control parameters of Table 1 and the formation tester tool parameters of Table 2.

[0048] In some embodiments, the control parameter is stored in a formation tester memory, downloaded while testing, or a combination thereof. The method may include automatically executing the adjusting and using steps of the method disclosed herein while downhole. Further, the optimized formation test may be executed automatically while downhole. The methods described herein can be used as an advisor to the formation tester operator or implemented with the formation tester for fully automated testing. For formation testing while drilling tools (FTWD), for example, downhole implementation of the testing and optimization methods described herein provide benefits due to limited communication with the formation tester while downhole. Using the methods described the formation tester can adapt to
conditions with no intervention by an operator. All of the methods, processes, and logic can be implemented within the real-time control software without requiring the operator to directly communicate with the formation tester. This enables a formation tester to work autonomously and achieve the test objectives.

[0049] In some embodiments, an adjusted value of the test criteria set comprises a bubble point drawdown limit \( P_{bp} \) (Table 3).

[0050] In some embodiments, the method includes storing the control parameter and/or the test criterion in a testing database, and documenting at least one of the formation tests in the testing database.

[0051] The embodiments set forth herein are merely illustrative and do not limit the scope of the disclosure or the details therein. It will be appreciated that many other modifications and improvements to the disclosure herein may be made without departing from the scope of the disclosure or the inventive concepts herein disclosed. Because many varying and different embodiments may be made within the scope of the inventive concept herein taught, including equivalent structures or materials hereafter thought of, and because many modifications may be made in the embodiments herein detailed in accordance with the descriptive requirements of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in a limiting sense.
## Appendix A

### Table 1 - Test Control Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
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<td>Rate Selection Fixed or Variable</td>
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<td>Drawdown Volume</td>
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<td>Drawdown Control Pressure</td>
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<tr>
<td>Minimum Drawdown Pressure</td>
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<tr>
<td>Maximum Drawdown Time</td>
<td>$T_{dd\ max}$</td>
<td>sec</td>
</tr>
<tr>
<td>Minimum Drawdown Time</td>
<td>$T_{dd\ min}$</td>
<td>sec</td>
</tr>
<tr>
<td>Maximum Buildup Time</td>
<td>$T_{bu\ max}$</td>
<td>sec</td>
</tr>
<tr>
<td>Minimum Buildup Time</td>
<td>$T_{bu\ min}$</td>
<td>sec</td>
</tr>
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<td>Number of Drawdowns/Buildup Tests</td>
<td>$N_{dd}$</td>
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<td>Table 2 - Tool Parameters</td>
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<td></td>
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<tr>
<td>----------------------------------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
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<td>$r_{p1}$</td>
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<tr>
<td>Probe 2 Radius (optional)</td>
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<td>in</td>
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<td>Minimum Flow Rate</td>
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<td>Maximum Flow Rate</td>
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<td>cc/sec</td>
</tr>
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<td>Minimum Pretest Control Volume</td>
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<tr>
<td>Total Pretest Volume</td>
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</tr>
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<td>$\Delta P_{dd\ max}$</td>
<td>psi</td>
</tr>
<tr>
<td>Minimum Drawdown Limit</td>
<td>$\Delta P_{dd\ min}$</td>
<td>psi</td>
</tr>
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<td>cc</td>
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<td>$n$</td>
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<td>q&lt;sub&gt;dd max&lt;/sub&gt;</td>
<td>cc/sec</td>
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<tr>
<td>--------------------------</td>
<td>-------------------</td>
<td>---------</td>
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<tr>
<td>Drawdown Differential Desired</td>
<td>ΔP&lt;sub&gt;dd&lt;/sub&gt;</td>
<td>psi</td>
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<td>Drawdown Limit (Bubble Point)</td>
<td>P&lt;sub&gt;bp&lt;/sub&gt;</td>
<td>psia</td>
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<td>Buildup Pressure Stability</td>
<td>σ&lt;sub&gt;bu&lt;/sub&gt;</td>
<td>psi/min</td>
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<td>Buildup Temperature Stability</td>
<td>ν&lt;sub&gt;bu&lt;/sub&gt;</td>
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</tr>
<tr>
<td>Stability Time Period</td>
<td>t&lt;sub&gt;bu&lt;/sub&gt;</td>
<td>sec</td>
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<td>Table 4 - Optimization Calculation Variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probe radius</td>
<td></td>
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<tr>
<td>Prove flow coefficient</td>
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<td>Exact Mobility</td>
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<td>Exact Mobility equals $M_{dd}$ when $P_{Exact_{1}} = P_{stop_{1}}$</td>
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<tr>
<td>Drawdown Mobility</td>
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<td>Final buildup pressure using Exact function</td>
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<td>Measured pretest flow rate</td>
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<td>Measured pressure at end of drawdown</td>
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<td>Measured hydrostatic pressure</td>
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<td>Measured drawdown time period</td>
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<td>Measured Exact function magnitude</td>
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<td>Optimized drawdown pressure differentials</td>
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<td>$M_{Exact_{1}}$</td>
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<td>$P_{Exact}$</td>
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<td>$q_o$</td>
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<td>$P_{dd_{end}}$</td>
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<td>$P_{hyd}$</td>
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<td>$\Delta t_p$</td>
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<tr>
<td>$\beta$</td>
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<td>$\Delta P_{do}$, $\Delta P_{do_{1}}$, $\Delta P_{do_{2}}$</td>
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<td>$V_{do}$</td>
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<td></td>
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</tr>
<tr>
<td>psi</td>
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</tr>
</tbody>
</table>
Determine Mobility & Buildup Pressure

\[ M_{\text{Exact}} = \frac{14,696}{2\pi} \left( \frac{q_1}{\beta_1} \right) \left( \frac{\tau_p}{r_{p1} + r_{p1}} \right) \left( 1 - e^{-\frac{\Delta t_p}{\alpha}} \right) \]

\[ M_{\text{Exact}} \approx M_{dd} = \frac{14,696}{2\pi} \left( \frac{q_1}{P_{\text{stop1}} - P_{dd\_end1}} \right) \left( \frac{\tau_p}{r_{p1} + r_{p2}} \right) \]

\[ P_{\text{Exact}} = P_{dd\_end} + \beta \approx P_{\text{stop}} \]

Where:
- \( \Delta t_p \)  draw down production time
- \( \alpha \)  Exact curve fit time constant (sec)
- \( \beta \)  Exact curve fit build up constant (psi)

Graph 1

Pressure (psi) vs. Time (sec)
First Determine Optimal Drawdown $\Delta P_{do}$

If $\Delta P_{dd\_max} > (P_{hyd} - P_{exact} - \Delta P_{dd})$, Then $\Delta P_{do1} = \Delta P_{dd}$
Else $\Delta P_{do1} = \Delta P_{dd\_max} - (P_{hyd} - P_{exact})$

If $P_{\min} < P_{exact} - \Delta P_{dd}$ Then $\Delta P_{do2} = \Delta P_{dd}$
Else $\Delta P_{do2} = P_{exact} - P_{\min}$

If $P_{do1} < P_{do2}$ Then $\Delta P_{do} = \Delta P_{do1}$
Else $\Delta P_{do} = P_{do2}$
Next Optimize Second Drawdown Probei, Fixed Rate

\[ Q_{do} = \Delta P_{do} M_{Exact} \left( \frac{r_{p1}}{\tau_p} \right) \frac{2\pi}{14,696} \]

If \( T_{do} > T_{dd\_max} \) Then

\[ V_{do} = T_{dd\_max} \cdot Q_2 \]

\[ V_{do} = \frac{(V_{pt\_max} - V_i)}{2} \]

\[ T_{do} = \frac{V_{do}}{Q_{do}} \]

Graph 3

\[ \Delta t_{dd1} \]

\[ \Delta t_{dd2} \]

\[ \Delta P_{dd} \]

\[ t_{stop} \]
Optimize Second Drawdown
Probel, Fixed Rate

\[ Q_{do} = \Delta P_{do} M_{Exact} \left( \frac{r_{p1}}{\tau_p} \right) \frac{2\pi}{14,696} \]

If \( T_{do} > T_{dd\_max} \) Then
\[ V_{do} = T_{dd\_max} \cdot Q_2 \]

\[ V_{do} = \frac{(V_{pt\_max} - V_i)}{2} \]

\[ T_{do} = \frac{V_{do}}{Q_{do}} \]

Graph 4

\[ \Delta t_{dd1} \]

\[ \Delta t_{dd2} \]

\[ t_{stop} \]
Tight Tests – Limit Next Drawdown to $P_{\text{min}}$

\[ Q_{do} = \Delta P_{do} M_{\text{Exact}} \left( \frac{r_{p1}}{r_p} \right) \frac{2\pi}{14,696} \]

If $T_{do} > T_{dd\_max}$ Then

\[ V_{do} = T_{dd\_max} \cdot Q_2 \]

\[ V_{do} = (V_{pt\_max} - V_i) / 2 \]

\[ T_{do} = V_{do} / Q_{do} \]

Graph 5

$Q_i$, $Q_2$, $P_{\text{min}}$, $\Delta t_{dd1}$, $\Delta t_{dd2}$, $t_{\text{stop}}$
Tight Tests – Limit Next Drawdown to \( P_{\text{min}} \)

\[
Q_{do} = \Delta P_{do} \cdot M_{\text{Exact}} \left( \frac{r_{pl}}{r_p} \right) \frac{2\pi}{14,696} \left( \frac{V_{i} - V_{do}}{V_{i} - V_{do, \text{max}}} \right)^{2} \]

\[
T_{do} = \frac{V_{do}}{Q_{do}}
\]

Graph 6
Tight Tests

\[ Q_{dq} = \Delta P_{dq} M_{Exact} \left( \frac{r_{p1}}{r_p} \right) \frac{2\pi}{14,696} \]

If \( Q_{dq} < Q_{min} \) Then \( q_{dq} = Q_{min} \)

\[ V_{dq} = \frac{V_{pt_{max}} - V_i}{2} \]

\[ T_{dq} = \frac{V_{dq}}{Q_{dq}} \]

\[ t_{dd} = -\alpha \ln \left( 1 - \frac{P_{Exact} - \Delta P_{dq}}{\beta} \right) \]

\[ V_{dq} = t_{dd} \cdot q_{dq} \]
CLAIMS

What is claimed is:

1. A method for formation testing comprising:
   establishing a control parameter and a test criterion for testing a formation;
   providing a formation tester equipped with the control parameter and the test criterion
   in a well bore at a test location;
   performing a first formation test;
   controlling the first formation test using the control parameter and the test criterion;
   collecting test data from the first formation test; and
   adjusting the control parameter using the test data.

2. The method of claim 1 further comprising:
   performing a second formation test; and
   controlling the second formation test using the adjusted control parameter and the test criterion.

3. The method of claim 2 further comprising:
   collecting additional test data from the second formation test; and
   re-adjusting the control parameter using the additional test data.

4. The method of claim 1 further comprising controlling a subsequent formation test using
   the test criterion, the test data, and the adjusted control parameter.

5. The method of claim 1 wherein the formation tests are pressure tests.

6. The method of claim 1 further comprising re-adjusting the control parameter after each
   subsequent formation test and based on test data of each immediately preceding formation test,
   and using the re-adjusted control parameter for each subsequent formation test.

7. The method of claim 6 further comprising optimizing the most recent formation test by
   using the adjusted control parameter that is based on all prior formation tests.

8. The method of claim 1 further comprising automatically executing the collecting and
   adjusting steps while downhole.

9. The method of claim 7 further comprising automatically executing the optimized
   formation test while downhole.

10. The method of claim 1 wherein the control parameter includes test control objectives.

11. The method of claim 10 wherein the control parameter further includes formation tester
    specifications.
12. The method of claim 1 wherein the testing control parameter includes test control objectives including at least one parameter that controls a formation test in progress and formation test initial parameters.

13. The method of claim 12 wherein the formation test initial parameter includes at least one of a flow rate, a drawdown volume, a drawdown time, and a buildup time range.

14. The method of claim 1 wherein the control parameter includes controlling a drawdown pressure of the first formation test to a minimum pressure.

15. The method of claim 1 wherein the control parameter includes controlling a drawdown of the first formation test using a predetermined range of flow rates.

16. The method of claim 1 wherein the control parameter includes controlling a drawdown of the first formation test to a maximum drawdown time.

17. The method of claim 1 wherein the control parameter includes controlling a buildup of the first formation test to a minimum buildup time.

18. The method of claim 1 wherein the control parameter includes controlling a buildup of the first formation test to a maximum buildup time.

19. The method of claim 18 further comprising controlling a buildup time based on a test criterion to terminate the buildup before the maximum buildup time is reached.

20. The method of claim 19 wherein the test criterion includes a pressure stability, a temperature stability, or a combination thereof.

21. The method of claim 1 wherein the controlled formation test comprises:
   moving a drawdown device to flow a formation fluid at a flow rate into the formation tester for a pretest, thereby producing a drawdown pressure; and
   automatically controlling the drawdown pressure to a minimum pressure criterion \( P_{\text{min}} \)
   by controlling the flow rate or terminating the drawdown device movement.

22. The method of claim 21 wherein the minimum pressure \( P_{\text{min}} \) is determined by an absolute pressure limit determined using a hydrostatic well bore pressure and a formation tester parameter, wherein the absolute pressure limit defines the lowest pressure the formation tester can reduce a pressure from the hydrostatic well bore pressure when performing a drawdown.

23. The method of claim 22 further comprising terminating the pretest drawdown substantially at the minimum pressure \( P_{\text{min}} \).

24. The method of claim 23 wherein the formation tester parameter includes a system response time \( t_{\text{sys}} \), and further comprising predicting a pressure within the system response time \( t_{\text{sys}} \), and, when the predicted pressure at \( t_{\text{sys}} \) is at or below the minimum pressure \( P_{\text{min}} \), then terminating the pretest drawdown.
The method of claim 24 wherein the predicting and the terminating when the predicted pressure at $A_{sys}$ is at or below the minimum pressure $P_{mi,n}$ further comprise performing a regression of recorded drawdown pressure data using a predictive function which estimates when the minimum pressure $P_{mi,n}$ will occur.

26. The method of claim 1 wherein the first formation test comprises controlling a buildup time of a pretest.

27. The method of claim 26 wherein the buildup time is controlled by not terminating the buildup until at least a minimum buildup time has passed.

28. The method of claim 26 wherein the buildup time is controlled by terminating the buildup when the change in pressure or temperature over a time range meets the test criterion.

29. The method of claim 26 wherein the buildup time is controlled by terminating the buildup when a predetermined maximum buildup time has been reached.

30. The method of claim 21 further comprising, after the initial drawdown and pretest, determining an optimized drawdown rate $q_{do}$ and a volume $V_{do}$.

31. The method of claim 30 further comprising determining estimated formation parameters from the initial pretest.

32. The method of claim 31 further comprising determining an optimal drawdown pressure differential $\Delta P_{d, o}$ based on the previous pretest, test control parameters of Table 1, and formation tester parameters of Table 2.

33. The method of claim 32 further comprising calculating an initial estimate of the optimized drawdown rate $q_{do}$ using the estimated formation parameters determined from the initial pretest, the optimal drawdown pressure differential $\Delta P_{d, o}$ based on the previous pretest, the test control parameters of Table 1, and the formation tester parameters of Table 2.

34. The method of claim 33 further comprising determining if the optimized drawdown rate $q_{do}$, a drawdown time $t_{do}$, and a volume $V_{do}$ are within predetermined limits.

35. The method of claim 30 wherein the optimized drawdown rate $q_{do}$ comprises:

formation parameters from the preceding drawdown including:

$$M_{Exact} \approx M_{dd} = \frac{14.696}{2\pi \cdot 2.54} \left( \frac{q_1}{P_{stop} - P_{dd, end}} \right) \left( \frac{\tau_p}{r_p} \right)$$

$$P_{\Sigma, Exact} = P_{stop}$$

or if the exact $\alpha$, $\beta$ parameters are used then,

$$P_{Exact} = P_{dd, end} + \beta$$

$$M_{Exact} = \frac{14.696}{2\pi} \left( \frac{q_{do}}{\beta} \right) \left( \frac{\tau_p}{r_p} \right) \left( 1 - e^{-\frac{\Delta P}{\alpha}} \right)$$

an optimal drawdown pressure estimate including:

if $\Delta P_{dd, max} > (\Phi_{yd} - P_{exact} - \Delta P_{dd, o})$ then $\Delta P_{do} = \Delta P_{dd}$
else \[ APdol = APdd_{\max} - (Phyd - Pexact) \]

if \[ P_{\min} < P_{\exact} - \Delta P_{dd} \] then \[ \Delta P_{dd} = \Delta P_{dd} \]
else \[ \Delta P_{dd} = P_{\exact} - P_{\min} \]
if \[ P_{\do} < P_{\do2} \] then \[ \Delta P_{do} = \Delta P_{do} \]
else \[ \Delta P_{do} = P_{\do2} \]

an optimal drawdown rate estimate including:

\[ q_{do} = \Delta P_{do} M_{\Exact} \left( \frac{r_{p}}{r_{p^2}} \right) \frac{2\pi}{14.696} \]

adjusting the optimal drawdown rate to be within the formation tester limits, including:

if \[ q_{do} > Q_{\max} \] then \[ q_{do} = Q_{\max} \]
else if \[ q_{do} < Q_{\min} \] then \[ q_{do} = Q_{\min} \]
end and \( q_{do} \) is unchanged;

adjusting the drawdown time and the drawdown volume to practical limits, including:

if \[ q_{do} = Q_{\min} \] then \[ t_{do} = -\alpha \ln \left( 1 - \frac{P_{\exact} - \Delta P_{do}}{\beta} \right) \]
\[ V_{do} = t_{do} \cdot q_{do} \]
else \[ V_{do} = q_{do} \cdot T_{dd\text{\_max}} \]
if \[ V_{do} < V_{pL\text{\_max}} \] then \[ V_{do} = V_{pL\text{\_max}} \]
and \[ t_{do} = T_{dd\text{\_max}} \]

36. The method of claim 26 further comprising continuing the pretest for at least a specified minimum buildup time \( t_{bu\_min} \).
37. The method of claim 36 further comprising determining when to terminate the pretest using a buildup stability \( \sigma_{bu} \) (p.s.i./sec).
38. The method of claim 37 further comprising determining the buildup stability \( \sigma_{bu} \) using a linear regression of a pressure data recorded over a specified stability time period \( \Delta t_{bu} \).
39. The method of claim 38 further comprising replacing a previous buildup stability \( \sigma \) with the new buildup stability \( \sigma_{bu} \), and transmitting the new buildup stability \( \sigma_{bu} \) in real time.
40. The method of claim 38 wherein the buildup stability \( \sigma_{bu} \) is determined by performing a linear regression over a predetermined period of time of the control parameter to determine the slope (p.s.i./sec), and updating the buildup stability \( \sigma_{bu} \) as the buildup progresses.
41. The method of claim 40 further comprising terminating the pretest if stability \( \sigma < \sigma_{bu} \) is reached after the minimum buildup time \( t_{bu\_min} \).
42. The method of claim 40 further comprising continuing the buildup until either stability \( \sigma < \sigma_{bu} \) or the maximum buildup time \( t_{bu\_max} \) is reached, then terminating the pretest.
43. The method of claim 42 further comprising signaling the pretest termination using an uplink command during a mud pumps-on mode or continuing the buildup to the maximum buildup time \( t_{bu\_max} \) according to: if the minimum buildup time \( t_{bu\_min} \) is reached, and the buildup stability is less than the buildup stability of the test criterion, then the buildup is terminated and either a new formation test can start or the formation testing is completed.
44. The method of claim 37 further comprising signal pulsing the buildup stability $\sigma_{bu}$ to the surface of a well.

45. The method of claim 44 further comprising indicating supercharging with a negative value of the buildup stability $\sigma_{bu}$ and changing a testing procedure in response to the negative buildup stability $\sigma_{bu}$.

46. The method of claim 37 further comprising indicating that a mudcake thickness has substantially stabilized if the buildup stability $\sigma_{bu}$ indicates a pressure is increasing, and estimating a supercharge pressure using a stable mudcake model.

47. The method of claim 37 further comprising indicating that a mudcake thickness is increasing or unstable if the buildup stability $\sigma_{bu}$ is negative or a pressure is decreasing, and estimating a supercharge pressure using a dynamic mudcake model.

48. The method of claim 21 further comprising maintaining a drawdown pressure differential $AP_{d0}$ during a second or subsequent formation test.

49. The method of claim 1 wherein the control parameter comprises the test control parameters of Table 1 and the formation tester parameters of Table 2.

50. The method of claim 1 wherein the control parameter is stored in a formation tester memory, downloaded while testing, or a combination thereof.

51. The method of claim 1 further comprising adjusting a test criterion including a bubble point drawdown limit $P_{bp}$.

52. The method of claim 1 further comprising:

   storing the control parameter or the test criterion in a testing database; and
   documenting at least one formation test in the testing database.

53. A method for formation testing comprising:

   establishing a set of control parameters for testing a formation;
   performing a first formation test using the control parameters;
   determining optimum control parameters for a next formation test based on results from
   the previous formation test;
   performing the next formation test using the optimum control parameters; and
   then, repeating the determining optimum control parameters and performing the next
   formation test for each subsequent formation test.

54. A method for formation testing comprising:

   establishing a set of control parameters and test criteria for testing a formation;
   providing a formation tester in a well bore at a test location;
performing a first pressure test, wherein the first pressure test is controlled by the set of control parameters and test criteria;

adjusting the set of control parameters and test criteria based on the results of the first pressure test;

using the adjusted set to control a second pressure test subsequent to the first pressure test;

adjusting the set after the second pressure test and each subsequent pressure test; and using the adjusted set of control parameters and test criteria for each subsequent pressure test.

55. A system for formation testing comprising:

a formation tester; and

an electronic storage medium and a processor including a control parameter and a test criterion for testing a formation;

wherein the electronic storage medium and the processor are configured to:

execute a first formation test;

control the first formation test using the control parameter and the test criterion;

collect test data from the first formation test; and

adjust the control parameter using the test data.

56. The system of claim 55 wherein the electronic storage medium and the processor are further configured to:

perform a second formation test; and

control the second formation test using the adjusted control parameter and the test criterion.

57. The system of claim 56 wherein the electronic storage medium and the processor are further configured to:

collect additional test data from the second formation test; and

re-adjust the control parameter using the additional test data.

58. The system of claim 55 wherein the electronic storage medium and the processor are further configured to control a subsequent formation test using the test criterion, the test data, and the adjusted control parameter.

59. The system of claim 55 wherein the electronic storage medium and the processor are further configured to re-adjust the control parameter after each subsequent formation test and based on test data of each immediately preceding formation test, and use the re-adjusted control parameter for each subsequent formation test.
FIG. 2
SUBSTITUTE SHEET (RULE 26)
Establishing control parameters for testing a formation

Performing a first formation test using the control parameters

Determining optimum control parameters for a next formation test based on results from the previous formation test

Performing the next formation test using the optimum control parameters

FIG. 8
600 Establishing a control parameter and a test criterion for testing a formation
602 Providing a formation tester in a well bore at a test location
604 Performing a first formation test
606 Controlling the first formation test using the control parameter and the test criterion
608 Collecting test data from the first formation test
610 Adjusting the control parameter using the test data
612 Performing a second formation test
614 Controlling the second formation test using the adjusted control parameter and the test criterion
616

FIG. 9
702 Establishing a set of control parameters and test criteria for testing a formation

704 Providing a formation tester in a well bore at a test location

706 Performing a first pressure test controlled by the set of control parameters and test criteria

708 Adjusting the set of control parameters and test criteria based on the results of the first pressure test

710 Using the adjusted set to control a second pressure test subsequent to the first pressure test

712 Adjusting the set after the second pressure test and each subsequent pressure test

714 Using the adjusted set for each subsequent pressure test

FIG. 10
**INTERNATIONAL SEARCH REPORT**

**International application No.**
PCT/US2012/025820

**A. CLASSIFICATION OF SUBJECT MATTER**

**G01V 9/00(2006.01)i, E21B 47/06(2006.01)i**

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)

G01V 9/00; E21B 47/10; E21B 47/06; E21B 49/08; E21B 21/08; E21B 49/00

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

- Korean utility models and applications for utility models
- Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: formation, parameter, criteria, drawdown, pressure

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Relevant to claim No.</th>
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<td>US 7210344 B2 (JEAN-MARC FOLLINI et a l.) 01 May 2007 See column 3, line 2 - column 14, line 11 and figures 2.6.</td>
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search

25 OCTOBER 2012 (25.10.2012)

Date of mailing of the international search report

29 OCTOBER 2012 (29.10.2012)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. 82-42-472-7140

Authorized officer

MYUNG Dae Keun
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