

Description

This invention relates generally to a method of recording at least one detected phenomenon occurring during a series of events. More particularly, but not by way of limitation, the present invention relates to a method of recording, in an electronic memory device, the pressure and temperature detected during a plurality of events which occur in a well.

It is known that there is a need for methods for recording phenomena during various events. For example, pressure and temperature in a downhole environment often need to be recorded during alternately flowing and non-flowing (closed-in) periods during the testing of an oil or gas well.

In the specific example of the testing of an oil or gas well, a Bourdon tube device can be used mechanically to record pressure and temperature by creating a scribed metallic chart containing a line representing the detected phenomenon, such as pressure. The Bourdon tube device has at least two shortcomings in that it has a limited data recording capacity and a limited programability.

As an alternative to the Bourdon tube type of recording device, electronic memory gauges have been used to record electronically the pressure and temperature in electrical digital form. In the specific example of data recordation during the testing of an oil or gas well, various electronic memory gauges have been manufactured or marketed by such companies as Geophysical Research Corporation, Sperry Corporation and Panex Corporation. These devices have used electronic memories for receiving digital data derived from transducers which are responsive to pressure or temperature.

The types of such electronic memory gauges known to us have a shortcoming in that they can only be programmed to sample pressure and temperature, for example, at one set of contiguous time intervals. A specific example is shown in US-A-4414846. Several possible sequences of time periods and corresponding sample rates are given but only one set of continuous time intervals can be entered into the device. Although the interval lengths can be varied within predetermined ranges, only one set of time intervals can be programmed into the electronic memory gauges at one time. Heretofore, this one set of time intervals has corresponded to a single set of time periods at which the events have been expected to occur. For example, if it were desired to record pressure and temperature in a well during two different events, such as a flowing period and a closed-in period, one such electronic memory gauge would be programmed with a first estimated time interval during which it was expected that the flowing event would occur, and with a second estimated time interval during which it was expected that the closed-in event would occur. Because the pressure and temperature are generally to be recorded at different rates during different events, one sample rate would be entered for the first time interval and another sample rate would be entered for the second time interval. This presents a problem in that if the actual times of the flowing and closed-in events are not correctly estimated by the selected time intervals, the rates at which the pressure and temperature will be sampled during the respective time intervals will not correctly correspond to the desired sample rate for the event that is actually occurring.

By way of more specific example, assume that it will take six hours to run a testing string containing the memory gauge into the well borehole. During this event of running into the hole, the sample rate for recording the phenomena (e.g. the pressure and temperature) is to be 10 minutes. Assume that the next event is a first flow period which is to be completed within 30 minutes following the running of the testing string into the hole. During this interval, the sample rate is to be 3 minutes. Subsequent events, with their estimated time of completion and their desired sample rates shown in parentheses, include a first closed-in period (1 hour, with a sample rate of 15 seconds), a second flow period (1 hour, with a 3 minute sample rate), a second closed-in period (2 hours, with a 15 second sample rate for the first hour and a 1 minute sample rate for the second hour), and pulling out of the hole (6 hours, with a 10 minute sample rate). If any of the foregoing anticipated time schedules, which have been entered into the memory gauge as known to the art, are not precisely met by what actually occurs (as is the case in nearly every well test), it can be readily understood from the foregoing that such a difference between the actual and estimated times for the events will most likely cause the detected phenomena during subsequent events to be sampled at a rate which is different from the desired rate for the specific event. For example, if it actually took 7 hours to run into the hole, rather than the estimated 6 hours with which the aforementioned gauge was programmed, the memory gauge would be taking 15-second samples during the actual first flow event rather than the desired 3-minute samples. Assuming the actual first flow event lasted the estimated 30 minutes, then during the subsequent actual first closed-in period the gauge would be taking samples at the 3-minute sample rate which was programmed to commence at 7.5 hours from the starting time. During the actual first closed-in period, the gauge would not be gathering the quantity of information that was desired.

Therefore, there is the need for a method by which a recording means, such as an electronic memory gauge used for recording pressure and temperature in an oil or gas well, can be programmed to record the

detected phenomena so that the desired quantity of data is less likely to be lost due to a difference between the estimated time at which an event is anticipated to occur and the actual time at which the event occurs. It is also desirable that such a new method be capable of use with a specific presently known memory device which can ultimately receive only a single set of time intervals. There is also the need for such a method to be capable of selecting a sample rate and a sample ratio for each time interval.

We have now devised a method wherein, in effect, a single set of time intervals is generated from two different sets of time periods. Thus, two time lines are created with different periods assigned to respective events during which phenomena are to be recorded, and these are combined into a single set of time intervals, which set is entered into the memory device. The method of the present invention selects one of possibly a plurality of sample rates for each time interval. In a preferred embodiment, the fastest sample rate is selected so that the chance of data loss is eliminated or at least reduced. It is also preferred to use ratios of the sampling of one phenomenon relative to another to be entered and used in recording the desired information. Thus, by the present invention, a better time estimate and a better selection of sample rates and ratios are achieved than could be achieved by simply loading the prior art memory devices with a single initial estimate of times and sample rates.

The present invention provides a method of recording at least one phenomenon detected during a series of events, in which a time period and a corresponding sampling rate is allocated to each event to define the frequency at which the phenomenon is desired to be recorded during each event, the method being characterised by defining, for each event, a first period of time and a second period of time during which the event might occur; assigning a sample rate to each of said first and second time periods corresponding to the same one of the events so that a sample rate is defined for each event, being the frequency at which it is desired to record said at least one phenomenon; deriving from said series of first and second time intervals and said first and second sample rates a single set of contiguous time intervals each having an associated sample rate; and recording said at least one phenomenon at the respective sample rate during each of said contiguous time intervals.

In more detail with respect to a particular method of recording, in an electronic memory device, the pressure and temperature detected during a plurality of events occurring in a well, the method comprises defining a plurality of first time periods, each of the first time periods representing a first period of time during which one of the events might occur, and defining a plurality of second time periods, each of the second time periods representing a second period of time during which one of the events might occur. This method also includes assigning a sample rate to each of the first time periods and each of the second time periods corresponding to the same one of the events so that a plurality of sample rates is defined in correspondence with the plurality of events. Each of the sample rates defines the frequency at which at least one of the pressure and temperature is to be recorded during the respective time periods. The inventive method also includes deriving from the plurality of first time periods, the plurality of second time periods, and the plurality of sample rates a single set of time intervals having a respective sample rate associated with each one of the time intervals. The method also comprises entering the single set of time intervals and each associated respective sample rate in the electronic memory device, activating the electronic memory device, lowering the electronic memory device into the well, and recording at least one of the pressure and temperature in response to the respective sample rate within each of the time intervals. In a preferred embodiment, the method further comprises assigning a pressure-to-temperature sample ratio to each of the first time periods and each of the second time periods corresponding to the same one of the events so that a plurality of pressure-to-temperature sample ratios is defined in correspondence with the plurality of events. This preferred embodiment also comprises associating a respective one of the plurality of pressure-to-temperature sample ratios with each one of the time intervals and entering each respective one of the pressure-to-temperature sample ratios associated with a time interval in the electronic memory device. In this preferred embodiment, the aforementioned step of recording includes recording the pressure and temperature at the respective sample rate and in the respective pressure-to-temperature sample ratio within each of the time intervals.

The aforementioned step of deriving the single set of time intervals includes, for at least one selected time within each of the first time periods and the second time periods, comparing all of the sample rates for those of the plurality of events which could be occurring at the selected time and selecting the fastest one of the compared sample rates. This deriving step further comprises grouping consecutively occurring ones of the selected sample rates having the sample value to define one of the time intervals for each group of the consecutively occurring, same-valued sample rates.

In order that the invention may be more fully understood, reference is made to the accompanying drawings, wherein:

FIGURE 1 is a schematic diagram showing a testing string, including an electronic memory gauge and a tester valve, disposed in the borehole of a well and also showing a computer system located at the surface.

FIGURES 2A-2G depict a flow chart of a program for programming the computer shown in Figure 1.

FIGURE 3 is a histogram of minimum and maximum time lines having time periods, time segments, time intervals, sample rates and events shown thereon.

FIGURE 4 is an illustration of a printout showing the derived time intervals in absolute time and with the associated sample rates and ratios.

FIGURE 5 is an illustration of a printout showing the derived time intervals in real time and with the associated sample rates and ratios.

Detailed Description of a preferred Embodiment

The following description of the method of the present invention will be made with reference to a specific usage wherein pressure and temperature are to be recorded during a drill stem test conducted in a borehole of a well. Apparatus for conducting such a test is schematically illustrated in FIG. 1.

In FIG. 1, a well borehole 202 having a surface well structure and equipment assembly 204 of a type as known to the art located at the mouth of the borehole 202 are schematically depicted. Extending into the borehole 202 from the surface well structure and equipment assembly 204 is a testing tool string 206 shown associated with a packer 208 of a type as known to the art. The testing string 206 has a tester valve 210 of a type as known to the art and a memory gauge 212 of a type as known to the art contained therein. The electronic memory gauge 212 includes pressure and temperature transducers, electronic recording and control sections, and a battery power supply of types as known to the art. For example, the electronic recording and control section of the memory gauge 212 can be a Geophysical Research Corporation Model EMR 502 electronic recording and control section including a data storage means having the known capability of receiving up to twenty time intervals and of receiving a respective sample rate associated with each time interval. This device detects pressure and temperature through its pressure and temperature transducers and records, in digital format, the detected information at the respective sample rate during each respective one of the up to twenty time intervals.

Located at the surface of the well borehole 202 is a computer 214 of a type as known to the art for analyzing the data recorded in the memory gauge 212. For example, a Hewlett-Packard computer of a type as known to the art to be used at a well site for receiving and analyzing the data from the electronic memory gauge 212 can be used. The computer 214 receives the information from the memory gauge 212 through a suitable input/output port 216 of a type as known to the art. Data can be output through the input/output port 216.

Attached to the computer 214 for allowing an operator to control the operation thereof are a keyboard 218 and a video screen 220 of types as known to the art. To provide a hard copy output, there is also shown in FIG. 1 a printer 222 of a suitable type as known to the art.

In performing the method of the present invention, the computer 214 is programmed with an application program 224. The application program 224 is entered into the computer by any suitable means known to the art, such as from a program storage disc. The preferred embodiment of the application program 224 of the present invention is set forth in a program listing. The portion of the program listing relating to the present invention is shown in the flow chart set forth in FIGS. 2A-2G. Because the flow chart is self-explanatory to at least those having ordinary skill in the pertinent arts, the operation of the application program 224 will be described by way of example and with reference to a histogram 226 shown in FIG. 3. The term "histograph" is the term we have used to mean a graphical presentation of minimum and maximum times required to perform a series of events. The basic form of a histogram is two time lines plotted parallel to one another using the same scale. Along one time line a minimum sequence of events is shown at the times at which they are anticipated to occur, and along the other time line a maximum anticipated sequence of events is shown. Other information such as will be subsequently described can be shown on a histogram.

With reference to FIG. 3, the histogram 226 will be used to describe the preferred embodiment method of the present invention. Initially, however, the structure of the specific histogram 226 will be described.

The histogram 226 includes a first time line 228 and a second time line 230, each having the same scale and commencing at the same starting point, which starting point in the preferred embodiment of FIG. 3 is designated by the numeral "0." The time line 228 is marked with times defining minimum time periods representing anticipated initial periods during which events might occur. Specifically, the event of running in the hole ("RIH") is designated as likely to occur within the minimum time period between 0 and 12 hours.

The other events and their anticipated minimum or initial periods are specified in the following table:

Event	Length of Time (hrs.)	Minimum Time Period at which Event is Anticipated to Occur (Absolute Time from Starting Time - Hrs.)
first flow period (1FP)	1	12-13
first closed-in period (1CIP)	1 (first sub-period) 1 (second sub-period) 0 (third sub-period)	13-14 14-15 15-15
second flow period (2FP)	6	15-21
second closed-in period (2CIP)	1 (first sub-period) 2 (second sub-period) 3 (third sub-period) 6 (fourth sub-period)	21-22 22-24 24-27 27-33
acidizing (ACID)	4	33-37
third flow period (3FP)	24	37-61
third closed-in period (3CIP)	1 (first sub-period) 2 (second sub-period) 3 (third sub-period) 42 (fourth sub-period)	61-62 62-64 64-67 67-109
reverse circulation (REV)	2	109-111
pull out of hole (POOH)	14	111-125

The foregoing minimum time periods are selected prior to a well test based on anticipated job requirements. In the illustrated preferred embodiment, these job requirements indicate that each time period is contiguous with each immediately preceding and each immediately succeeding event, if any. For example, the event of running in the hole is immediately succeeded by the first flow period which is immediately succeeded by the first closed-in period and so on. These contiguous time periods, therefore, have common, or coincident, end and start times. For example, the first flow period is defined between 12 and 13 hours whereas the first closed-in period is defined between 13 and 15 hours so that the time of 13 hours specifies the end time for the estimated minimum first flow period and the start time for the estimated minimum first closed-in period. Similarly, the time of 15 hours defines the end time of the estimated minimum first closed-in period and it defines the start time of the estimated minimum second flow period.

The time line 230 is demarcated by times and events in a manner similar to the time line 228 except that the times of the time line 230 define anticipated final or maximum periods during which the events are anticipated to occur. The events, their anticipated lengths and resultant anticipated time periods are specified in the following table:

Event	Length of Time (hrs.)	Maximum Time Period at which Event is Anticipated to Occur (Absolute Time from Starting Time - Hrs.)
running in hole (RIH)	14	0-14
first flow period (1FP)	2	14-16
first closed-in period (1CIP)	1 (first sub-period)	16-17
	2 (second sub-period)	17-19
	1 (third subperiod)	19-20
second flow period (2FP)	8	20-28
second closed-in period (2CIP)	1 (first sub-period)	28-29
	2 (second sub-period)	29-31
	3 (third sub-period)	31-34
	10 (fourth sub-period)	34-44
acidizing (ACID)	6	44-50
third flow period (3FP)	32	50-82
third closed-in period (3CIP)	1 (first sub-period)	82-83
	2 (second sub-period)	83-85
	3 (third sub-period)	85-88
	58 (fourth sub-period)	88-146
reverse circulation (REV)	3	146-149
pull out of hole (POOH)	16	149-165

In the preferred embodiment, the events along the maximum time line 230 are also contiguous so that an end time of one time period is also a start time of the next adjacent time period. For example, the hour 16 is the end time for the estimated maximum first flow period and the start time for the estimated maximum first closed-in period. Therefore, when the time periods are contiguous as shown in FIG. 3, an end time of one time period coincides with a start time of the next time period.

FIG. 3 also shows solid diagonal lines connecting a start time for a minimum time period with a start time for a maximum time period and connecting an end time for a minimum time period with an end time for a corresponding maximum time period; "corresponding" here meaning associated with the same event. For example, the times of 12 and 14 hours correspond, respectively, to the start of the minimum first flow period and the start of the maximum first flow period. The time of 13 hours is connected to the time of 16 hours because they represent the corresponding ends of the minimum time period and the maximum time period associated with the first flow period event. This demarcation defines time segments associated with each event. That is, there is a time segment 232 associated with the event of running in the hole. This segment is bounded by the common start time of both the minimum time line 228 and the maximum time line 230 and by the diagonal connecting the respective end times at 12 and 14 hours. A time segment 234 is defined in association with the first flow period. The first closed-in period has three time segments 236, 238, 240 associated with respective ones of the first, second and third sub-periods of the first closed-in period. The 15-21 minimum time period and the 20-28 maximum time period, and the associated interconnecting diagonal lines, define a time segment 242 for the second flow period. The second closed-in period includes time segments 244, 246, 248, 250. The acidizing period has a time segment 252 whereas the third flow period has a time segment 254. The third closed-in period includes time segments 256, 258, 260, 262 respectively corresponding to the first, second, third and fourth sub-periods of the third closed-in period. The reverse circulation event has a time segment 264 and the pulling out of the hole event has a time segment 266.

Assigned to each time segment is a respective sample rate which defines the frequency at which a selected phenomenon, such as the exemplary pressure or temperature, is to be recorded during the respective time segment. For example, during the time segment 232 during which the running in the hole event is anticipated to occur, no samples need be taken. In the preferred embodiment of the present invention, a zero sample rate is an infinite sample rate because there is an infinite time between samples since no sample is taken. The time segment 234 has a sample rate of .017 hours, which is a rate for taking a sample approximately every 1 minute, 1.2 seconds. The time segment 238 has a .05 hour sample rate which translates to taking a sample every three minutes. The time segment 240 has a .1 hour sample rate

which translates to one sample being taken every six minutes. The time segment 250 has a .25 hour or 15 minute sample rate, and the time segment 264 has a .5 hour or 30 minute sample rate. The remaining assignment of sample rates to time segments is shown in FIG. 3. The assignments are effectively made as to each time increment between and including the minimum start time and the maximum end time of the time segment.

Although not shown in FIG. 3, each time segment can also have a ratio entered when two or more phenomena are to be sampled. In our specific example wherein both pressure and temperature are to be sampled, a ratio of the number of pressure samples to be taken for each temperature sample can be entered. These ratios are not shown in FIG. 3 for purposes of simplifying the drawing. The resultant ratios derived from the utilization of the present method as will be more particularly described hereinbelow are shown in FIGS. 4 and 5, also to be described subsequently.

To effectively create the histogram shown in FIG. 3 and described hereinabove, an operator of the computer 214, after having loaded the applications program 224 therein, converses with the computer 214 and the program 224 through the keyboard 218 and the video screen 220. In response to prompts displayed at the screen 220 through the operation of the program 224, the operator enters elapsed time information and sample rates and ratio information from which the computer can, in effect, construct the time lines 228, 230 and the time segments 232-266 and assign the sample rates and ratios to the respective time segments.

Once the time, sample rate and ratio information for the illustrated embodiment has been entered into the computer 214, the computer effectively creates the histogram as shown in FIG. 3 and derives therefrom a series of contiguous time intervals so that each of the time intervals includes at least a portion of at least one of the minimum or maximum time periods and so that each of the time intervals has associated therewith one of the sample rates and ratios associated with those portions of the minimum or maximum time periods included within the respective time interval. In the preferred embodiment, the fastest sample rate and the minimum ratio are selected. In the preferred embodiment, there are twenty or less time intervals created so that the time intervals generated can be loaded into the Geophysical Resources Corporation electronic memory gauge used in the exemplary specific embodiment.

To derive the time intervals, the program 224 controls the computer 214 so that the possible sample rates which could be needed at critical times are examined. In the preferred embodiment the "critical times" are at each start time and end time of both the minimum and maximum time periods. For example, 12 hours is shown in FIG. 3 to be the start time of the minimum time period of 12-13 hours defined for the first flow period (it is also the end time of the minimum running in hole time period of 0-12 hours). The computer 214, under control of the program 224, recognizes the hour 12 as a critical hour and so compares each possible sample rate which could be needed for each event which has been estimated to possibly occur at that time. From FIG. 3, the needed sample rate at 12 hours could be 0.00 if the running in hole event were still occurring (this event was estimated as possibly occurring for up to the first 14 hours), or the needed sample rate could be .017 if the first flow period event were commenced. The computer 214 compares these two sample rates and selects the faster one, which in this example is .017 because 0.00 represents an infinite sample period.

The computer 214 steps to the next critical start or end time, which is at the 13 hour mark in the illustrated embodiment. This time represents the end time of the minimum first flow period event and the start time of the first sub-period of the minimum first closed-in period event. At this time point, the computer 214 compares three numbers because at 13 hours the actual event could be the running in hole event (with a sample rate of 0.00) or the first flow period event (with a sample rate of .017) or the first sub-period of the first closed-in period event (with a sample rate of .017). The fastest rate is selected so that, again, .017 is the selected sample rate.

At the 14 hour mark, the next critical time for the specific histogram shown in FIG. 3, the computer 214 compares the assigned sample rates for the possible events that could be occurring at that time. The 14 hour time point is the end time of the first sub-period of the minimum first closed-in period event and the start time of the second sub-period of the minimum first closed-in period, and the 14 hour time point is also the end time of the maximum running in hole event and the start time for the maximum first flow period. Comparing the sample rates of these possible events again results in the .017 sample rate being selected as the fastest of the possible sample rates to be needed at 14 hours. A similar result is obtained when the analysis is made at both the 15 hour time point and the 16 hour time point.

FIG. 3 shows that the 17 hour time point is the end time for the first sub-period of the maximum first flow period event and it is also the start time for the second sub-period of the maximum first closed-in period event. At this 17 hour mark, the second sub-period of the first closed-in period could be occurring (designated by the time segment 238 which has a sample rate of .05 assigned thereto) or the third sub-

period of the first closed-in period could be occurring (designated by the time segment 240 with an assigned sample rate of .1) or the second flow period could be occurring (designated by the time segment 242 with an assigned sample rate of .05). As with the previous time periods, these events are determined in FIG. 3 by reading straight across between the corresponding times on the maximum elapsed time line 230 and on the minimum elapsed time line 228, both of which time lines have the same scale, and by noting which time segments are crossed. In comparing these three possible events and their associated sample rates, the .05 sample rate is selected in the preferred embodiment since it is the fastest of the possible needed sample rates.

The computer 214, under control of the program 224, recognizes that prior to the 17 hour mark the selected sample rate was 0.17 and that at the 17 hour mark the needed rate is .05. In response thereto, the computer 214 groups the previous .017 sample rates into one group which becomes a respective time interval. The computer 214 continues this process of examining the possible sample rates which might occur at the specified times along the minimum and maximum time lines 228, 230 and of grouping the consecutively occurring, same-valued sample rates into respective time intervals. For the specific illustration set forth in FIG. 3, the time intervals are designated by the horizontal dot-dash lines and the associated selected fastest sample rates are shown along the right-hand margin. The time intervals are identified by the reference numerals 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294.

In examining FIG. 3, it will be noted that each of the time intervals starts and ends at a respective one of the predetermined period start or end times along either the minimum time line 228 or the maximum time line 230. Each of these time intervals thus includes at least a portion of at least one of the minimum time periods or maximum time periods. For example, the time interval 280 extends from 34 hours to 37 hours, thereby including part of the minimum acidizing period defined between 33 and 37 hours and part of the fourth sub-period of the maximum second closed-in period defined between 34 and 44 hours.

The foregoing selection of the sample rates is performed by the portion of the program shown in the flow chart of FIGS. 2A-2G. Broadly, this program iterates or loops at each critical time until all the potential rates have been compared. When the critical time is on the minimum time line 228, the comparison is from the next possible future rate back to the last possible rate needed at that time. For example, at the 67 hour mark on the minimum time line 228 shown in FIG. 3, the program first compares the future rate of .25 for the time segment 262 to a predetermined "seed" value which is some maximum default sample rate preset in the program. This comparison results in .25 being selected. The program loops and next compares the .25 rate to the .1 rate for the time segment 260, representing the most recent past event measured relative to the critical point of 67 hours. This comparison results in the .1 rate being selected because it is a faster rate than .25. This looping, comparing and selecting continues until all possible events which could be occurring at the 67 hour mark have been checked. This means the comparison for the embodiment shown in FIG. 3 continues back through the rates of .05, .017 and .1 associated with the time segments 258, 256, 254, respectively. When the critical time is on the maximum time line 230, the comparison is performed from the last possible rate to the most future rate possibly needed at that time. For example, at the 82 hour time point on the maximum time line 230, the program first compares the past rate of .1 assigned to the time segment 254 with the seed value. The following comparisons then proceed, in order, through the sample rates assigned to the time segments 256, 258, 260, 262 which encompass events which it is estimated could occur at 82 hours.

When a respective ratio defining the number of samples of one phenomenon to be recorded relative to the number of samples of another detected phenomenon is assigned to each of the time segments 232-266, the computer 214, under control of the program 224, compares the possible ratios in a manner similar to how the possible sample rates are compared. In the preferred embodiment, the minimum ratio of those possible ratios needed at any one of the particular times is selected.

Once the time intervals, sample rates and ratios have been derived, this information is transferred from the computer 214 to the electronic memory gauge 212. In the preferred embodiment, this transfer occurs before the memory gauge 212 is lowered into the well borehole 202. The transfer can occur in any suitable manner, such as either by connecting the electronic memory of the gauge 212 to the port 216 and actuating the computer 214 to electronically transfer the information from its memory into the memory of the gauge 212 or by loading the derived information into an EPROM within the computer 214 and then physically removing the EPROM from the computer 214 and inserting it into a suitable receptacle in the memory gauge 212.

Once this transfer has occurred, the memory gauge 212 is activated or energized in a manner as known to the art, such as by connecting the electronic circuits to the battery in the exemplary embodiment of the memory gauge 212.

Once activated, the memory gauge 212 is run into the borehole 202 and the phenomena are detected by the memory gauge 212 in a manner as known to the art. This data collection is performed at the sample rates and in the ratios and during the time intervals as provided by the method of the present invention.

At the end of the testing period, the memory gauge 212 is pulled out of the borehole 202. The data contents of the memory gauge 212 are then entered into the computer 214 in a manner as known to the art, such as through the port 216, for analysis by the computer in a manner as known to the art.

In addition to transferring the time interval, sample rate and ratio information to the memory gauge 212 for thereafter controlling the operation of the memory gauge 212, the information derived by the method of the present invention can be printed from the computer 214 via the printer 222. The printout can be scaled in either absolute time or real time.

FIG. 4 is an illustration of an absolute time printout 296. The printout 296 shows the minimum and maximum time lines spaced parallel to each other. In between these two lines the boundaries of the time intervals and the associated sample rates and pressure-to-temperature ratios are specified. Although not shown in FIG. 4 for purposes of simplicity, the printout 296 can also include designations representing the events and other information as desired.

The absolute time printout 296 shown in FIG. 4 indicates that the first time interval, which is designated by the reference numeral 268 in FIG. 3, commences at the absolute start time and continues until 12 hours later. During this first time interval, no samples are to be taken of either pressure or temperature.

The second time interval, designated by the reference numeral 270 in FIG. 3, extends from 12 hours to 17 hours. During this time interval, samples are to be taken every 1 minute, 1.2 seconds (.017 hours) with eleven pressure readings being recorded at this sample rate for every one temperature reading recorded.

The third time interval, which is designated by the reference numeral 272 in FIG. 3, extends from 17 hours to 21 hours with a sample rate of 3 minutes (.05 hours) and a pressure-to-temperature ratio of 3:1.

FIG. 4 also shows the other time interval boundary times and the associated sample rates and ratios. These other time intervals correspond to the time intervals 274-294 shown in FIG. 3.

FIG. 5 shows a printout 298 from the printer 222 which is similar to the one shown in FIG. 4 except that the printout 298 of FIG. 5 is scaled in real time. In the preferred embodiment, the real time is noted by the operator when the memory gauge 212 is activated prior to being lowered into the well borehole 202. This real time is correlated to the zero absolute start time shown in FIGS. 3 and 4. From this real time start time, the absolute times indicated in FIGS. 3 and 4 can be converted to the corresponding real times. For example, in FIG. 5 the real time noted at the start time was 13:23:21.00 on September 20, 1984. Therefore, 12 hours later, the end of the first time interval 268 would be the 1:23:21.00 September 21, 1984 reading specified in FIG. 5. The other times shown in FIG. 5 are similarly computed from the 13:23:21.00 September 20, 1984 start time. The sample rates and pressure-to-temperature ratios are the same in FIG. 5 as those shown in FIG. 4.

By defining the minimum and maximum time periods as performed in the preferred embodiment of the present invention, a better estimate of when the actual event will occur can be derived. Additionally, selecting the fastest sample rate for an event which could be occurring at any particular time insures that an adequate quantity of information will be obtained. Furthermore, selecting the minimum ratio of samples of one phenomenon relative to another phenomenon insures that enough data of one phenomenon relative to the quantity of another will be obtained.

Although the preferred embodiment of the present invention has been described to be specifically useful with a Hewlett-Packard computer and a Geophysical Resources Corporation memory gauge to record pressure and temperature in a downhole environment, the present invention can be adapted for other uses and equipment. In the specific environment of oil and gas wells, the present invention is particularly useful for drill stem tests and hydrostatic pressure surveys. However, the present invention can be adapted for other uses.

Claims

1. A method of recording at least one phenomenon detected during a series of events, in which a time period and a corresponding sampling rate is allocated to each event to define the frequency at which the phenomenon is desired to be recorded during each event, the method being characterised by defining, for each event, a first period of time and a second period of time during which the event might occur; assigning a sample rate to each of said first and second time periods corresponding to the same one of the events so that a sample rate is defined for each event, being the frequency at which it is desired to record said at least one phenomenon; deriving from said series of first and second time intervals and said first and second sample rates a single set of contiguous time intervals each having



Once activated, the memory gauge 212 is run into the borehole 202 and the phenomena are detected by the memory gauge 212 in a manner as known to the art. This data collection is performed at the sample rates and in the ratios and during the time intervals as provided by the method of the present invention.

At the end of the testing period, the memory gauge 212 is pulled out of the borehole 202. The data contents of the memory gauge 212 are then entered into the computer 214 in a manner as known to the art, such as through the port 216, for analysis by the computer in a manner as known to the art.

In addition to transferring the time interval, sample rate and ratio information to the memory gauge 212 for thereafter controlling the operation of the memory gauge 212, the information derived by the method of the present invention can be printed from the computer 214 via the printer 222. The printout can be scaled in either absolute time or real time.

FIG. 4 is an illustration of an absolute time printout 296. The printout 296 shows the minimum and maximum time lines spaced parallel to each other. In between these two lines the boundaries of the time intervals and the associated sample rates and pressure-to-temperature ratios are specified. Although not shown in FIG. 4 for purposes of simplicity, the printout 296 can also include designations representing the events and other information as desired.

The absolute time printout 296 shown in FIG. 4 indicates that the first time interval, which is designated by the reference numeral 268 in FIG. 3, commences at the absolute start time and continues until 12 hours later. During this first time interval, no samples are to be taken of either pressure or temperature.

The second time interval, designated by the reference numeral 270 in FIG. 3, extends from 12 hours to 17 hours. During this time interval, samples are to be taken every 1 minute, 1.2 seconds (.017 hours) with eleven pressure readings being recorded at this sample rate for every one temperature reading recorded.

The third time interval, which is designated by the reference numeral 272 in FIG. 3, extends from 17 hours to 21 hours with a sample rate of 3 minutes (.05 hours) and a pressure-to-temperature ratio of 3:1.

FIG. 4 also shows the other time interval boundary times and the associated sample rates and ratios.

These other time intervals correspond to the time intervals 274-294 shown in FIG. 3.

FIG. 5 shows a printout 298 from the printer 222 which is similar to the one shown in FIG. 4 except that the printout 298 of FIG. 5 is scaled in real time. In the preferred embodiment, the real time is noted by the operator when the memory gauge 212 is activated prior to being lowered into the well borehole 202. This real time is correlated to the zero absolute start time shown in FIGS. 3 and 4. From this real time start time, the absolute times indicated in FIGS. 3 and 4 can be converted to the corresponding real times. For example, in FIG. 5 the real time noted at the start time was 13:23:21.00 on September 20, 1984. Therefore, 12 hours later, the end of the first time interval 268 would be the 1:23:21.00 September 21, 1984 reading specified in FIG. 5. The other times shown in FIG. 5 are similarly computed from the 13:23:21.00 September 20, 1984 start time. The sample rates and pressure-to-temperature ratios are the same in FIG. 5 as those shown in FIG. 4.

By defining the minimum and maximum time periods as performed in the preferred embodiment of the present invention, a better estimate of when the actual event will occur can be derived. Additionally, selecting the fastest sample rate for an event which could be occurring at any particular time insures that an adequate quantity of information will be obtained. Furthermore, selecting the minimum ratio of samples of one phenomenon relative to another phenomenon insures that enough data of one phenomenon relative to the quantity of another will be obtained.

Although the preferred embodiment of the present invention has been described to be specifically useful with a Hewlett-Packard computer and a Geophysical Resources Corporation memory gauge to record pressure and temperature in a downhole environment, the present invention can be adapted for other uses and equipment. In the specific environment of oil and gas wells, the present invention is particularly useful for drill stem tests and hydrostatic pressure surveys. However, the present invention can be adapted for other uses.

Claims

1. A method of recording at least one phenomenon detected during a series of events, in which a time period and a corresponding sampling rate is allocated to each event to define the frequency at which the phenomenon is desired to be recorded during each event, the method being characterised by defining, for each event, a first period of time and a second period of time during which the event might occur; assigning a sample rate to each of said first and second time periods corresponding to the same one of the events so that a sample rate is defined for each event, being the frequency at which it is desired to record said at least one phenomenon; deriving from said series of first and second time intervals and said first and second sample rates a single set of contiguous time intervals each having



an associated sample rate; and recording said at least one phenomenon at the respective sample rate during each of said contiguous time intervals.

2. A method in accordance with claim 1, wherein said step of deriving includes: for at least one selected time within each of said first and second time periods, comparing all the sample rates for those of said series of events which could be occurring at the selected time and selecting the fastest one of the compared sample rates; and grouping consecutively occurring ones of the selected sample rates having the same value to define one of said contiguous time intervals for each group of the consecutively occurring, same-valued sample rates.
3. A method in accordance with claim 1 or 2, in which two phenomena are recorded, namely pressure and temperature.
4. A method in accordance with claim 3, wherein: said method further comprises: assigning a pressure-to-temperature sample ratio to each of said first and second time periods corresponding to the same one of the events so that a plurality of pressure-to-temperature sample ratios are defined in correspondence with said plurality of events; associating a respective one of said plurality of pressure-to-temperature sample ratios with each one of said time intervals; and entering each of said associated respective one of said plurality of pressure-to-temperature sample ratios in said electronic memory device; and wherein said step of recording includes recording said pressure and temperature at the respective sample rate and in the respective pressure-to-temperature sample ratio within each of said time intervals.
5. A method in accordance with claim 4, wherein said step of associating includes selecting the minimum pressure-to-temperature sample ratio of those sample ratios assigned to the first and second time periods having at least a portion thereof included within the respective one of said time intervals.
6. A method in accordance with any of claims 1 to 5, wherein said step of deriving includes: defining each of said time intervals so that it includes at least a portion of at least one of said first time periods and said second time periods; and selecting said respective sample rate so that it is the fastest of those sample rates assigned to the first and second time periods having at least a portion thereof included within the respective one of said time intervals.
7. A method in accordance with any one of the preceding claims, wherein: each of said first time periods is an estimated minimum time period during which the respective one of the events might occur; and each of said second time periods is an estimated maximum time period during which the respective one of the events might occur.
8. A method in accordance with any one of the preceding claims, further comprising measuring said time intervals from the time of activating said memory device.
9. A method in accordance with any preceding claim, wherein the recording device comprises a programmable memory device and wherein said method includes the further steps of programming said memory device with said series of contiguous time intervals and the associated sample rates, and activating said memory device for recording said at least one phenomenon at the respective sample rate during each of said time intervals.

Patentansprüche

1. Verfahren zur Aufzeichnung wenigstens einer Gegebenheit, die während einer Reihe von Ereignissen erfaßt wurde, bei dem jedem Ereignis ein Zeitabschnitt und eine entsprechende Abtastrate zugeordnet wird, um die Frequenz zu bestimmen, mit der die Gegebenheit während jedes Ereignisses aufgezeichnet werden soll, dadurch gekennzeichnet, daß für jedes Ereignis ein erster Zeitabschnitt und ein zweiter Zeitabschnitt bestimmt werden, während derer das Ereignis eintreten könnte; daß jedem der ersten und zweiten Zeitabschnitte, die demselben Ereignis zugeordnet sind, eine Abtastrate zugewiesen wird, so daß für jedes Ereignis eine Abtastrate bestimmt wird, welche die Frequenz ist, mit der die wenigstens eine Gegebenheit aufgezeichnet werden soll; daß aus den Reihen von ersten und zweiten Zeitintervallen und



den ersten und zweiten Abtastraten ein einziger Satz aneinander anschließender Zeitintervalle mit jeweils einer zugehörigen Abtastrate abgeleitet wird; und daß die wenigstens eine Gegebenheit während jedes der aneinander anschließenden Zeitintervalle mit der betreffenden Abtastrate aufgezeichnet wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Ableitungsschritt einschließt, daß während wenigstens einer ausgewählten Zeit innerhalb jedes der ersten und zweiten Zeitabschnitte alle Abtastraten für diejenigen aus der Reihe von Ereignissen, die zu der ausgewählten Zeit auftreten könnten, verglichen werden und die rascheste Abtastrate aus den verglichenen Abtastraten ausgewählt wird; und daß aufeinander folgend auftretende ausgewählte Abtastraten mit gleichen Werten gruppiert werden, um für jede Gruppe der aufeinander folgend auftretenden Abtastraten von gleichem Wert eines der aneinander anschließenden Zeitintervalle zu bestimmen.
3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß zwei Gegebenheiten, nämlich Druck und Temperatur aufgezeichnet werden.
4. Verfahren nach Anspruch 3, dadurch gekennzeichnet, daß das Verfahren ferner umfaßt, daß jedem der ersten und zweiten Zeitabschnitte, die demselben Ereignis zugeordnet sind, ein Druck-zu-Temperatur-Abtastverhältnis zugewiesen wird, so daß eine Vielzahl von Druck-zu-Temperatur-Abtastverhältnissen entsprechend der Vielzahl von Ereignissen bestimmt wird; daß jedes der Vielzahl von Druck-zu-Temperatur-Abtastverhältnissen jeweils einem der Zeitintervalle zugeordnet wird; und daß jedes der jeweils zugeordneten aus der Vielzahl von Druck-zu-Temperatur-Abtastverhältnissen in die elektronische Speichereinrichtung eingegeben wird; und daß der Aufzeichnungsschritt einschließt, daß der Druck und die Temperatur innerhalb jedes Zeitintervalls mit der jeweiligen Abtastrate und in dem jeweiligen Druck-zu-Temperatur-Abtastverhältnis aufgezeichnet werden.
5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß der Zuordnungsschritt einschließt, daß das Minimum des Druck-zu-Temperatur-Abtastverhältnisses aus denjenigen Abtastverhältnissen ausgewählt wird, die den ersten und zweiten Zeitabschnitten zugewiesen sind, von denen wenigstens ein Teil in dem betreffenden Zeitintervall enthalten ist.
6. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß der Ableitungsschritt einschließt, daß jedes Zeitintervall so bestimmt wird, daß es wenigstens einen Teil wenigstens eines der ersten und der zweiten Zeitabschnitte enthält; und daß die jeweilige Abtastrate so gewählt wird, daß sie die rascheste derjenigen Abtastraten ist, die den ersten und zweiten Zeitabschnitten zugewiesen sind, von denen wenigstens ein Teil in dem betreffenden Zeitintervall enthalten ist.
7. Verfahren nach einem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß jeder erste Zeitabschnitt ein geschätzter minimaler Zeitabschnitt ist, während dessen das betreffende Ereignis auftreten könnte; und daß jeder zweite Zeitabschnitt ein geschätzter maximaler Zeitabschnitt ist, während dessen das betreffende Ereignis auftreten könnte.
8. Verfahren nach einem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß ferner eingeschlossen ist, daß die Zeitintervalle ausgehend von der Zeit der Inbetriebnahme der Speichereinrichtung gemessen werden.
9. Verfahren nach irgendeinem vorstehenden Anspruch, dadurch gekennzeichnet, daß die Aufzeichnungseinrichtung eine programmierbare Speichereinrichtung aufweist und daß das Verfahren ferner die Schritte enthält, daß die Speichereinrichtung mit den Reihen aneinander anschließender Zeitintervalle und den zugeordneten Abtastraten programmiert wird und daß die Speichereinrichtung zur Aufzeichnung der wenigstens einen Gegebenheit mit der betreffenden Abtastrate während jedes Zeitintervalls in Betrieb genommen wird.

Revendications

1. Procédé d'enregistrement d'au moins un phénomène détecté pendant une série d'événements, dans lequel une période de temps et une fréquence d'échantillonnage correspondante sont allouées à chaque événement pour définir la fréquence avec laquelle on désire enregistrer le phénomène pendant



- chaque événement, le procédé étant caractérisé en ce qu'on définit, pour chaque événement, une première période de temps et une seconde période de temps pendant lesquelles l'événement peut apparaître ; on assigne une fréquence d'échantillonnage à chacune desdites première et seconde périodes de temps correspondant au même événement de telle sorte qu'une fréquence d'échantillonnage soit définie pour chaque événement, en étant la fréquence à laquelle on désire enregistrer ledit au moins un phénomène ; on dérive de ladite série de premiers et seconds intervalles de temps et desdites premières et secondes fréquences d'échantillonnage un jeu unique d'intervalles de temps contigus ayant chacun une fréquence d'échantillonnage associée ; et on enregistre ledit au moins un phénomène à la fréquence d'échantillonnage respective pendant chacun desdits intervalles de temps contigus.
2. Procédé selon la revendication 1, dans lequel ladite étape consistant à dériver consiste, pour au moins un moment choisi situé à l'intérieur de chacune desdites premières et secondes périodes de temps, à comparer toutes les fréquences d'échantillonnage pour les événements de ladite série d'événements qui peuvent apparaître au moment choisi et à choisir la plus rapide des fréquences d'échantillonnage comparées ; et à regrouper celles des fréquences d'échantillonnage choisies apparaissant de manière consécutive et ayant la même valeur pour définir un desdits intervalles de temps contigus pour chaque groupe de fréquence d'échantillonnage de même valeur apparaissant de manière consécutive.
3. Procédé selon la revendication 1 ou 2, dans lequel deux phénomènes sont enregistrés, c'est-à-dire la pression et la température.
4. Procédé selon la revendication 3, dans lequel ledit procédé comporte en outre l'association d'un premier rapport d'échantillonnage pression/température à chacune desdites première et seconde périodes de temps correspondant au même événement de telle sorte que plusieurs rapports d'échantillonnage pression/température sont définis en correspondance avec lesdits plusieurs événements ; l'association d'un des rapports d'échantillonnage respectif desdits plusieurs rapports d'échantillonnage rapport/température avec chacun desdits intervalles de temps ; et l'entrée de chacun desdits premiers rapports d'échantillonnage respectifs desdits plusieurs rapports d'échantillonnage pression/température dans le dispositif à mémoire électronique ; et dans lequel ladite étape consistant à enregistrer comporte l'enregistrement de ladite pression et de ladite température à la fréquence d'échantillonnage respective et selon le rapport d'échantillonnage respectif pression/température à l'intérieur de chacun desdits intervalles de temps.
5. Procédé selon la revendication 4, dans lequel ladite étape consistant à associer comporte la sélection du rapport d'échantillonnage pression/température minimal parmi les rapports d'échantillonnage assignés à la première et à la seconde période de temps ayant au moins une partie comprise à l'intérieur d'un intervalle de temps respectif parmi lesdits intervalles de temps.
6. Procédé selon l'une des quelconque des revendications 1 à 5, dans lequel ladite étape consistant à dériver comporte : la définition de chacun desdits intervalles de temps de telle sorte qu'il comporte au moins une partie d'au moins une desdites premières périodes de temps et desdites secondes périodes de temps ; et la sélection de ladite fréquence d'échantillonnage respective de telle sorte qu'elle soit la plus rapide des fréquences d'échantillonnage assignée aux premières et secondes périodes de temps ayant au moins une partie comprise à l'intérieur de l'un des intervalles de temps respectif parmi lesdits intervalles de temps.
7. Procédé selon l'une quelconque des revendications précédentes, dans lequel : chacune desdites premières périodes de temps est une période de temps minimale estimée pendant laquelle l'événement respectif peut apparaître ; et chacune desdites secondes périodes de temps est une période de temps maximale estimée pendant laquelle l'événement respectif peut apparaître.
8. Procédé selon l'une quelconque des revendications précédentes, comportant en outre la mesure desdits intervalles de temps à partir du temps d'activation du dispositif à mémoire.
9. Procédé selon l'une quelconque des revendications précédentes, dans lequel le dispositif d'enregistrement comporte un dispositif à mémoire pouvant être programmé et dans lequel ledit procédé comporte en outre les étapes consistant à programmer ledit dispositif à mémoire à l'aide de ladite série

EP 0 188 365 B1



d'intervalles de temps contigus et des fréquences d'échantillonnage associées, et à activer ledit dispositif à mémoire pour enregistrer ledit au moins un phénomène à la fréquence d'échantillonnage respective pendant chacun desdits intervalles de temps.

5

10

15

20

25

30

35

40

45

50

55