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A New Wireline Tool : Temperature Logging by DTS & DTSS Techniques

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Summary

The Distributed Temperature Sensing (DTS) technique using an optical fiber sensor is a relatively new method in temperature logging.The key technique is optical time domain reflectometry (OTDR). A laser pulse is launched into an optical fiber. As the pulse passes through the fiber, energy is lost owing to scattering. The intensity of the backscattered light decays exponentially with time, given uniform losses within the fiber. Therefore, knowing the speed of the light in the fiber, it is possible to convert this intensity against distance. Among the scattered light components, Raman scattering due to molecular vibrations is temperature sensitive. Raman back-scattering is used for distributed temperature sensing (DTS), while Brillouin waves are used for distributed temperature and strain sensing (DTSS). General wireline logging practice, this method is referred to as the "wireline DTS installation. Nevertheless, in contrast to conventional wireline logging, where the logging tool(sonde)is moved along the section of the borehole to be scanned, the DTS cable remains in place during the measurement of the temperature profiles. For long-term monitoring or in cases when full access to the interior of the borehole is needed, the sensor cables are installed behind the borehole casing

Because it is not necessary to move point sensor during measurement, the DTS technique enables us to make simultaneous monitoring of the temperature profile of the well at a time interval of a few to several minutes. This feature of the DTS temperature logging system is suitable for detecting temporal change of the temperature profile of a geothermal well such as during injection and production tests.

Introduction

Recently, Applications of DTS & DTSS Techniques: Locations of fractures can be detected clearly by the temporal change of the temperature. Fractures are more clearly detected during injection than recovery.. The DTS logging can show the fracture locations more clearly and easily than conventional temperature logging systems. The water level can be traced by the DTS logging. The pressure profile of a borehole can be calculated from the water level and the temperature profile data.Comparison between the calculated pressure value from temperature profile and the measured pressure value suggests that it may be possible to evaluate the amount or rate of inflow into the borehole from the reservoir.. To ensure this comparison is valid, precise calibration of the single-ended fiber sensor is required.

The DTS technique has an advantage over a conventional point probing logging system in that it enables us to make simultaneous monitoring of the temperature profile of the well at a time interval of a few to several minutes. This feature is suitable for detecting temporal changes in the temperature profile of a geothermal well such as during temperature recovering after drilling, injection tests and production tests. Distributed temperature sensing (DTS) is a valuable tool used to understand the dynamics of oil and gas production and injection rates

Theory

Raman scattering due to molecular vibrations is temperature sensitive.

Among the scattered light components, Raman scattering due to molecular vibrations is temperature sensitive. Raman scattering signal is split into two "bands" displaced

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approximately symmetrically about the incident wavelength: the Stokes band and the Anti-Stokes band . The intensity of the Stokes band is only little temperature sensitive, whereas the intensity of Anti-Stokes band is strongly temperature dependent.

Raman back-scattering is used for distributed temperature sensing (DTS), while Brillouin waves are used for distributed temperature and strain sensing (DTSS).

$$\frac{I_a}{I_s} = \frac{\left(\bar{\gamma}_0 + \bar{\gamma}_k\right)^4}{\left(\bar{\gamma}_0 - \bar{\gamma}_k\right)^4} \exp\left(\frac{-hc\,\bar{\gamma}_k}{KT}\right)$$

where

$I_a \Rightarrow$ intensity of the Anti -Stokes band

$I_s \Rightarrow$ intensity of the Stokes band

$\overline{\gamma_0} \Rightarrow$ wave number of the incident light

$\overline{\gamma_k} \Rightarrow$ shift amount of the wave number

$T \Rightarrow$ temperature (K)

$K \Rightarrow$ Boltzman' s constant

$h \Rightarrow$ Plank' s constant

$c \Rightarrow$ light velocity

Using OTDR technique and temperature dependency of the Raman backscattering light, it is possible to measure the temperature along the entire length of the optical fiber. In actual measurement, signals must be stacked (or averaged) for several tens of seconds to several minutes because the intensity of the Raman scattering is very weak.

In the case of temperature sensing, the phenomenon of Raman scattering (where light is scattered through an interaction with molecular vibrations within the glass) provides a convenient, temperature-dependent signal. The early workers in the field used the well-known temperature dependence of the ratio between the powers in the upper and lower sidebands of the Raman signal as the sensing mechanism. Later on, the instrumentation was simplified by using only the anti-Stokes (high-frequency) signal, as this is the more sensitive of the two sidebands Fibre-optic distributed temperature monitoring offers special advantages for remote measurements in hazardous environment or in a situation where there is a large amount of electromagnetic noise and possibility of data corruption. It also offers particular advantage in places where there is risk of sparking due to atmospheric volatility, such as oil refineries. Distributed anti-Stokes Raman thermometry (DART) is becoming a major technology for measurement of temperature along optical fibres. The distributed temperature sensing (DTS) method, based on optical time domain reflectometry (OTDR) using Raman effect, represents a powerful breakthrough in temperature measurements by providing fast, accurate and high-resolution information. In the DTS technique, a pulse laser is coupled to an optical fibre through a directional coupler. The light is backscattered through the fibre due to changes in density and composition as well as due to molecular and bulk vibrations. The backscattered light consists of a Rayleigh component, a Brillouin component and a Raman component. Thermally influenced molecular vibrations cause the Raman backscattered component to change and therefore it is sensitive to temperature. The anti-Stokes component is strongly dependent upon temperature, while the Stokes component is weakly dependent on temperature. Therefore, the ratio of anti-Stokes to Stokes signal provides an absolute value of temperature irrespective of laser power, launch conditions and fibre geometry. Combining the temperature measurement technique of Raman backscatter with distance measurement through time-of-flight of light, DTS provides temperature measurements along the length of the fibre.

It may be noted that all intensity signals are recorded at a fixed wavelength (Raman anti-Stokes) in OTDR mode and peaks represent increase in backscattered light of anti-Stokes component due to temperature changes

Method

Measurement results and examples of evaluation Mallik(GasHydrate research consortia),Mackenzie Delta,Beaufort sea,Canada

GasHydrate(white gold), a new source of energy,one unit of crystal fuel releases 164 unit of methane gas are explored in permafrost region & marine continental margins.

At present, Metadata （Markup Language） is recognized as one of the most efficient ways to facilitate data management, storage, integration, exchange, discovery and retrieve. Therefore the CODATA Gas Hydrate Data Task Group proposed and specified Gas Hydrate Markup Language (GHML) as an extensible conceptual metadata model to characterize the features of data on gas hydrate . Gas Hydrate Markup Language (GHML) to connect various hydrate databases: laboratory data, (b) field data, and (c) simulations

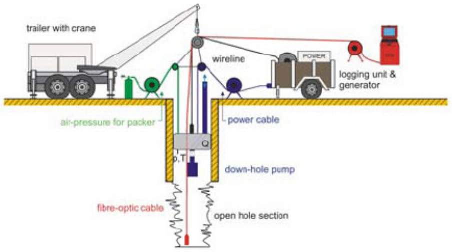
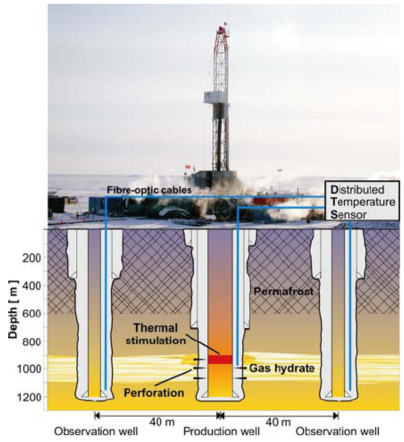
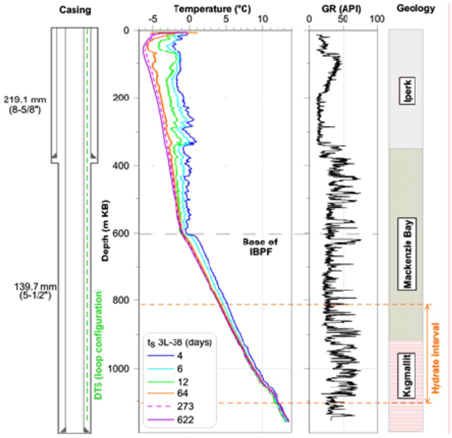


Fig.(1):Experimental set-up of the wire-line installation of the sensor cable.

Figure source(Fig.1,2&3) Mallik GasHydrate Reports/Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences



Fig(2):The Mallik 2002 Gas Hydrate Production Research Well Program drilling rig and a schematic cross section of the field experiment. After completion of the well the fibre-optic Distributed Temperature Sensing cable is embedded in the cement annulus between the casing and the borehole wall (modified after Henninges et al., 2003).



Fig,(3):Temperature profiles of the Mallik 3L-38 observation well for successive times after completion of the well (ts), cased-hole gamma-ray log (GR), well completion diagram (left) and sequence boundaries (right). IBPF = ice bearing permafrost. Modified after Henninges et al., 2004.

Excerpts of the recorded temperature data from one of the lateral observation wells are displayed in Figure6 as temperature profiles for successive points in time after the cementing of the well. As a result of the thermal disturbance due to the drilling process, a continuous process of equilibration of the wellbore temperature to the temperature of the surrounding formation can be observed. The disturbed temperature profiles exhibit specific patterns, which are related to the mobilization of latent heat during the melting of permafrost and the decomposition of gas hydrate, as a result of the drilling and completion of the wells. These patterns were used as indicators for the location of the base of the ice bonded permafrost and the gas hydrate occurrences (Henninges et al., 2004).

Technology to optimize production : Probing oil fields

As more wells are being completed to produce commingled reservoirs, better methods are being developed to determine zonal flow contributions and breakthrough location of unwanted fluids in order to optimize recovery and drive down production costs. Additionally, production optimization with high oil and gas prices requires continuous information on the production performance of each layer to design and plan prevention and remedial actions. DTS Transient Analysis is one of the methods that has been developed to enable realtime acquisition of data that can accomplish the above needs. Optical-fibre sensors have become an indispensable tool in the oil and gas industry, helping engineers to not only locate wells, but also get the most out of them.

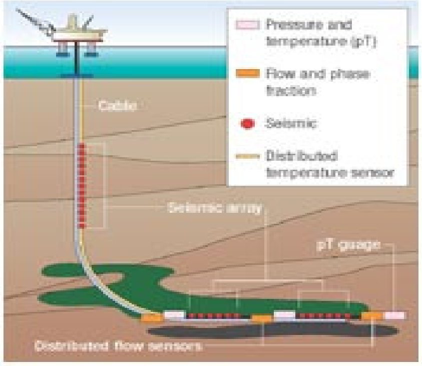


Fig.(4) : Fibre-optic OBC(Ocean Bottom Cable) system /*Figure Courtesy:Nature Photonics* **2**, 147 - 149 (2008)

A fibre-optic ocean-bottom seismic system. Thousands of sensors are trenched in the seafloor and connected back to topside facilities for monitoring.

A fibre-optic four-component seismic station. Three identical accelerometers are placed orthogonal to each other inside a sensor package together with a hydrophone. The sensor package is spliced into the cable, and several thousands of these stations are connected in a full-scale OBC system.

For in-well applications, fibre-optic sensors offer high reliability owing to their passive nature. Within wells, the environmental conditions are challenging, with temperatures in excess of 100 °C and even as great as 200 °C, and the reliability of conventional electrical sensors suffers under such conditions. The passive nature of fibre-optic sensors is also an advantage when the sensors are located beneath the sea, eliminating failures caused by electronic components exposed to water. The small size and weight of fibre sensors are added benefits, enabling sensors to be located at otherwise inaccessible sites. In addition, the low loss and large bandwidth of optical fibres enables transmission of huge amounts of data over tens of kilometres. Several different fibre-optic sensors are available today.

Although most fibre-optic sensors for the oil and gas industry have been made for in-well sensing, there is growing interest in fibre-optic monitoring systems for subsea and sea-bottom applications. These include ocean-bottom seismic cable (OBC) systems, for example, where the large-scale multiplexing capability and passive nature of fibre-optic sensing systems can be fully exploited. An OBC system comprises thousands of seismic stations placed in trenches at the bottom of the ocean. Each station (commonly called a 4C station) includes four components: one fibre-optic hydrophone and three fibre-optic accelerometers for the measurement of pressure waves and vibrations. The sensors are installed on the seafloor in a regular pattern, and seismic signals are generated using an airgun in the water.

Each sensor measures the direct pressure wave from this airgun as well as the reflection of this wave from the rock formation underneath the sensor. Differing physical properties of the formation affect the reflected signals. By appropriate signal processing and interpretation it is possible to predict the location of oil and gas reservoirs and, by repeating these surveys over time, it is possible to monitor dynamically the effect of oil production on the reservoir, so-called 4D monitoring. With thousands of sensors installed on the seafloor it is possible to cover a large area of the subsurface, providing the reservoir engineer with a global view of the reservoir.

Conclusion:

Analysis of the geothermal conditions and the derivation of the stability field for methane hydrate are often based on the interpolation of single, thermally disturbed bottom-hole temperature measurements and drill-stem test data from petroleum exploration wells and about the thermal properties of the formation regarding formation evaluation . Nanosensor (fibre optics) can be made fashionable by using DTS ,Spatial and temporal variation of temperature during a Gas Hydrate production Test in Mallik gashydrates.The size and distribution of natural methane hydrate occurrences and the release of gaseous methane through the dissociation of methane hydrate are predominantly controlled by the subsurface pressure and temperature conditions. Because of the related change in enthalpy, both the formation and dissociation of gas hydrate in nature are inevitably coupled to the transport of heat within the surrounding formation. Knowledge about the thermal properties of hydrate bearing rocks (i.e. thermal conductivity, specific heat, and latent heat of phase transition) is therefore of crucial importance.

Advantages of the deployment of fibre-optic distributed temperature sensing proved to be successful for temperature monitoring in boreholes under a wide range of conditions. One of the main advantages of DTS technology is, that continuous temperature profiles can be registered with high spatial and temporal resolution. This favours the observation of dynamic subsurface processes involving temperature changes.

Real Time Fiber Optic Casing Imager (RTCI) provides a 3-dimensional image of the casing or sand control screens as they are stressed during production by shifting formations such as salt or unconsolidated sandstones.

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