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Hiroo Matsumoto

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Feature Article

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Hiroo Matsumoto

Abstract

Horiba has developed a portable water quality checker (U-10) and water quality monitor (WP-100) capable of easily measuring the pH, conductivity, turbidity, dissolved oxygen content, water temperature and other basic indicators of water quality. The U-10 has been designed for easy use in outdoor environments, while the WP-100 can be used for either continuous measurements or batch measurements. This paper will describe the configuration of these instruments, the design and characteristics of the durable, high-precision sensors and introduces the variety of easy-to-use functions.

1. Introduction

Together with air quality, the preservation of water quality is a fundamental issue for maintaining a livable global environment. In Asia, in particular, rapid economic growth along with the desire to preserve the environment has lead to rapidly growing demand for a simple, high-precision instrument to assess water quality. The basic indicators of water quality include the pH, conductivity, turbidity, amount of dissolved oxygen, and the water temperature.

Horiba has for many years manufactured and sold a wide range of measuring instruments for monitoring the water quality of rivers, lakes, and marshes. However, most of these instruments are large-scale measuring systems with large sampling units and stations. These systems often entail tremendous cost and require frequent maintenance.It is for this reason that Horiba has developed a handy multi-item water quality checker (the U-10) and portable water quality monitor (the WP-100) that can take both continuous measurements and batch measurements using sensors in the U-10. The WP-100 has the capability of storing approximately one month of measurement data. This makes it easy to draft preliminary surveys and prepare pollution maps when installing new water quality monitoring and measurement stations in river, lakes, and marshes. This paper will introduce the configuration and features of these water quality monitors.

2. Instrument Configuration

2.1 U-10 Configuration

The U-10 is divided into an instrument body having a display and operation buttons; and a sensor unit with five types of sensors, a preamplifier, and an electrode cable. These two units are joined by a connector section. Polyphenylene ether resin, which possesses superior waterproofing and weather-resistance properties, is used for the outer casing in both units (**Figure 1**). This instrument uses cartridge-type sensors

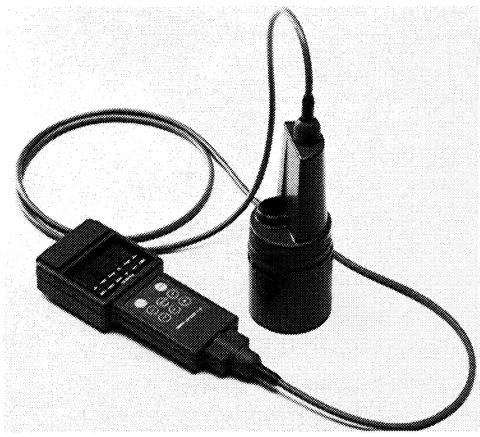

Figure 1 Water Quality Checker, U-10

to allow easy replacement of the sensors if the pH electrodes or dissolved oxygen (DO) electrodes wear out or are damaged. The turbidity sensor employs a glass tube passing vertically through the sensor body as a measurement cell, and an optical system is located around the measurement cell. This allows the taking of accurate turbidity measurements even under direct sunlight. The entire sensor is surrounded with a cylindrical-shaped guard. This guard prevents the sensors from being damaged during measurement and serves as a stand when calibrating or storing data. To take a measurement, the operator holds the cable, and lowers the sensor unit down into the water to be sampled. The length of the standard cable is 2 m, but an optional 10 m cable is also available.

2.2WP-100 Configuration

The WP-100 is divided into an operation unit with a display, operation buttons and a terminal board for external signal connection; a sensor unit identical to that of the U-10; and a flow cell unit with a measuring tank, solenoid valve, and other valves. These units are connected by a cable and connectors (**Figure 2**). The operation unit and sensor unit are used for batch measurements, while the operation unit, sensor unit, and flow cell unit are used for continuous measurements.

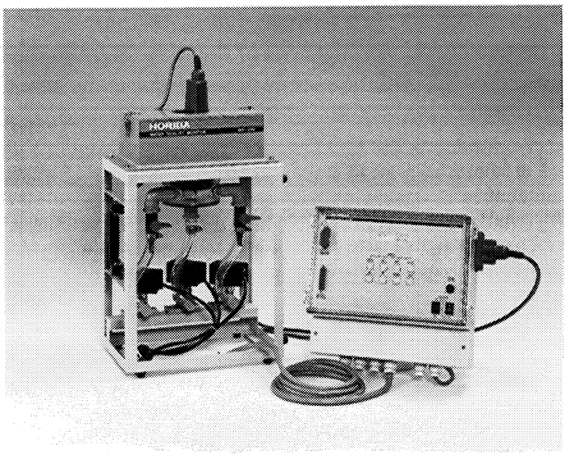

Figure 2 Portable Water Quality Monitor, WP-100

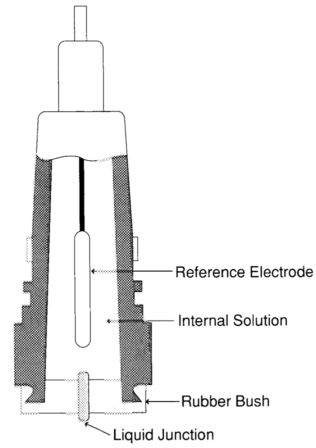

Figure3 Reference Electrode for pH Sensor

(1) Operation unit

The case of the operation unit is made of polycarbonate resin and satisfies IP 65 (IEC 529, Degree of protection provided by enclosures), making it acceptable for rugged outdoor use. The output signal can be sent to a digital printer or to a personal computer with RS-232C output.

(2) Flow cell unit

The flow cell unit is capable of continuous and stable long-term measurement provided that simple maintenance is performed regularly. The flow cell unit is also compact and lightweight so that it can be easily moved or installed at the measurement site.

(3) Internal circuitry

Like the U-10, the preamplifiers for the sensors in the WP-100 are incorporated into the sensor unit. After the sensor signal is converted to a low impedance signal by the preamplifier, it is sent to the operation section. This reduces the influence of noise and allows high-precision measurements to be taken regardless of the cable length or bends in the cable. The power supply uses a switching system for both 100 V AC and 12 V DC, thus allowing measurements to be easily taken at locations without AC power.

(4) Example system configuration

A typical system configuration of the WP-100 is shown in **Figure 8**.

3. Characteristics of Sensor Units

3.1 pH Sensor

Although the pH sensor's glass electrode is not affected by the sample pressure, but the internal solution in the reference electrode does comes into contact with the sample. In some cases, the pressure of the sample could cause problems. In order to submerge the sensor unit in the sample for measurement, such as for batch measurements, the reference electrodes must have a closed structure. Even in this case, however, if the pressure in the sample is high, the sample will flow into the internal solution via the liquid junction. This is liable to result in transient electrical potential in the solution due to the flow potential and other factors. To avoid such problems, the U-10's reference electrode (model 7210) has the structure shown in **Figure 3**. The rubber bush bends according to the sample pressure to reduce the inflow and outflow of the sample from the solution junction. This allows stable measurements to be taken. The success of this structure has been proven in tests in which the pressure-compensation reference electrode was taken as a standard electrode. **Figure 4** shows the potential difference resulting between both electrodes when equivalent pressures at a water depth of 0 m (0 kPa) and 10 m (1 kPa) are applied alternately to model 7210. The results show that the potential difference for the different pressure conditions is roughly 2 mV, with a pH conversion equivalent to 0.03 pH. This indicates that the effect of the sample pressure is extremely small. In addition, model 7210 uses a gel as the internal solution, ensuring that drying or changes in concentration of the internal solution do not occur.

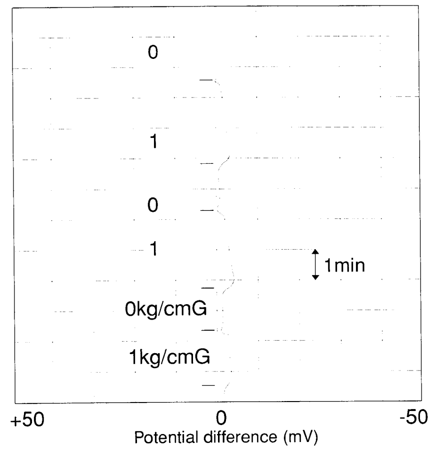

Figure 4 Pressure Influence to Reference Electrode (model 7210)

3.2 Conductivity Sensor

The electrode of the electrolytic conductivity sensor is made of titanium because of this material's superior corrosion resistance. As shown in **Figure 5**, the titanium electrode also protrudes from the sensor so that even if air bubbles form, they will not affect the measurement value. In addition, special surface treatment of the titanium electrode and improvements in the internal circuitry have been incorporated to raise the measurable limit to 100 mS/cm^{-1} and allow measurements even in salt water.

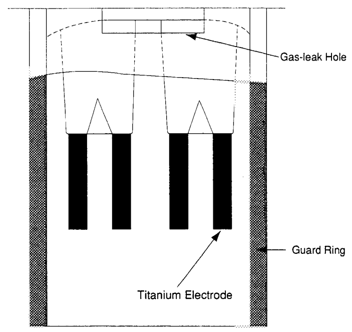

Figure 5 Conductivity Sensor

3.3 Turbidity Sensor

The turbidity sensor uses a pulse-lighting infrared LED as the light source. This method is less affected by coloration of the sample than systems based purely on transmitted light or scattered light. **Figure 6** shows the effect of the sample color on the turbidity sensor when using a 200-degree kaolin standard solution which has been colored with black ink for multi-pen recorders. The results given in this figure show that the color has virtually no effect on the measurement. Formazine and kaolin were mainly used as the standard solution for the turbidity. Observations with the turbidity sensor indicated a linear relationship between both substances, as shown in the formula below.

$$T_K = 0.433T_F$$

where T_K = Turbidity with kaolin standard solution (kaolin degree)

T_F = Value indicated by the sensor (NTU, formazine degree)

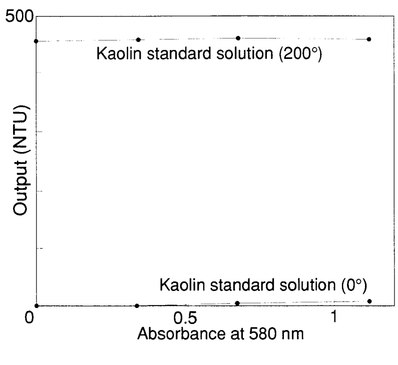

Figure 6 Color Influence of Turbidity Sensor

3.4 Dissolved Oxygen Sensor

By increasing the surface area of the diaphragm in the DO sensor, the effects of the sample pressure due to the curvature of the diaphragm are reduced. The results of a pressure effect test conducted on the DO sensor (7542) are shown in **Figure 7**, indicating that stable measurements can be performed. Like the test for the pH sensor, the pressure effect test applied an equivalent pressure alternately at a water depth of 0 m and 10 m.

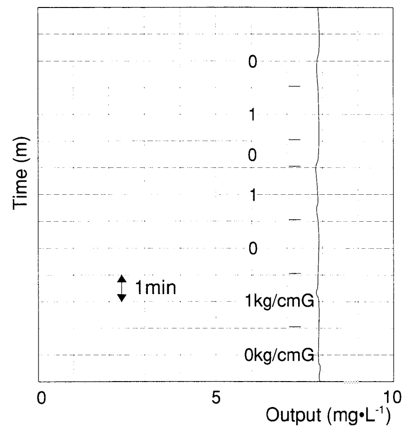

Figure 7 Pressure Influence to DO Sensor (model 7542)

4. Special Functions

4.1 Special Functions in the U-10

(1) Automatic calibration function

The U-10 features a handy automatic calibration function. The user simply fills the special calibration beaker with the phtalate pH standard solution, immerses the sensor, and then presses the button. The automatic calibration function performs one-point calibration for the pH (pH 4.01, 25 °C), span-point calibration for the electrolytic conductivity (4.49 mS/cm^{-1}, 25 °C), and zero-point calibration for the turbidity. This function ensures that the water quality checker is used to its full potential. In addition, a two-point calibration function is also included for instances when more precise measurements will be performed.

(2) Data memory function

The U-10 can store the results of up to 20 measurements of all six parameters. This data can be recalled and displayed at any time, enabling the user to store the measurement data at the site, and then recall the data and process it after returning to the lab.

(3) Automatic salinity correction function

To accurately measure the DO, salinity correction must be performed according to the salt concentration of the sample. The U-10 calculates the salt concentration based on the measured electrolytic conductivity, and then uses this value (calculated salt concentration) to display the DO value with the salinity correction. This function allows accurate measurement of the DO of fresh water, brackish water, or salt water even when the salt concentration of the sample is not known.

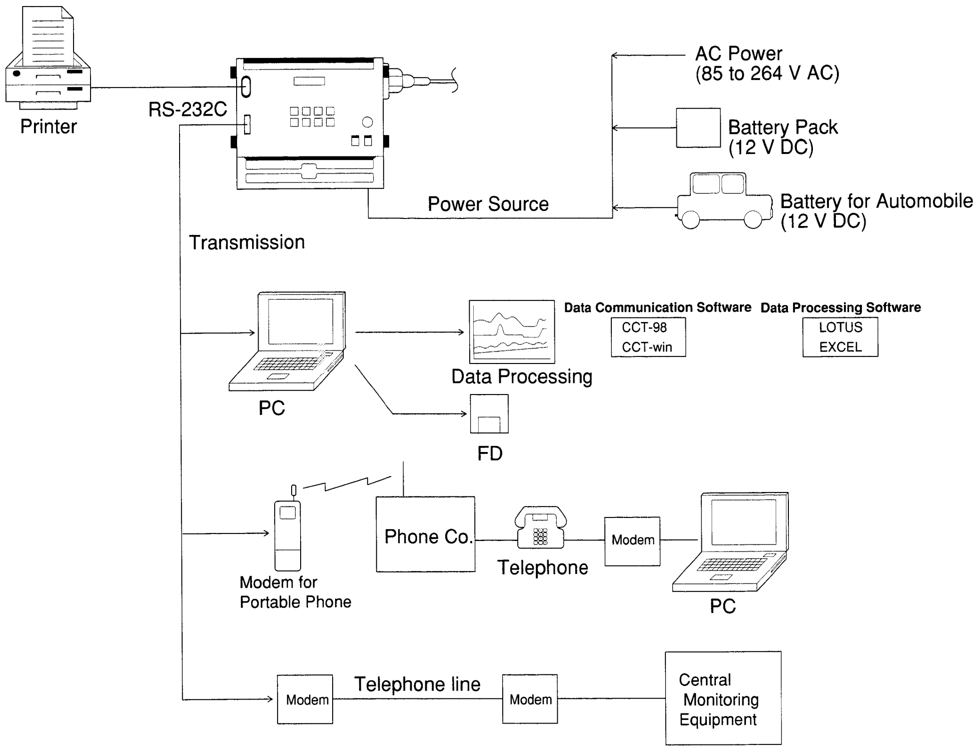

Figure 8 Application Example of WP-100

4.2 Special Functions in the WP-100

In addition to the features of the U-10 described above, the WP-100 has the following special functions.

(1) Continuous measurement and batch measurement function

In addition to the batch measurements performed by the U-10, the WP-100 can also make continuous measurements of the water quality at a single measurement point. Continuous measurement combines the cycle of drainage, measurement, drainage, cleaning, and standby into a single process which is repeated continuously to monitor changes in water quality over time. The allotted time for each process is set according to the measurement site, water quality characteristics, monitoring time, and other factors. The minimum time required for each measurement is five minutes.

(2) Data memory function

If the measurement cycle for the WP-100 is set at one hour for continuous measurement, approximately one month of data can be stored in memory. As with the U-10, the stored data can be processed with a computer by using the RS-232C system.

(3) Alarm function

The maximum and minimum concentration values for each measurement parameter can be programmed into the WP-100. When these values are exceeded, the current measurement value flashes on the display and an alarm signal is output. When this data is printed out, an alarm mark is shown to facilitate data analysis.

Conclusion

The U-10 and WP-100 offer a degree of compactness and portability, indoor or outdoor, unmatched by conventional water quality monitoring equipment, yet they are capable of performing continuous measurements. Moreover, they are highly cost-effective. Given the growing awareness of water pollution, particularly in developing countries, and the need for effective and inexpensive monitoring equipment, Horiba hopes that these instruments will make a significant contribution to preservation of the global environment.

Hiroo Matsumoto
Assistant Manager
Environmental & Process Control R&D Dept.
Development and design of water-quality analyzer