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The F-20 Series Cordless pH Meter

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Feature Article

The F-20 Series Cordless pH Meter

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Abstract
The F-20 series, the latest table-top pH meter, frees the user from the restraints of conventional cable-linked electrodes because the electrode contains a signal transmitter. Another new concept is the user-oriented handling of function keys. This paper describes the construction and features of the F-20 series, centering on the cordless measuring function, which is this product's most exciting feature.

1. Introduction

Microprocessors came into common use in pH meters about five years ago, and pH meters have since become increasingly sophisticated. Today the typical pH meter features an extremely large number of functions. In many cases, this has resulted in a complexity of operation that intensifies, rather than alleviates, the burden on the operator.

In a survey we recently conducted to determine what users want from pH meters, we found that the greatest concern was not measurement itself but peripheral matters including ease of operation. We also encountered long-standing complaints such as a desire for eliminating scale calibration and electrode cords. Our newly developed F-20 series of pH meters provides answers to these concerns and represents a major advance toward a next-generation pH meter.

2. System Calibration and Features

2.1 System Components

The components of the F-20 system are shown in **Figure 1**. The overall system consists of the F-20 unit with a detachable printer and cordless receiver, a cordless transmitter capable of four-channel communication, a separate free-arm stand, and an automatic calibration unit that completely automates the task of calibration. Connection to a computer or recorder is also possible.

2.2 Features

(1) Cordless pH measurement

By eliminating the cord connecting the pH electrode and the meter unit, true cordless pH measurement has been achieved. There is no longer a need to bring sample containers close to the unit, or worry that the cord will catch and cause a sample spill. The F-20 base unit can communicate to remote electrodes using up to four channels. This feature allows the user to perform high-precision measurement by selecting electrodes according to the properties of the sample

(2) Automatic calibration unit

Calibration work, a bother with ordinary pH meters, has been completely automated. Just set the timer on the pH meter to the desired start time, and calibration and cleaning is done automatically. Automatic calibration can thus be timed to take place overnight so that the F-20 is ready to perform measurements at the start of the workday.

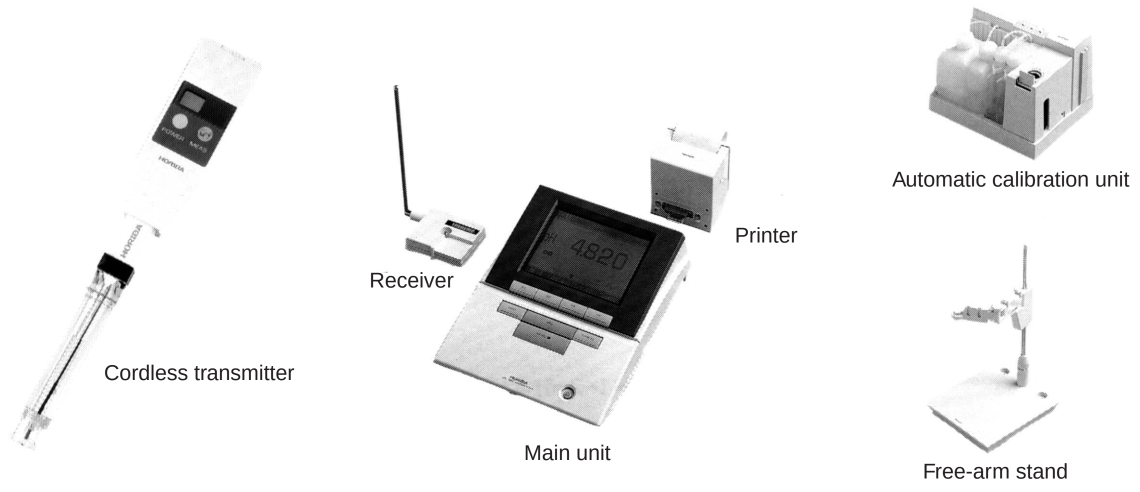

Fig. 1 Measuring system of the F-20 cordless pH meter.

Automated calibration also eliminates the worry of calibration mistakes due to inexperienced operators.

(3) Wall-mounted display

The use of a cordless electrode makes it possible to perform measurement with the base unit hanging on a wall or vertical surface, as shown in **Figure 2**. This enables efficient use of space in cramped laboratory conditions.

Fig. 2 Wall-mounted receiving unit

(4) Interactive operation

The F-20 is the first to display operator prompts using Chinese characters. This interactive method, like that of a computer, enables the user to configure complex measurement conditions with ease (**Figure 3**).

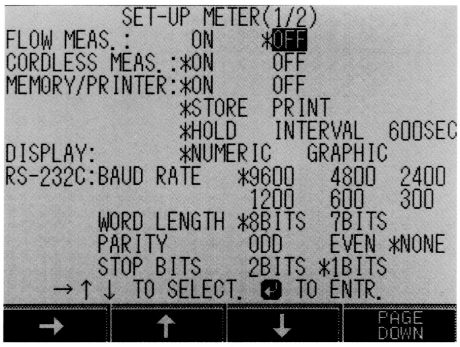

Fig. 3 Configuring measuring conditions using the interactive systems

(5) Graphic display of measurement results

While most instruments made in recent years are digital, there is still a strong demand for analog instruments because analog displays allow the user to observe the progress of a measurement. With the F-20 Series, simply switch to graphic display (**Figure 4**) and the measured values are successively plotted on the screen in realtime. Measurement progress is displayed in a manner similar to that of an analog device. The time axis (X-axis) and pH measurement range (Y-axis) can also be configured to match the sample.

(6) Ion measurement

Simply connect the ion-selective electrode and switch to ion measurement mode, and the F-20 converts into an ion meter (**Figure 5**). The ion meter supports multiple isothermal intersecting points that differ with the ion type and is capable of automatic temperature compensation.

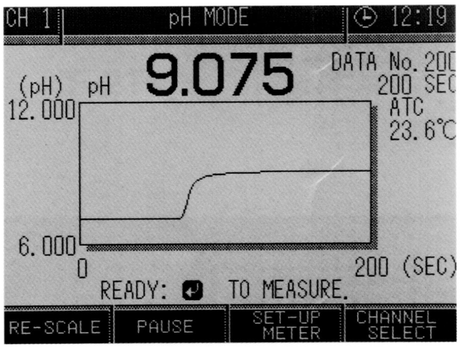

Fig. 4 Graphic display of measurement results

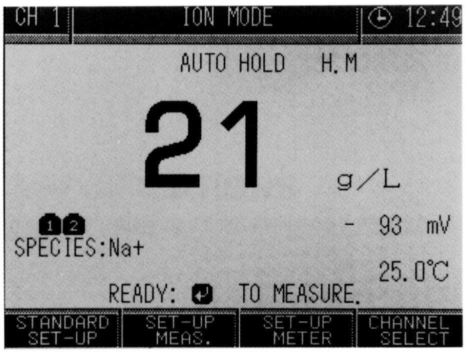

Fig. 5 Measurement of ion concentration

*1: Isothermal intersecting point.
The point at which the potential of the electrode does not change even when the solution temperature changes.

(7) Separate free-arm stand

The F-20 uses a separate free-arm stand for the electrode instead of combining the F-20 unit and electrode stand into a single unit. With ordinary integrated stands the electrode tends to move in an arc and it is difficult to place the electrode in the desired position. The separate free-arm stand provides improved vertical movement for a marked improvement in operability.

3. Cordless pH Measurement

3.1 Internal Configuration Diagram

Figure 6 shows the internal configuration of the F-20.

The transmitter unit consists of the cordless pH electrode and the transmitter; the two devices are easily attached and detached by means of a connector. An impedance converter circuit is incorporated into the cordless pH electrode for output to the transmitter at low impedance. The analog pH and temperature signals from the electrode are converted to a digital signal by a 14-bit A/D converter in the transmitter and read into the CPU as digital data. The data are converted into serial data and encoded to assure signal integrity, sent to the high-frequency transmitter, and then transmitted through the built-in antenna to the F-20 meter.

The receiving unit consists of the pH meter assembly and the receiver. The two devices are easily attached and detached by mean of a connector. The receiver receives the transmitted data and sends it to the CPU. The CPU decodes the data and sends the reading to the pH meter through the meter's I/O board.

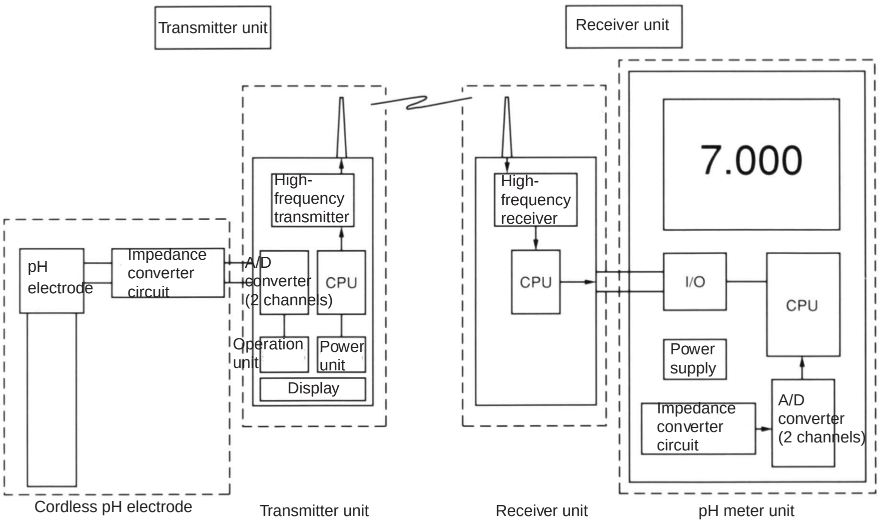

Fig. 6 Diagram of the F-20 communication system

3.2 Transmitter and receiver

Table 1 shows the specifications of the transmitter. **Table 2** shows the specifications of the receiver.

Table 1 Specifications of transmitter

Type	FW-20T
Measurement unit	pH/temperature
Measurement range	pH 0 -14
Temperature	0 - 80℃
Transmission frequency	300 MHz band
Modulation method	FM
Transmission method	PCM
Transmission output	Weak radio (conforms to Wireless Telegraphy Act)
Control method	Microprocessor control
Display	LCD (channel display)
Number of channels	Four (four transmitters per receiver)
Transmission interval	Depends on channel setting
Transmission distance	Approximately 5 m (depends on environment)
Power supply	Two Lithium batteries (CR2039)
Battery life	Approximately 5000 samples (30 seconds per sample)

Table 2 Specifications of receiver

Type:	FW-20R
Frequency:	300 MHz band (supplied from pH meter unit)
Number of channels:	Four
Reception distance:	Approximately 5 m (depends on environment)
Power supply:	7 - 12 V DC

3.2.1 Use of low-power transmitters

In Japan, depending on the frequency band and power used, low-power transmitters, such as those used by the F-20, are not required to have a license and are not subject to restriction by the Wireless Telegraphy Act. The cordless pH meter uses a low-power transmitter that does not require a license since it is assumed that most applications will be within a range of several square meters in a laboratory. This allowed us to create an inexpensive cordless pH meter that is easy for anyone to use.

3.2.2 Use of 300 MHz frequency band

The characteristics of various frequencies must be taken into account when choosing a frequency to be used for cordless communication. The relation of transmission power to frequency for low-power devices has been established as shown in **Figure 7**, and output restrictions become increasingly strict above 322 MHz.

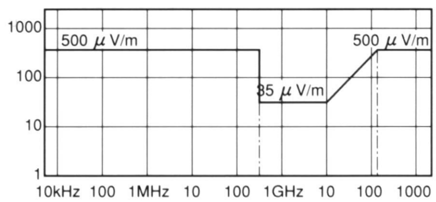

Fig. 7 Allowance of field intensity at 3m from small radio station

At the same time, the effects of interference in the field from common appliances must be avoided. For example, local TV frequencies (up to 291 MHz), motors, and high-voltage power sources can cause interference. Based on these considerations, we chose the 300 MHz band for the cordless pH meter.

3.2.3 Channel transmission system

A different transmission frequency is normally used for each channel when continuously transmitting data from multiple transmitters because simultaneous transmission on the same frequency results in jamming of the signals. However, when multiple frequencies are used, a circuit for each frequency is required in the receiver and selection and management of the transmitter frequencies is necessary at the time of purchase.

In the transmission system we developed, one receiver can receive signals from up to four transmitters on the same frequency. This was accomplished by means of multi-channel TX random transmission (**Figure 8**), whereby the transmission interval is varied for each transmitter channel. For example, data is transmitted once every 850 ms when a transmitter is set to channel 1. During the 850 ms interval, actual data transmission only lasts 85 ms and no

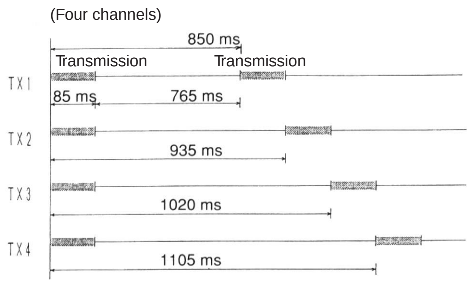

Fig. 8 TX random transmission with multiple channels

transmission takes place during the remaining 765 ms. When a transmitter is set to channel 2, transmission again only lasts 85 ms and the remaining 850 ms is free. As such, if one channel transmits when another channel is not transmitting, communication can take place at the same frequency without jamming. In addition, we vary the transmission interval so that even if two signals overlap at any particular time, they will not overlap at the next interval and thus jamming does not occur.

We designed the F-20 Series for a maximum of four channels; however, five channels are possible if the transmission interval is lengthened.

3.2.4 Low power consumption

To reduce the size of the transmitter of the cordless electrode we used a coin-type battery for the power source, and a major technical issue was how to minimize power consumption by the transmitter. Power consumption in the transmitter can be divided into three intervals: conversion of electrode input into digital data and transmission of data (both of which are active states), and the standby state during which the unit is essentially inactive. As **Figure 9** shows,

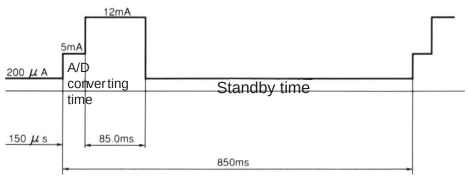

Fig. 9 Transmitter operation and its power consumption

considerable power is consumed during transmission, and thus it is possible to prolong battery life by reducing the number of times transmission takes place. One method for accomplishing this is to eliminate the transmission of unnecessary data. The measured value received from the electrode at a particular instant is compared with the previously transmitted data, and if the difference between the voltages is within a certain limit, the new data is not transmitted.

For example, transmission stops when the pH electrode stabilizes after placement in a sample, and then resumes if the voltage changes after placement in a new sample. Thus, unnecessary data is not transmitted and battery life is prolonged.

The circuitry has also been designed to minimize power consumption, and as a result approximately 5000 samples (30 seconds per sample) can be measured before the battery must be replaced.

4. Automatic Calibration Unit

4.1 Unit Configuration

Figure 10 shows the external appearance of the automatic calibration unit. The overall assembly consists of a standard solution pack (pH 4 and 7), rinse solution bottle (cleaning water), waste solution bottle, and an encased control unit.

The control unit consists of a motor, bellows pump, switch valve, and chamber. Suction and discharge is performed by the bellows, and solution switching is performed by the switch valve.

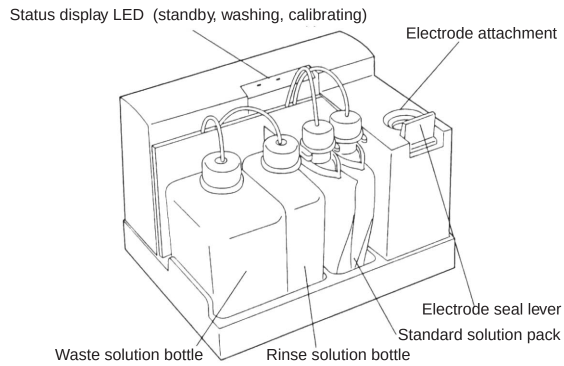

Fig. 10 Auto calibration unit

4.2 Measurement accuracy of automatic calibration

The calibration sequence is shown in **Figure 11**. Solution remaining in the tubes is first discharged and then the tubes are washed with pure water. Standard solution 1 (for example, neutral phosphate solution, pH 7) is drawn in, dual washing takes place, and then the solution is discharged. Standard solution 1 (pH 7) is once again drawn in and the calibration sequence begins at the pH meter unit. Calibration ends when the electrical potential stabilizes. The same process is then repeated using standard solution

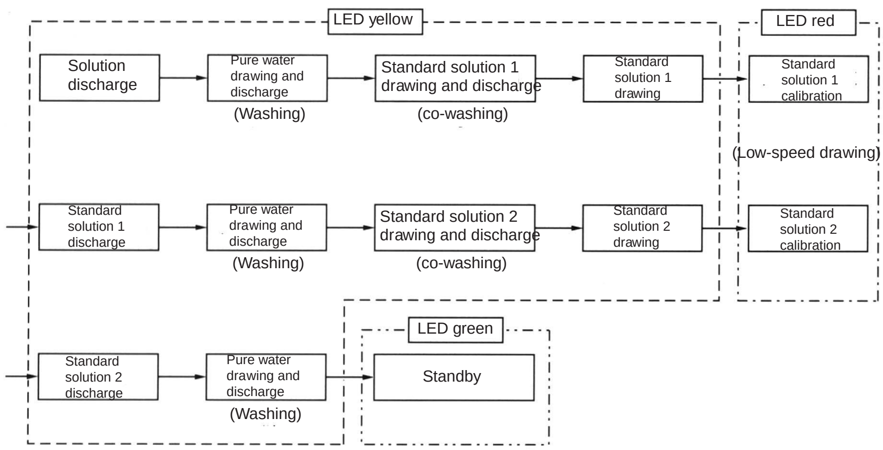

Fig. 11 Calibration sequence

2 (for example, standard solution of phtalic acid salt, pH 4) and two points are thus calibrated. Washing with water then takes place and the calibration sequence ends.

Table 3 shows measurement results for both automatic calibration and manual calibration. With the addition of the dual washing process, the two calibration methods agree to pH 0.01. When calibration is repeated 20 times using the automatic calibration unit, error is reduced to a level of pH 0.01 and good reproducibility is obtained.

Table 3 Comparison data of manual and automatic calibration modes

	Manual calibration value	Automatic calibration value	
		Before co-washing	When calibrated
pH7	6.86	6.88	6.86
pH4	4.01	4.04	4.01

5. Conclusion

This article introduced the F-20 series of tabletop pH meters featuring cordless pH measurement and an automatic calibration unit. The F-20 was developed with consideration given to not just the pH meter itself but the entire pH measurement system, and we hope that it will point the way for future pH measurement. We would be very happy to hear any comments and suggestions from those who engage in pH measurement.

References

1) Tsutomu Masuda, Cordless Control Handbook, Denpajikensha (1989), pp. 14-15.

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