DTSX200 Distributed Temperature Sensor for Oil and Gas Production

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Recently, the development of unconventional resources, such as heavy oil, oil sands, and shale gas, has been progressing in line with the increase in global energy demand. Yokogawa developed the DTSX200 distributed temperature sensor (DTS) to facilitate the efficient recovery of unconventional resources by monitoring temperature distribution underground. Implementing Yokogawa's optical measuring technology, the DTSX200 is able to withstand the harsh environment, a factor required of oil and gas mining sites, and can operate with limited power such as with solar batteries. In addition, this DTS has strengthened the relationship with customer's networks by providing an interface with the production control system using a secure protocol, and by using data formats that are the standard in the oil and gas industry. These factors all improve the efficiency of natural resource production.

INTRODUCTION

The development of difficult to recover unconventional energy resources, is progressing [(1)]. Figure 1 shows an example of how unconventional heavy oil is extracted from tar sand by reducing its viscosity with steam. To ensure efficient mining, changes in the underground temperature distribution will need to be monitored.

Fiber-optic distributed temperature sensors (DTS), which can measure the temperature distribution along an optical fiber with a length of several kilometers are expected to be applied to such mining sites.

Conventional products however have some problems with use under such harsh environmental conditions as oil and gas mining sites. Customers who are engaged in resource extraction have therefore been seeking fiber-optic distributed temperature sensors with excellent environmental resistance [(3)] as a solution for improving the efficiency of resource extraction.

To satisfy such customers' needs and solve the problems inherent in them, Yokogawa has developed the DTSX200 distributed temperature sensor for mining sites of resource extraction by applying its expertise of its optical measurement technology to process control.

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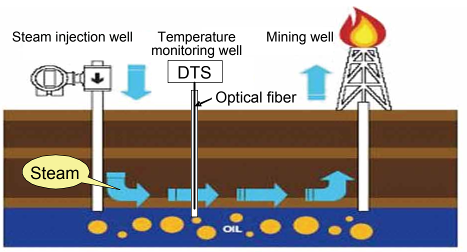

Figure 1 Example of temperature monitoring with a fiber-optic distributed temperature sensor

The DTSX200 measures the distributed temperatures along the optical fiber, which is itself being used as a sensor. For example, a 6-km long optical fiber can measure temperatures at one meter intervals along the fiber, totaling 6000 points.

The DTSX200 has the following features superior to those of products from other manufacturers:

1) Tolerance to harsh environments
2) Compact size, light weight, and low power consumption
3) High compatibility with production control systems

MEASUREMENT PRINCIPLE

This section explains a principle of distributed temperature measurements in which an optical fiber is used as a sensor. Incident light scatters inside the optical fiber. Figure 2 shows the spectrum of scattering light in an optical fiber. According to the scattering generation mechanism, scattering light is classified into three types: Rayleigh scattering light which frequency is equal to that of incident light, Brillouin scattering light with a frequency shift of approx. ±10 to 13 GHz, and Raman scattering light with a frequency shift of approx. ±10 to 13 THz. The DTSX200 uses the temperature dependence of Raman back scattering light intensity to measure temperatures.

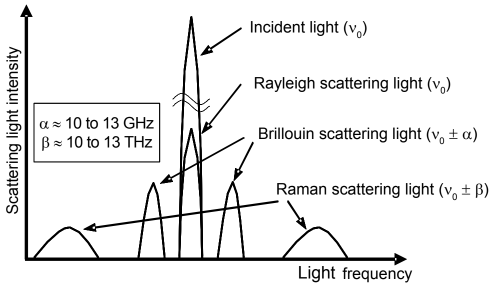

Figure 2 Scattering light spectrums

Figure 3 shows a conceptual diagram of distributed temperature measurement. When a light pulse is entered as an incident light and sampling of the intensity of its Raman back scattering light is started at the light receiving section, the sampling time is the time from the light incidence to the arrival of the scattering light generated at a certain point, determining the distance to the point, and the sampled intensity of the Raman back scattering light can determine the temperature at the corresponding point. Thus the distributed temperatures in the longitudinal direction of an optical fiber can be measured.

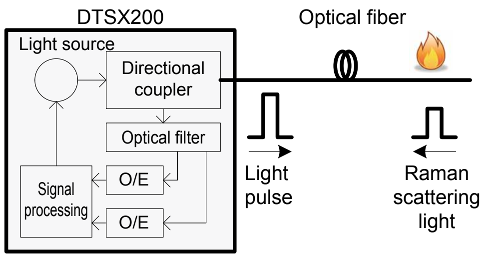

Figure 3 Conceptual diagram of distributed temperature measurement

FEATURES

Tolerance to Harsh Environments

With a wide operating temperature range of between −40°C and 65°C, the DTSX200 can stably measure temperature in harsh environments. The emission wavelength of the laser diode (LD) light emitting element changes depending on temperature, so it needs to be controlled by the Peltier device to keep its temperature constant. In the DTSX200, the LD can be controlled even if the ambient temperature significantly changes. This is because the elements to be temperature controlled have been assembled as compactly as possible.

The avalanche photodiode (APD) light receiving element changes its multiplication factor largely depending on temperature. To keep the multiplication factor constant regardless of its ambient temperature, the bias voltage is controlled while monitoring the temperature of its vicinity.

Explosive or corrosive gases may exist at oil and gas mining sites. For explosion proofing, the DTSX200 has achieved explosion proof construction as an energy limited apparatus by suppressing electric power at connecting points of the electronic circuits. To achieve resistance to corrosion, the parts have been selected by using accelerated corrosion tests. Figure 4 shows the results of the evaluation test. Commercially available optical lenses were evaluated for 60 days in a high temperature and high humidity atmosphere containing hydrogen sulfide, which is equivalent to a 10 year test in a corrosive gas environment. The lens of sample B became clouded due to improper coating materials, and could be used no longer. On the other hand, sample A indicated no changes in the optical performance, although some rust on the metal part of the lens housing was found. As a result, the DTSX200 satisfies the FM [Note 1], CSA [Note 2], and ATEX [Note 3] standards for explosion proofing and the ANSI/ISA-S71.04 standard Class G3 for resistance to corrosive gases.

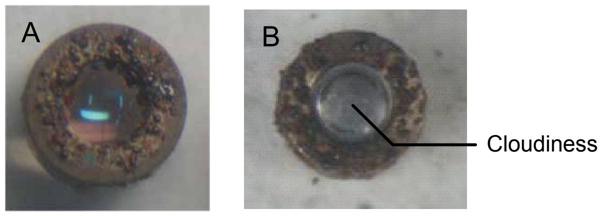

Figure 4 Results of accelerated corrosion test for optical lenses

Compact Size, Light Weight, and Low Power Consumption

By integrating optical systems and electronic circuits, the size of the DTSX200 is reduced to approximately one quarter the size of previous models, achieving one of the smallest distributed temperature sensors in the industry. A compactly designed optical switch module for selecting monitoring fibers can be mounted on the 19 inch rack with the DTSX200 main unit.

Power consumption of the DTSX200 has been reduced by using the platform for the STARDOM network based production system with low power consumption, and by making the portion to be temperature controlled for the LD compact, as mentioned above. Furthermore, the DTSX200 provides a power save function, which can automatically stop the power supply to the measurement circuits when a continuous temperature measurement is not required. By suppressing the power consumption not exceeding 10 W over the specified temperature range (for the main unit), it can be powered by solar panels or rechargeable batteries when the power infrastructure is not available.

High Compatibility with Production Control Systems

To improve the efficiency of production processes from temperature measurement to its control in production control systems for resource extraction, the DTSX200 provides the functions for coordinating with industrial instruments and control devices [(4)].

In addition, the DTSX200 has the following functions for

Note 1) Factory Mutual
Note 2) Canadian Standard Association
Note 3) Atmospheres Explosibles

seamlessly connecting with users' networks as well:

1) Secures compatibility with users' database by automatically generating the data with the format of the LAS Note 4) and WITSML Note 5) oil and gas industrial standards.
2) Facilitates easy connection with users' networks through secure SFTP (Secure Shell File Transfer Protocol) or HTTPS (Hypertext Transfer Protocol over Secure Socket Layer) file transfer protocols.
3) Provides the measures against wireless or internet communication failures by keeping communication data in the DTSX200 for an extended time and automatically retransmitting them upon recovery (in the case of HTTPS).
4) Provides higher level security by account management, measures against falsification, and so on.

SPECIFICATIONS AND FEATURES

Table 1 shows the major specifications of the DTSX200 achieving the above mentioned features. Figure 5 shows an external view of the DTSX200 equipped with a 16 channel optical switch module. The DTSX200 main unit is seen in the middle, power module on the left side, and optical switch module on the right.

Table 1 Major specifications of the DTSX200

Item	Specifications
Measure temperature range	–200 to 800°C (depending on optical fiber properties)
Temperature resolution	0.7°C (in the case of 6 km length of optical fiber, and 10 minutes measurement)
Distance resolution	1 m
Operating temperature range	–40 to 65°C (satisfying all specifications in the full range)
Power consumption	10 W or less (DTSX200 main unit only)
Tolerable corrosive gas	Tolerant to G3 (ANSI/ISA-S71.04)
Explosion proof capability	FM, CSA, ATEX certified
Communication interface	Modbus/TCP, SFTP, HTTPS

Figure 5 External view of the DTSX200

The optical switch module with up to 16 channels enables temperature measurements to be switched for multiple mining wells. The CPU module for the STARDOM FCN-RTU network based production system can be mounted on the slot on the left side of the main body.

The DTSX200 can process multiple measured temperatures of multiple channels. For this purpose, optional DTAP200 application software is provided for setting up the DTSX200 and displaying its measurement data. The DTAP200 has various functions such as setting up and control of the DTSX200 main unit and optical switch, display of measurement results, analysis of temperature changes, and setting up and display of the alarm, which provides users with information useful for temperature monitoring. Figure 6 shows an example of temperature display by the DTAP200.

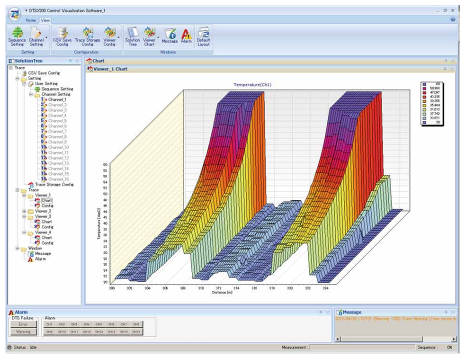

Figure 6 Example of temperature display (x-axis: distance, y-axis: temperature, z-axis: time)

Figure 7 shows an example of temperature measurement by the DTSX200 in a harsh environment, where the ambient temperature of the DTSX200 is changed stepwise from 70°C to –45°C to evaluate the dependency of its measurement on ambient temperature. During the process of changing the ambient temperature of the DTSX200 while keeping the temperature of an optical fiber to be measured at normal temperature, the fluctuation of the temperature measurement values does not exceed ±1°C, including the room temperature fluctuation of the optical fiber.

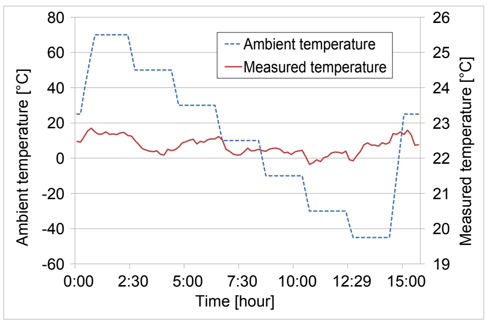

Figure 7 Example of characteristics of dependency on ambient temperature

The DTSX200 performs highly accurate measurements over a wide range of temperatures. Figure 8 shows the result of temperature measurement using a low temperature thermal chamber for –20°C to 80°C and a high temperature thermal chamber for 80°C to 300°C respectively. The y-axis is the difference from the reference temperature, and all values fall

Note 4) Log ASCII Standard
Note 5) Wellsite Information Transfer Standard Markup Language

within ±0.5 °C. By employing a new method able to more precisely determine the Raman shift wavenumber, which is an important parameter for temperature calibration, the DTSX200 can achieve highly accurate temperature measurement over such a wide range.

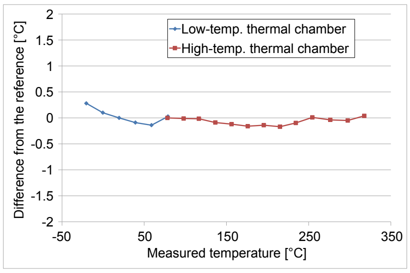

Figure 8 Example of temperature measurement from low temperature to high temperature

In mining wells, an optical fiber may change in its loss gradually (referred to as "darkening") by being exposed to high temperature, high pressure, and hydrogen gases, resulting in temperature measurement errors [5]. The DTSX200 employs a double ended configuration technique insusceptible to darkening. Figure 9 shows an example of the measurements over the section with constant temperature, where the temperature with the double ended configuration is not affected by loss change in the optical fiber although the temperature with the conventional single ended configuration is strongly affected.

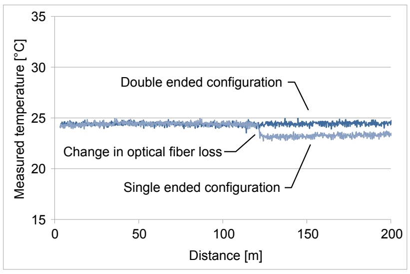

Figure 9 Effects of loss change in an optical fiber

APPLICATIONS

Figure 10 shows an application example of the DTX200 at a resource mining site. Infrastructures such as power or communications are often not developed at resource mining sites. In an example for an outdoor panel solution, the power is supplied with solar panels and rechargeable batteries, and wireless modems are used for communications.

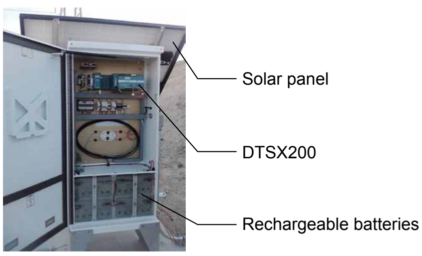

Figure 10 Application example of the DTSX200 at a resource mining site

The DTSX200 is usually used for measuring high temperatures in applications for resource mining, whereas it is also used for measuring low temperatures for leak detection in LNG tanks and pipelines. Figure 11 shows the result of leak detection in an ammonia pipeline, where the temperature is measured at every few seconds and a peak of approximately −40°C is observed at the leak point.

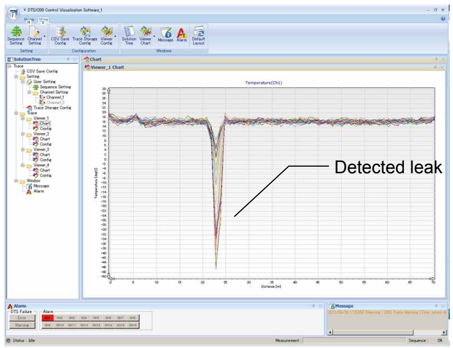

Figure 11 Ammonia leak detection

CONCLUSION

Based on Yokogawa's accumulated optical measurement technologies, the DTSX200 has achieved high tolerability in harsh environments and operation with limited power such as solar panels and rechargeable batteries. Furthermore, to improve the efficiency of resource production, the coordination functions with customers' networks have been enhanced by providing an interface with production control systems using a secure protocol and supporting data formats that are the standards in the oil and gas industry. Although this paper has described the applications for developing unconventional resources and detecting leaks in LNG tanks and pipelines, the DTSX200 can also be used for various other usages such as detecting fires in belt conveyors, architectural structures and the like, controlling temperatures at hot sections in plants, and monitoring temperatures of power lines.

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