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(54) **MATRIX TEMPERATURE PRODUCTION
LOGGING TOOL**

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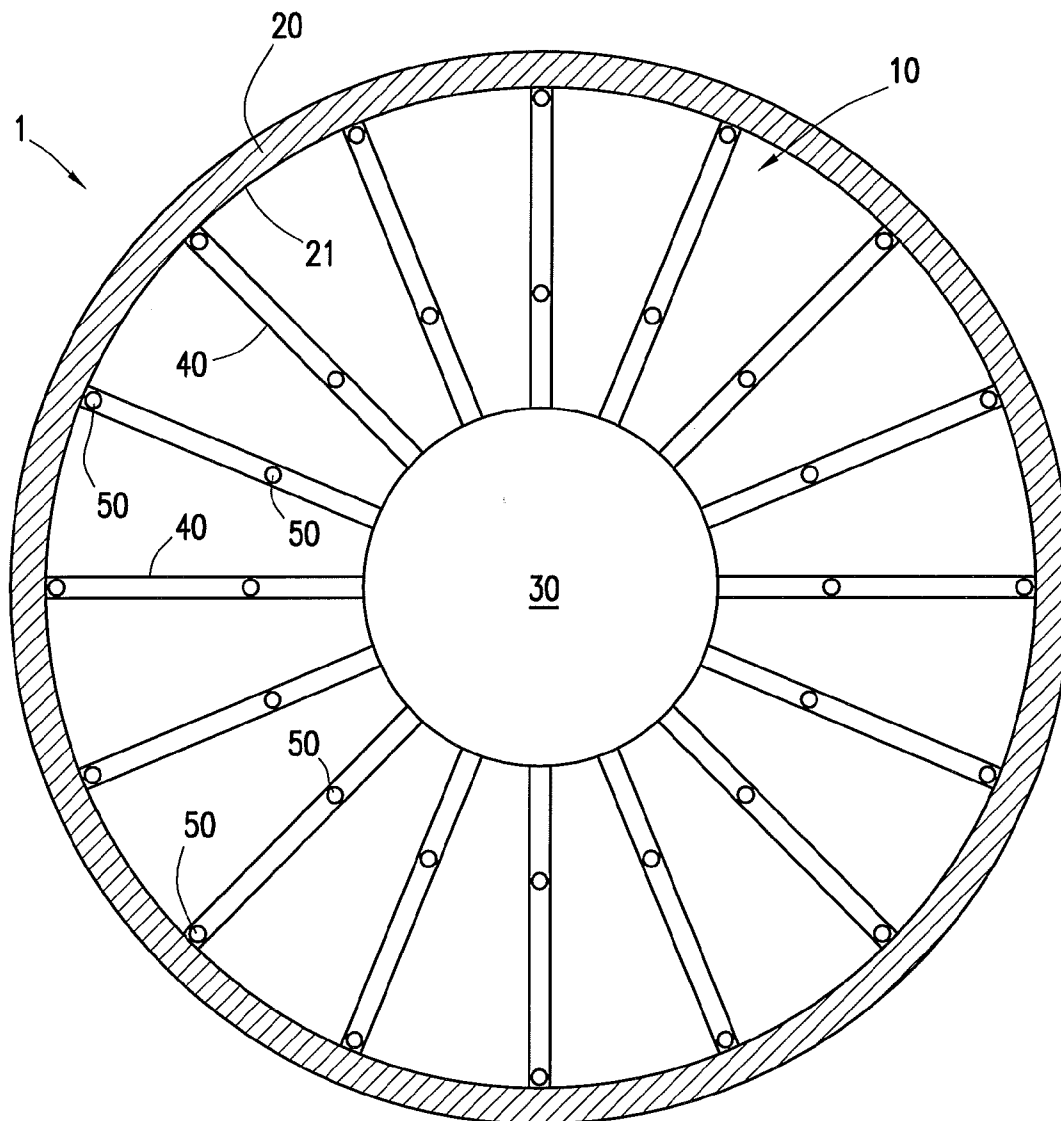
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(57) **ABSTRACT**

A matrix production logging tool for measuring the temperature of produced fluids in a wellbore. Accurate production allocation to the pathways between the oil/gas well and the reservoir provides required data for the economic optimization of the techniques and procedures used to complete future wells. The low maintenance tool provides precise upstream, downstream and inflow temperature measurements of produced fluids within the wellbore.

Related U.S. Application Data

(60) Provisional application No. 62/021,441, filed on Jul. 7, 2014.



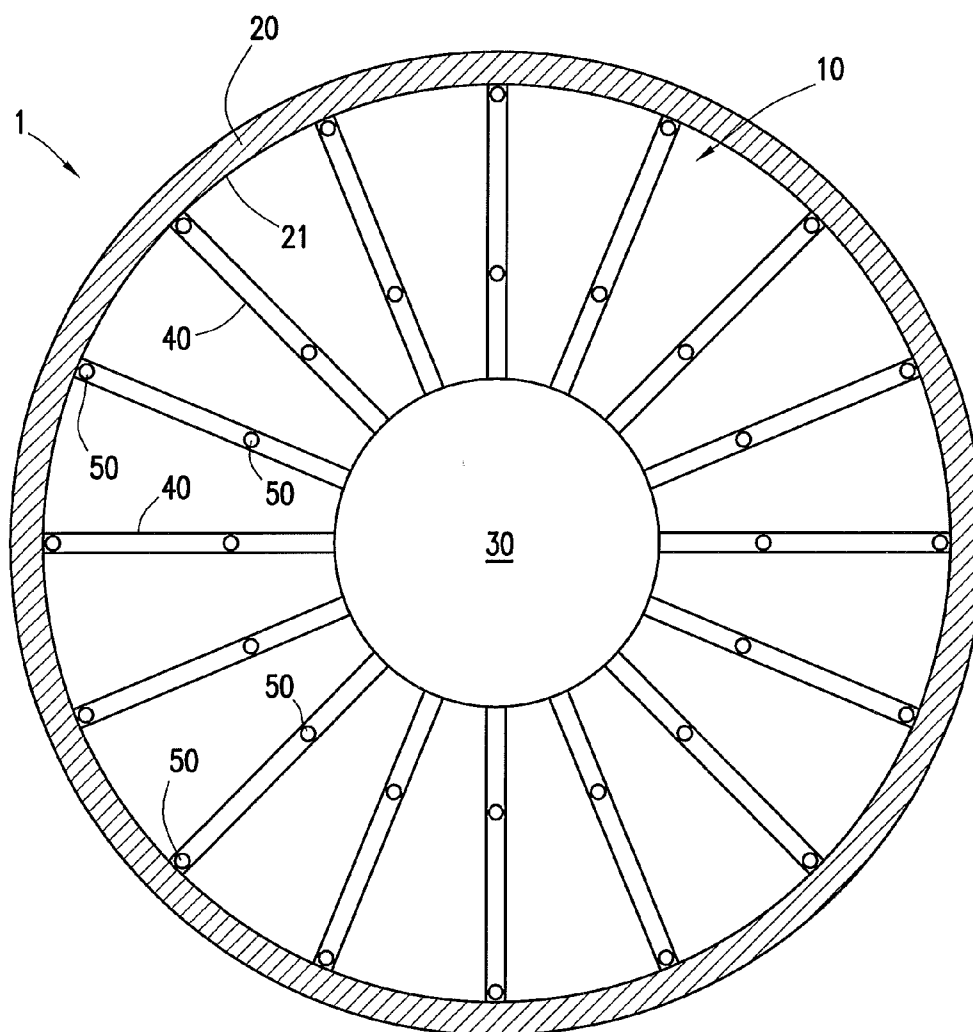


FIG. 1

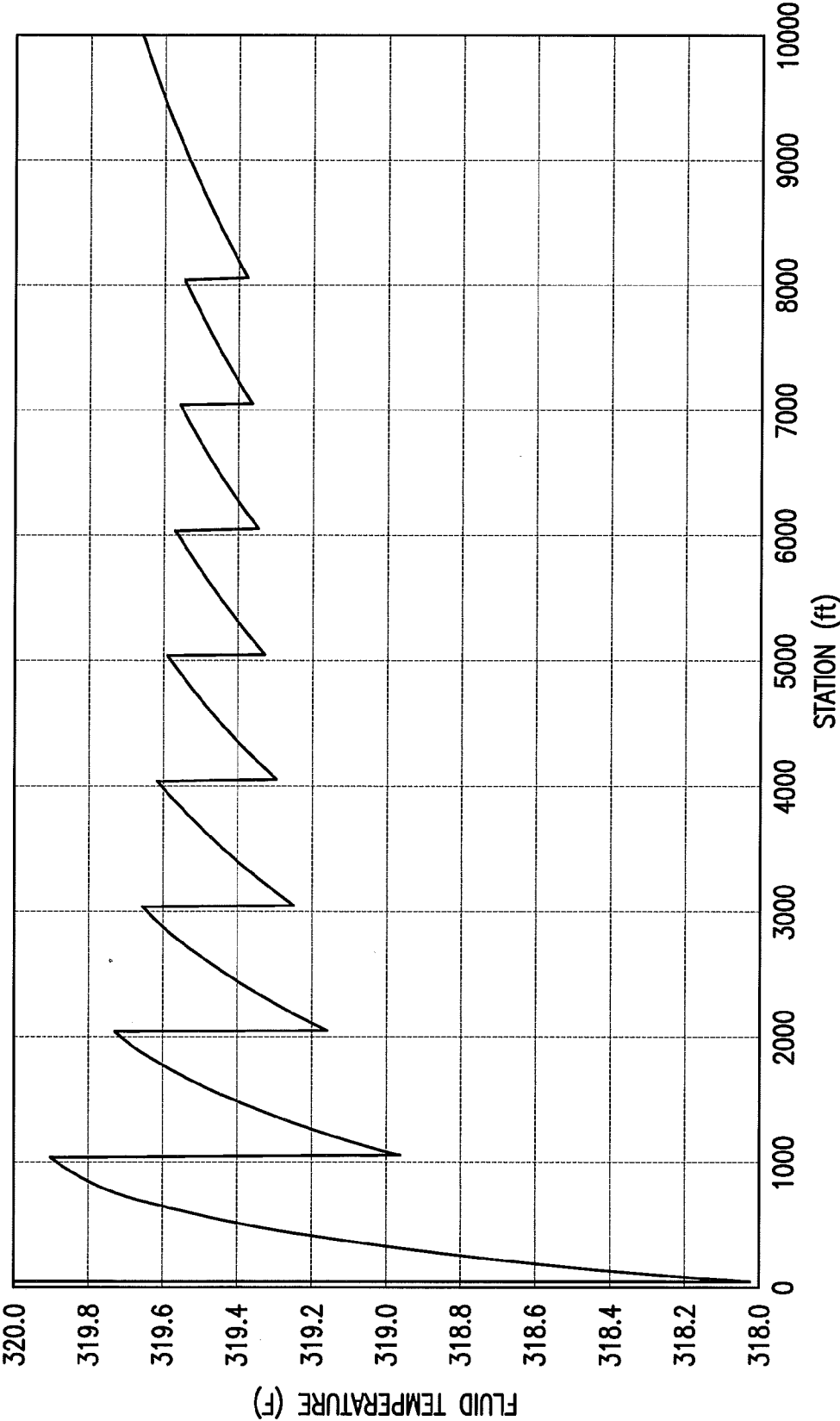


FIG. 2

MATRIX TEMPERATURE PRODUCTION LOGGING TOOL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a non-provisional application which claims benefit under 35 USC §119(e) to U.S. Provisional Application Ser. No. 62/021441 filed Jul. 7, 2014, entitled “MATRIX TEMPERATURE PRODUCTION LOGGING TOOL,” which is incorporated herein in its entirety.

FIELD OF THE INVENTION

[0002] This invention relates to a matrix production logging tool for measuring the temperature of produced fluids in a wellbore.

BACKGROUND OF THE INVENTION

[0003] Well logging surveys are often utilized in producing oil and gas wells in order to determine the fraction of oil, gas and unwanted water present in the production interval. This data along with measurements of the fluid flow velocity, cross-section of the well, pressure and temperature may be used to determine production rates and other information from each zone of interest in the well. Such data may be useful for optimizing the well's production, oil recovery, and water shut-off, in order to achieve better reservoir management and to reduce intervention costs. Future well's design and completion methodology may also be improved due to available surveys.

[0004] Such well logging surveys are performed by utilizing logging tools. Generally, a logging tool comprises at least one sensor and measures at least one parameter. For example, when measuring temperature within a wellbore or temperature of the produced fluids within a wellbore, a distributed temperature sensor can be mounted to the logging tool.

[0005] Distributed temperature sensing (DTS) is a known method of using an optical fiber to sense the temperature along the wellbore. For example, an optical fiber positioned in a section of the wellbore which intersects a producing formation or zone can be used in determining where and how much of known fluids are being produced as long as the fluid entering the wellbore measurably alters the temperature of the fluid already flowing within the wellbore. Temperature response of the produced fluids flowing within the wellbore between inflow locations is used in interpretations to estimate production along with wellbores length. As DTS spatially averages temperature over approximately 1 meter lengths it fails to provide precise measurements of the inflow temperature of produced fluids.

[0006] Logging tools have also included spinner type flow meters with attached temperature sensors which rotate when immersed within a flow stream. However, this type of logging tool has had issues with mechanical effectiveness. For example, the impeller of the spinner operates on a bearing which wears and requires frequent inspection and replacement to keep frictional effects from influencing the measurements. Another disadvantage, which increases logging time on the well, is that calibration must be done downhole by making several extra logging runs at various logging speeds. In reference to the fluid properties, the spinner speed is not only affected by changes in the velocity of the fluid but also by changes in the viscosity and density of the fluid.

[0007] Accurate production allocation to the pathways between the oil/gas well and the reservoir provides required data for the economic optimization of the techniques and procedures used to complete future wells. A need exists for a reliable, low maintenance tool to provide precise upstream, downstream and inflow temperature measurements of produced fluids within the wellbore that will be utilized to calculate production at each inflow location.

SUMMARY OF THE INVENTION

[0008] In an embodiment, a logging tool for use to determine temperature of produced fluid flowing into or within a wellbore includes: a core structure; an arm extendibly and pivotally mounted to the core structure, the arm is extended away from the core structure and is near the inner surface of the wellbore, wherein the arm pivots in one plane relative to the core structure; a data transfer device connected to the core structure for receiving, processing and storing data; and at least one temperature sensors attached to the arm, wherein the temperature sensor is located at a tip of the arm, wherein when the arm is extended away from the core structure the temperature sensor is at or near the inner surface of the wellbore.

[0009] In another embodiment, a logging tool for use to determine temperature of produced fluid flowing into or within a wellbore includes: a core structure; a plurality of arms extendibly and pivotally mounted to the core structure, at least one arm is extended away from the core structure and is near the inner surface of the wellbore, wherein each arm pivots in one plane relative to the core structure; a data transfer device connected to the core structure for receiving, processing and storing data; and at least one temperature sensor attached to each arm, wherein the temperature sensor is located at a tip the arm, wherein when the arm is extended away from the core structure the temperature sensor is at or near the inner surface of the wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention, together with further advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

[0011] FIG. 1 is a sectional view of the matrix temperature production logging tool disposed within a wellbore, according to an embodiment of the invention.

[0012] FIG. 2 is a simulated plot, according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Reference will now be made in detail to embodiments of the present invention, one or more examples of which are illustrated in the accompanying drawings. Each example is provided by way of explanation of the invention, not as a limitation of the invention. It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used in another embodiment to yield a still further embodiment. Thus, it is intended that the present invention cover such modifications and variations that come within the scope of the appended claims and their equivalents.

[0014] As previously discussed, capturing the upstream, downstream and inflow temperatures of produced fluids

around the inflow mixing point provides a significant amount of data necessary to determine inflowing produced fluid rates so far as there exists a measureable difference between the temperatures of the inflow and upstream fluids. Along with topside metered production rates and compositional data, the total production can be accurately allocated back to each production section of the wellbore by use of the matrix temperature production logging tool described herein.

[0015] Referring now to FIG. 1, a sectional view depicts the matrix temperature production log tool **10** disposed within a wellbore **1**. The wellbore may be a borehole, a casing or a tubing string. For explanatory purposes, the tool **10** described as being disposed within a tubing string **20**. It should be understood, however, that the principles described herein can be applied to many different wellbore structures, i.e., cased or uncased, horizontal or vertical. The tubing string may be horizontal or vertical. The tubing string **20** includes an inner surface **21**. The tubing string may also include perforations and/or slots.

[0016] Referring to FIG. 1, the tool **10** includes a core structure **30**, a plurality of arms **40** extendibly and pivotally mounted to the core structure **30** and a plurality of temperature sensors **50** attached to each arm **40**. The tool may be centralized within the tubing string through the use of a limited number of additional pivoted arms deployed both upstream and downstream or just upstream or downstream of the temperature sensors.

[0017] The tool **10** also includes a computer assembly or data transfer device, not shown. The computer assembly is typically disposed within the core structure **30** for receiving, processing, and storing and/or transmitting electronic signals generated from the tool **10**. For instance, the computer assembly receives electronic signals from the temperature sensors attached to each individual pivoted arm and then stores and/or transmits the data. The computer assembly may also include an electronic clock arrangement, batteries, and other circuits for storage and/or transmitting of data. The tool can further be coupled to a fiber optic line, not depicted, which may be deployed inside the wellbore. Data related to the wellbore gathered by the tool may be transmitted in real-time to the surface through the fiber optic line. The data can also be transmitted real-time via the data transfer device.

[0018] The core structure is kept away from the tubing string to ensure flow around the entire circumference of the core structure. Additionally, by keeping the core structure from contacting the inner surface of the tubing string, the temperature sensors at the tips or ends of the arms are given an opportunity to measure flow from perforations present at those locations where that contact between the tool's core structure and the tubing string would occur.

[0019] Individual arms or pivoted arms or pivoted rods or slender plates are extendibly pivotally attached to the core structure by a connection member, not shown, such as a pin. The arms do not rotate around the core structure. Rather, each of the arms will only pivot in their one plane relative to the core structure. Rotation of the arms about the core structure may cause unwanted mixing of the inflow and upstream fluids rendering the temperature measurement at the location of inflow less accurate. Although the tool **10** in FIG. 1 shows sixteen (16) arms, the number of arms attached to the core structure depends on operator need and mechanical feasibility. Any number of arms may radially extend from the core structure, i.e., deploy. Any number of arms may also be in an un-deployed position, wherein the arms are not radially

extended from the core structure. The number of pivoted arms deployed and/or un-deployed depends on operator need and mechanical feasibility. The pivoted arms may be arranged and configured around the core structure to obtain data from substantially the entire circumferential interior surface of the tubing string. At least one arm must be deployed in order for the temperature sensors to account for the temperature of produced fluid flowing into the tubing string. Preferably, the tool includes a plurality of deployed arms. The plurality of pivoted arms should be evenly spaced around the circumference of a core structure. When all the pivoted arms are deployed, the probability that a temperature sensor passes through the fluid flowing into the well from the reservoir increases. The arms may be manually or automatically extended or retracted. Each arm independently responds to the geometric anomalies or other changes in the configuration of the inner surface of the tubing string, such as dents, protrusions or bulges.

[0020] The arms serve as both the mounting and positioning structure for the temperature sensors. FIG. 1 depicts two temperature sensors **50** per arm **40**. At least one temperature sensor per arm should be located at the end or tip of the pivoted arm so as to be at or near the inner surface of the tubing string when the arm is deployed. Additional temperature sensors may be mounted on the arm. The additional temperature sensors may be mounted between the core structure and the tip of the pivoted arm where the initial temperature sensor is located. It is preferably to have a plurality of temperature sensors located along each arm.

[0021] The temperature sensors record the temperature of produced fluid flowing into and within the tubing string. Temperature sensors can include, but are not limited to, resistive temperature sensing devices, thermocouples, thermistors, infrared, pressure of known encased fluid, and laser or laser light within fiber optics. Other types of sensors can also be incorporated into the arms, such as sensors to determine the fluid phase(s) would provide further information that would enhance the allocation of production data.

[0022] FIG. 2 depicts a plot of simulated production fluid through a 10,000 foot horizontal tubing string with a total production rate of 500 barrels of oil per day. There were nine (9) inflow locations where equal amounts of produced fluid were flowing into the wellbore. The temperature data from the simulation was used to confirm that if three temperatures (inflow, upstream, downstream) at each inflow location could be measured, then production could be allocated to each location.

[0023] In closing, it should be noted that the discussion of any reference is not an admission that it is prior art to the present invention, especially any reference that may have a publication date after the priority date of this application. At the same time, each and every claim below is hereby incorporated into this detailed description or specification as an additional embodiment of the present invention.

[0024] Although the systems and processes described herein have been described in detail, it should be understood that various changes, substitutions, and alterations can be made without departing from the spirit and scope of the invention as defined by the following claims. Those skilled in the art may be able to study the preferred embodiments and identify other ways to practice the invention that are not exactly as described herein. It is the intent of the inventors that variations and equivalents of the invention are within the scope of the claims while the description, abstract and draw-

ings are not to be used to limit the scope of the invention. The invention is specifically intended to be as broad as the claims below and their equivalents.

1. A logging tool for use to determine temperature of produced fluid flowing into or within a wellbore comprising:

- a. a core structure;
- b. an arm extendibly and pivotally mounted to the core structure, the arm is extended away from the core structure and is near the inner surface of the wellbore, wherein the arm pivots in one plane relative to the core structure;
- c. a data transfer device connected to the core structure for receiving, processing and storing data; and
- d. at least one temperature sensor attached to the arm, wherein the temperature sensor is located at a tip of the arm, wherein when the arm is extended away from the core structure the temperature sensor is at or near the inner surface of the wellbore.

2. The logging tool according to claim 1, wherein the temperature sensor is selected from a group consisting of: resistive temperature sensing devices, thermocouples, thermistors, infrared, pressure of known encased fluid, laser or laser light within fiber optics.

3. The logging tool according to claim 1, wherein the logging tool includes a plurality of arms extendibly and pivotally mounted to the core structure.

4. The logging tool according to claim 3, wherein the plurality of arms include at least one temperature sensor.

5. The logging tool according to claim 3, wherein each arm includes a plurality of temperature sensors.

6. The logging tool according to claim 1, wherein the arm includes a plurality of temperature sensors.

7. The logging tool according to claim 1, wherein the data transfer device transfers data from the wellbore to the surface.

8. A logging tool for use to determine temperature of produced fluid flowing into or within a wellbore comprising:

- a. a core structure;
- b. a plurality of arms extendibly and pivotally mounted to the core structure, at least one arm is extended away from the core structure and is near the inner surface of the wellbore, wherein each arm pivots in one plane relative to the core structure;
- c. a data transfer device connected to the core structure for receiving, processing and storing data; and
- d. at least one temperature sensor attached to each arm, wherein the temperature sensor is located at a tip of the arm, wherein when the arm is extended away from the core structure the temperature sensor is at or near the inner surface of the wellbore.

9. The logging tool according to claim 8, wherein the temperature sensor is selected from a group consisting of: resistive temperature sensing devices, thermocouples, thermistors, infrared, pressure of known encased fluid, laser or laser light within fiber optics.

10. The logging tool according to claim 8, wherein each arm includes a plurality of temperature sensors.

11. The logging tool according to claim 8, wherein the data transfer device transfers data from the wellbore to the surface.

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