Wireless Heat Flow Logger LR8416

(Sold only in Japan)

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***Abstract*—As environmentally friendly homes, household electronics, and other products have come under increasing pressure to offer higher-performance insulation in recent years, demand for not only temperature measurement, but also heat flow measurement as a newly developed indicator has been rising. The Wireless Heat Flow Logger LR8416 is a multichannel logger that simplifies the process of measuring heat flows. This paper describes the product's features, design, and other characteristics.**

I. Introduction

Measuring the temperature at various locations on refrigerators, televisions, multifunction printers, and other household electronics is an important part of the development process. Temperature measurement is also becoming increasingly important in the products development, maintenance, and management of not only household electronics, but also homes and environmental and energy-related equipment.

However, the difficulty in pinpointing the actual movements of heat based on temperature measurements alone makes it necessary to measure heat flows in order to ascertain the principal causes of temperature variations. In the past, the settings needed to measure heat flows and the calculations that had to be performed on the resulting data were complex and time-consuming, posing challenges for technicians.

The Wireless Heat Flow Logger LR8416 was developed to eliminate these issues by simplifying the heat flow measurement process.

II. Overview

1) What are heat flows?

Heat is energy that changes temperature, and, like water and electricity, it flows from high to low areas. The extent of movement of heat is known as heat flow, which can be calculated as the amount of heat energy (W·s) flowing per unit area (m^2) per unit time (s). It is thus expressed as watts per square meter (W/m^2).

2) Advantages of heat flow measurement

Temperature measurement using thermocouples or thermography alone does not provide sufficient data for determining the specifics of the process by which

Appearance of the LR8416 (Sold only in Japan)

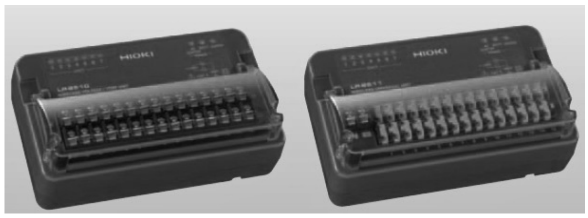

Fig. 1. Measurement Unit LR8510, LR8511

temperature changes (heat generation, heat absorption, magnitude, etc.). By measuring heat flows, the movement and amount of heat energy can be visualized, providing a leading indicator for temperature changes.

3) Product architecture

The LR8416 adds functionality for measuring heat flow to the Wireless Logging Station LR8410, which uses Bluetooth® wireless technology.

The system's compact, 15-channel measurement modules (LR8510, LR8511) and the display-equipped instrument (LR8416) communicate wirelessly and can be separated. Consequently, it is possible to position measurement modules near the measurement target and then simultaneously check measurement data and trend waveforms for up to 105 channels on 7 units at a maximum sampling rate of 100 ms using the LR8416 at a remote location. Fig. 1 illustrates the Measurement Unit LR8510 and LR8511.

Data is stored on the included SD memory card and can be analyzed in detail on a computer or monitored

Fig. 2. Heat Flow Sensor MF-180

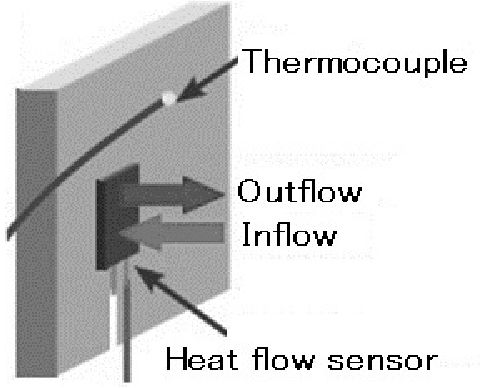

Fig. 3. Measurement Method

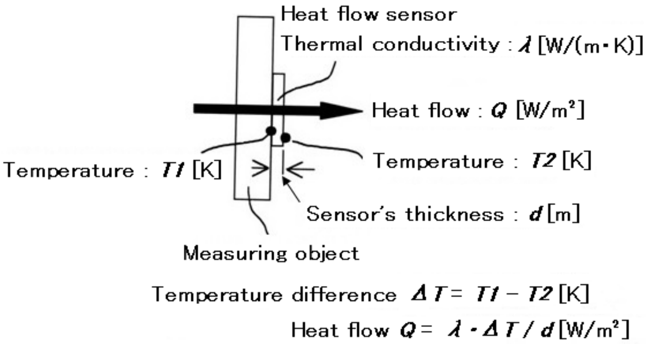

Fig. 4. Heat Flow Measurement Principle

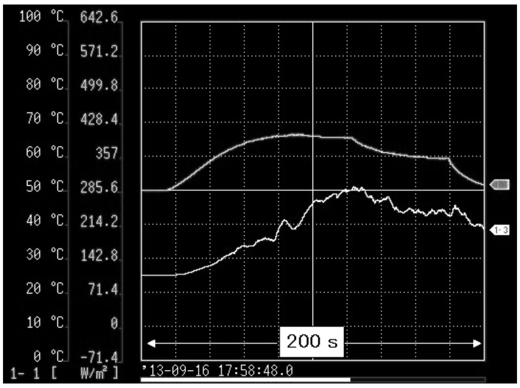

Fig. 5. Graduations (Y-axis) and Example Waveform

continuously from a remote location using the instrument's LAN/USB communications functionality.

III. Features

1) Heat flow sensors and measurement method

The LR8416 measures heat flows using heat flow sensors that have been connected to the measurement module. Each sensor has its own sensitivity constant. Until now, it had been necessary to calculate and enter the reciprocal of the sensitivity constant due to reliance on scaling. For example, for a sensitivity constant of 0.0269 mV/Wm^{-2}, it would have been necessary to calculate the reciprocal of 0.0269×10^{-3} (i.e., 37,175) and enter that value as the scaling value. This approach was both inconvenient and susceptible to errors resulting from mistaken calculations. The LR8416 allows heat flow sensors' sensitivity constants to be entered directly to complete the scaling process, eliminating both inconvenience and the possibility of calculation errors.

Fig. 2 portrays the Heat Flow Sensor MF-180, while Fig. 3 illustrates the methods used to measure temperature and heat flow with a thermocouple and heat flow sensor, respectively. As shown in Fig. 3, heat flow sensors are used by affixing them to the location at which the user wish to measure heat flow.

2) Heat flow measurement principle

Heat flow sensors have a thermopile structure consisting of numerous thermocouples connected in series, allowing heat flows to be derived by calculating temperature differences on both the sensor's surfaces at a high level of precision. Fig. 4 illustrates the heat flow measurement principle utilized by heat flow sensors.

3) Waveform display function

Because the base model (LR8410) could only display waveforms that had been scaled using a single series of graduations, it was difficult to compare multiple waveforms. By contrast, the LR8416 makes it easy to compare waveforms by adding functionality for displaying the graduations for two user-selected channels simultaneously. In addition, the instrument provides waveform display functionality so that only waveforms selected by the user are shown, smoothing the process of navigating among today's increasingly large number of measurement targets. Fig. 5 shows such graduations and example waveforms.

4) Five real-time waveform calculations

- Moving average

Calculates the average within a data range consisting of the specified number of points from the latest data. The moving average calculation is useful when wishing to eliminate noise due to air convection currents in the area where heat flows are being measured.

- Simple average

Calculates the average within the data range up to the latest data. Since the start data position for the calculation can be set, the user can calculate the average over the desired interval. The simple average calculation is useful when wishing to view average heat flow values.

- Integration

Calculates the sum up to the latest data point. Since the start data position for the calculation can be set, the user can calculate integration data for the desired interval. The integration calculation is useful when wishing to calculate the sum of heat energy. Fig. 6 shows a waveform for which integration has been performed at an interval of 1 min. after setting the start data position, allowing the user to see how the integration has been performed at the set interval.

- Heat flow rate

Heat flow rate, which is calculated from the temperature difference for both sides of the measurement target and heat flows, indicates how easily heat is transmitted and therefore serves as an indicator of insulation performance. The LR8416 enables heat flow rate calculation simply by setting the temperature and heat flow measurement channels for the equation provided for one waveform calculation. Fig. 7 is a screenshot of the screen used to configure the waveform calculation for heat flow rate.

- Basic arithmetic calculations

The four basic arithmetic operations (addition, subtraction, multiplication, and division) can be performed in real time using measurement data from each channel as well as the results of waveform calculations, allowing differences between data values and other parameters to be calculated.

5) Numerical calculation function

Integration has been added as a numerical calculation, allowing total heat energy to be viewed at a glance as a value. In addition, a calculation range can be specified and the results of calculations in the specified range saved as numeric values on an SD memory card. Fig. 8 shows the results of an integration numerical calculation.

IV. Applications of Heat Flow Measurement

Fig. 9 shows an example heat flow measurement application during heat generation testing of an inverter while a vehicle is being driven and then stopped. A heat flow sensor and thermocouple are affixed to the inverter inside the vehicle's engine room and connected to a measurement module. In this example, measurement data captured while the vehicle is then driven and stopped is uploaded to, and monitored by, the LR8416 in the vehicle interior. Since the measurement module can be placed in the engine room along with the heat sensor and thermocouple, there is no need to run wiring into the vehicle's interior.

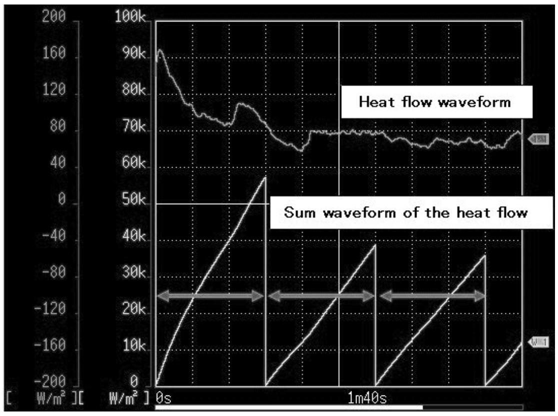

Fig. 6. Integration Waveform Calculation

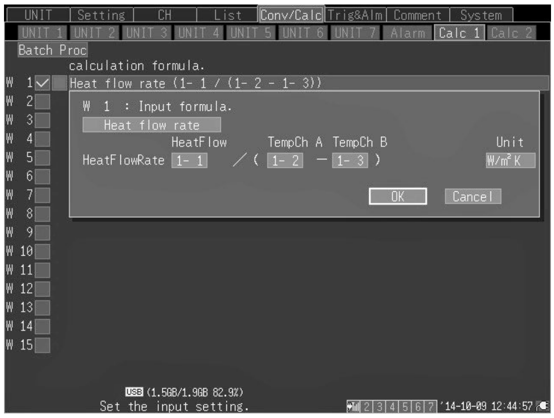

Fig. 7. Heat Flow Rate Settings Screen

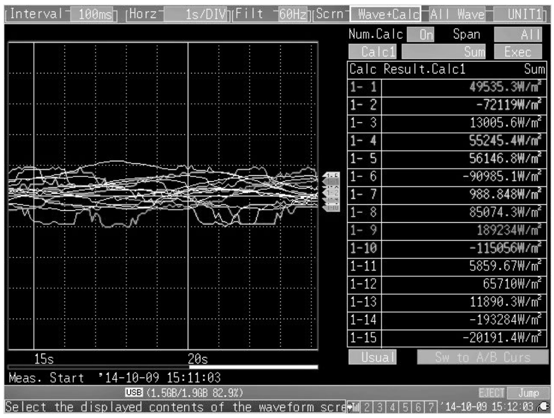

Fig. 8. Integration Numerical Calculation Results

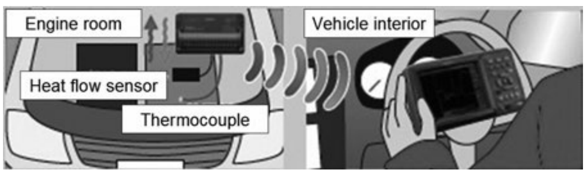

Fig. 9. A Heat Flow Measurement Application

Fig. 10 illustrates actual waveform data obtained from the above example application. Examination of the temperature waveform reveals that the inverter temperature rises when the vehicle is stopped. Examination of the heat flow waveform reveals that heat flows in the positive direction (heat outflow) while the vehicle is being driven but that the flow reverses to the negative direction (heat inflow) when the vehicle is stopped. Based on these indications, it is clear that the inverter itself gives off heat while the vehicle is being driven but that heat from surrounding components flows into the inverter when the vehicle is stopped, causing its temperature to rise. In this way, measurement of heat flows allows the movement of heat to be visualized in a way that is not possible with temperature measurement alone.

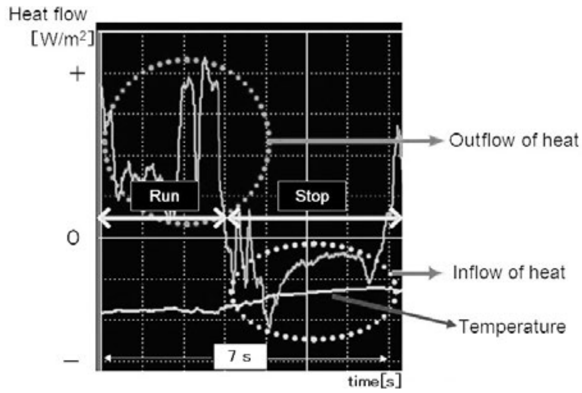

Fig. 10. Waveform Data While the Vehicle Is Being Driven

V. Wireless Communication

1) Advantages of wireless communication

As with the base model (LR8410), data is gathered wirelessly, eliminating the need to run wires to the instrument. Measurement modules, which offer a broad operating temperature range of −20°C to 60°C (−4.0°F to 140.0°F), can be placed in locations characterized by harsh temperatures while the LR8416 is used in a normal-temperature environment without the need to run wires between the devices—all data is captured wirelessly. In addition, minimizing the amount of wiring used has the advantage of not only reducing use of wiring, but also decreasing the effects of noise on the wiring.

2) Synchronization of data using wireless communication

When data is collected from multiple measurement modules wirelessly over an extended period of time, errors in the operating clock precision of each result in time shifts among measurement modules, preventing the number of measurement data points from matching. Since sending the corrected time wirelessly is susceptible to differences in transmit time depending on the communication state, the reliability of the transmitted times is suspect. While this reliability can be increased by attempting to transmit the time repeatedly, even that approach is affected by the communication state, and the communication load will increase with the number of retries attempted. To address these issues, Hioki chose to synchronize the data by means of a Piconet clock using Bluetooth® communication. A Piconet clock is a count value used when communicating via Bluetooth® communication. The values are shared among devices so that each has the same value at any given time. By using this Piconet clock to correct each measurement module’s time so that the LR8416’s time becomes the operating standard, it is possible to collect synchronized data without any shift in the number of data points over extended periods of time, even when using a recording interval of 100 ms.

3) Advantages of Bluetooth® communication

Since the frequency band used (2.4 to 2.4835 GHz) is divided into 79 channels at an interval of 1 MHz and the channel switched 1,600 times per second, Bluetooth® communication do not cause sustained interference with other wireless devices. Furthermore, the LR8416’s support for adaptive frequency hopping, which avoids use of frequencies where interference is likely to occur, ensures stable communication.

4) Functionality for peace of mind in the event communication is interrupted

Each measurement module has an internal buffer memory for storing measurement data while communication is interrupted. Measurement data is then retransmitted when communication resumes and restored in the LR8416. In addition, warning output or a warning email can be generated when communication is interrupted or a measurement module’s battery life falls below a certain point. In any case, measurement can be continued with peace of mind even if signals are down.

VI. Conclusion

By allowing compact measurement modules and the instrument to connect wirelessly and providing a simple solution for heat flow measurement, the LR8416 greatly expands the potential of heat flow measurement. In the future, Hioki expects new fields of heat flow measurement to make a significant contribution in numerous areas.

Reference

[1] Kurashima, T. Wireless Logging Station LR8410. Hioki Giho. 2014, vol. 35, no. 1, pp. 5-10. (Japanese).

Trademark Registration