Liquid-borne Particle Counter
For Pure Water
Model XP-L4

Technical Information

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1. Introduction

Liquid-borne particle counters are frequently used to control particle levels in wet stations. With the increasingly high levels of integration in semiconductors and the move towards the mass production of devices with design rules of 0.18 to 0.13 μm or less, the control of microscopic particles will necessarily also deal with smaller and smaller particle sizes.

This applies particularly to applications such as high-precision cleaning processes, where particle control in supply lines for ultra pure water will become increasingly important, with particle control for such supply lines needing to handle particle sizes of 0.1 μm and less.

To provide this level of particle control in ultra-pure water supply lines, RION has developed a particle counter capable of taking online measurements.

This is the Model XP-L4 Liquid-borne Particle Counter for Pure Water.

The XP-L4 is designed to take online measurements of particles as small as 0.05 μm in pure water.

The casing of the Liquid-borne Particle Counter for Pure Water XP-L4 includes a KS-17 sensor, a KZ-70 sensor controller for control and display, an XP-10S D/A converter, a flow rate controller with a built-in flow meter, an air purging unit and a built-in power supply. The XP-L4 uses light scattering to detect particles suspended in pure water and then measures the size and number of detected particles.

2. Measuring System

The Liquid-borne Particle Counter for Pure Water XP-L4 uses light scattering to detect particles suspended in pure water and then measures the size and number of particles.

The XP-L4 provides two particle size channels of 0.05 µm or larger and 0.1 µm or larger.

The casing for the Liquid-borne Particle Counter for Pure Water XP-L4 houses a KS-17 particle sensor, a KZ-70 sensor controller for sensor control and display, an XP-10S D/A converter with a built-in alarm function, a flow rate controller with a built-in flow meter, an air purging unit and a built-in power supply.

A high-pressure check valve to allow measurement of high-pressure samples and a printer are available as options.

When the optional high-pressure check valve is used, measurements can be taken at pressures up to 700 kPa, allowing you to select a wide variety of measurement points and take online measurements in a range of process types.

2-1. Flow System

The figure 1 shows the flow system for the Particle Counter for Pure Water XP-L4.

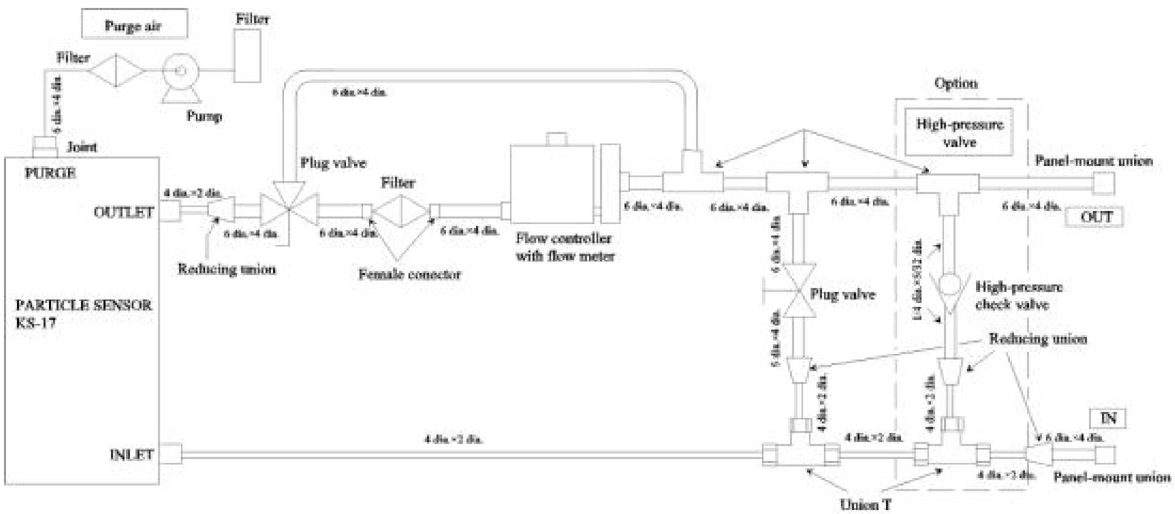


Figure 1 Flow system for the Particle Counter for Pure Water XP-L4

2-2. Electrical System

The figure 2 below shows the electrical system.

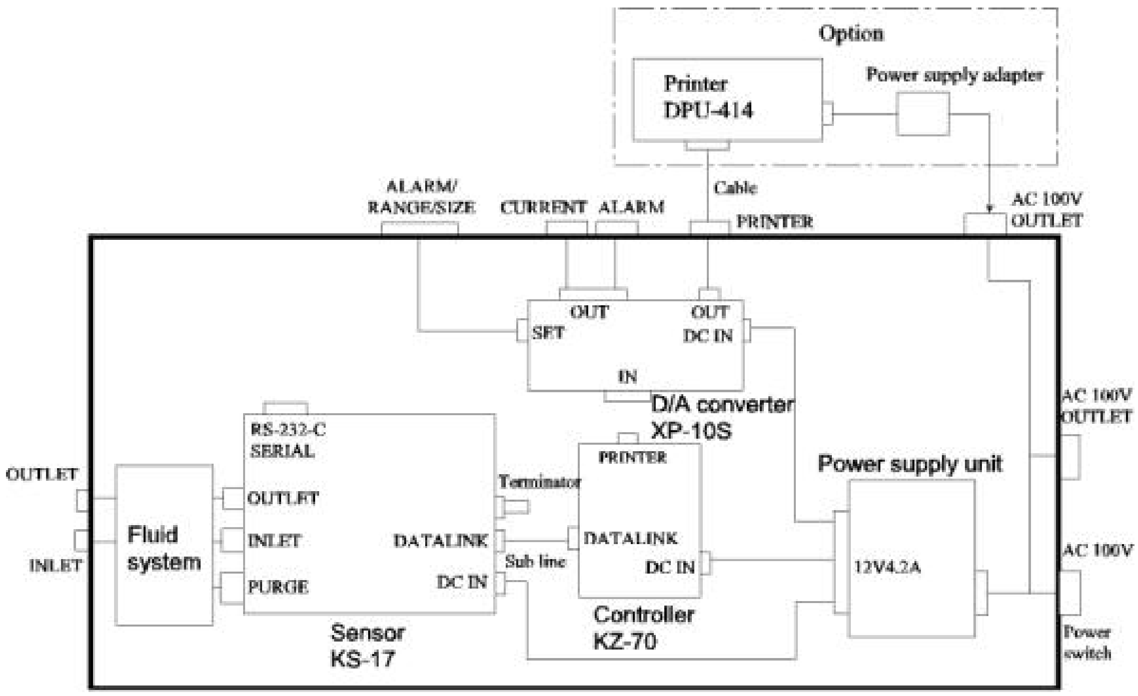


Figure 2 The electrical system the Particle Counter for Pure Water XP-L4

2-3. Specifications

The specifications for the Particle Counter for Pure Water XP-L4 are given below.

Specifications :

Sensor: According to specifications for KS-17

Control and display: According to specifications for KZ-70

D/A converter and alarm output: According to specifications for XP-10S

Material of fluid-contacting parts: Fused silica, PFA (sensor, joints, tubes)
PVC, PTFE, PCTFE, Viton, acrylic (flow controller, flow meter)

Sample fluid temperature range: 15 to 30ºC (no condensation in sensor cell)

Sample fluid pressure range: 100 to 300 kPa (gauge pressure)

With optional high-pressure check valve installed: 100 to 700 kPa (gauge pressure)

Ambient conditions for operation: +15 to +30ºC, max. 85% RH (no condensation)

Ambient conditions for storage: +10 to +50ºC, max. 85% RH (no condensation, no freezing in sample fluid flow system)

Sample fluid inlet/outlet: 4.0 dia. × 6.0 dia. or 3.96 dia. × 6.35 dia. flared tube joint

Flow controller: Diaphragm type, flow rate accuracy ±3%

Purge air unit: Sends clean air to sensor, for preventing atmospheric con-termination.

Flow rate: 3 to 7 L/min, filter pore size 0.1 µm

Bypass valve Allows bypassing flow controller, for external line purge valve and sample fluid line purging

Outputs

PRINTER: For connection of optional printer

ALARM: Alarm output connector, ON when alarm is activated

Maximum contact ratings: 110 V AC, 2 A; 24 V DC, 3 A
(resistive load)

CURRENT: D/A converter output. 4 - 20 mA current output

Maximum inclination angle: 2º (to assure correct operation of integrated leak sensor)

Power requirements: 100 V AC, 50/60 Hz, approx. 100 VA

Dimensions: 320 (W) × 260 (H) × 600 (D) mm (without protruding parts)

Weight: approx. 18 kg

Supplied accessories: 4.0 dia. × 6.0 dia. flared tube (with nut) 2 pcs.

Optional accessories: Printer DPU-414

High pressure check valve (factory option)

3. Particle Sensor

The sensor used in the Particle Counter for Pure Water XP-L4 is the KS-17 light-scattering Liquid-borne particle detector. The KS-17 is a partial-detection-type particle monitor for inline use that employs a light-scattering system to detect particles suspended in pure water and then measures the number of particles and their size.

The particle size channels provided by the KS-17 are 0.05 µm or larger and 0.1 µm or larger, and it offers a rated sample flow rate of 10 ml/min. with an effective measurement flow rate of 0.1 ml/min.

3-1 Principles and Features

As Figure 3 shows, Liquid-borne particle counters are broadly classified into high-detection types that use a wide pattern of laser beams and partial-detection types that use a narrower laser beam pattern.

Partial-detection systems achieve better particle detection resolution by increasing the light energy concentration. Partial detection also provides reduced optical noise since less light is scattered from the surfaces of the flow cell walls. Partial detection is used in the KS-17 sensor to allow measurement of the smallest possible particles.

The drawback of conventional partial-detection particle counters is that, because the concentration of the light energy in the flow cell is not uniform, the measurement resolution varies from place to place in the flow of particles. When large particles flow through areas with low light concentration, they may be mistakenly recorded as small particles. In addition, the probability that relatively small particles will be detected decreases. In other words, particle counting efficiency becomes dependent on particle size.

In the KS-17, the partial detection system was improved to ensure that this problem was resolved.

The KS-17 restricts its particle signal detection to the center of the detection area, thereby minimizing the differences in illumination light intensity and increasing the particle discrimination accuracy even when the light intensity is not distributed uniformly over the illuminated area. Specifically, this is achieved as follows:

1) By bending the flow cell into an L shape, the flow direction in the illuminated area is aligned with the incident light axis in order to eliminate particle discrimination errors along the incident light axis. See Figure 4.

2) A high-precision condensing lens group with low aberration was designed so as to accurately detect particle flow location data.

These improvements made it possible to detect 0.05 μm particles in pure water.

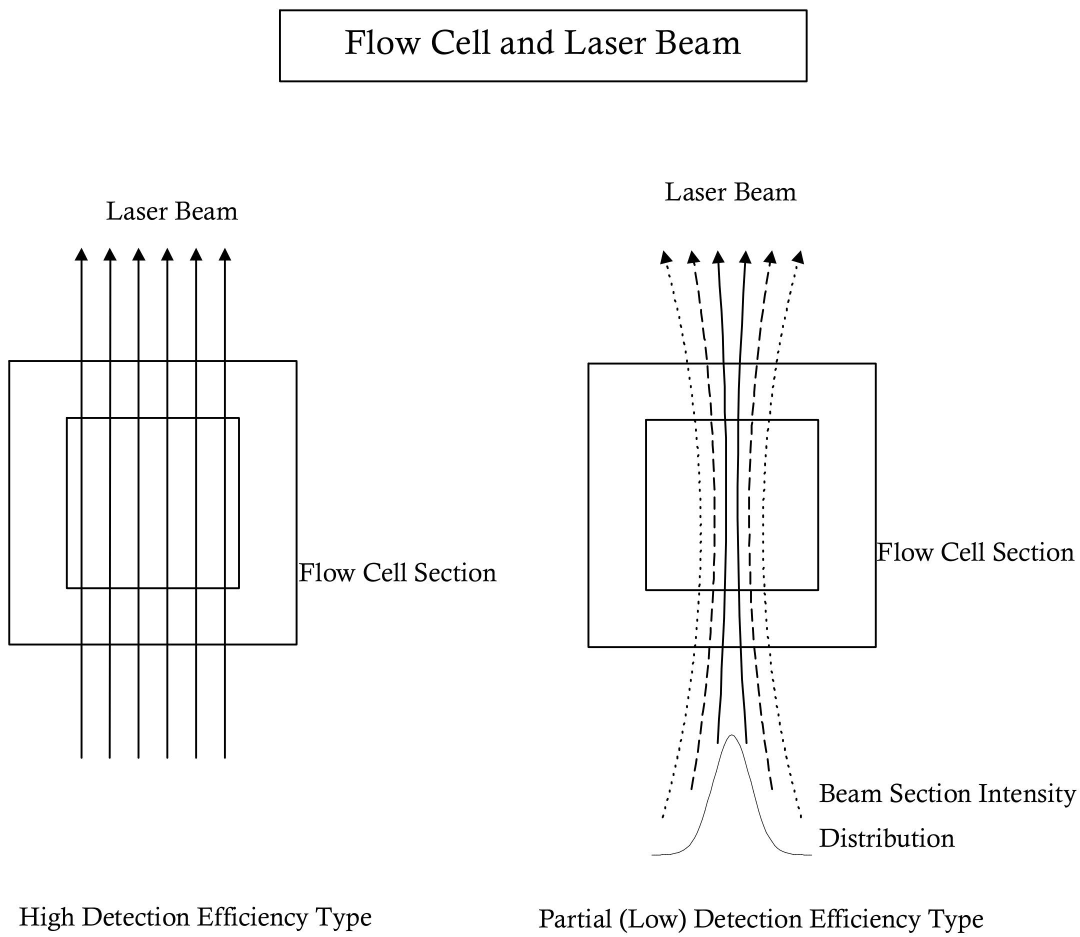
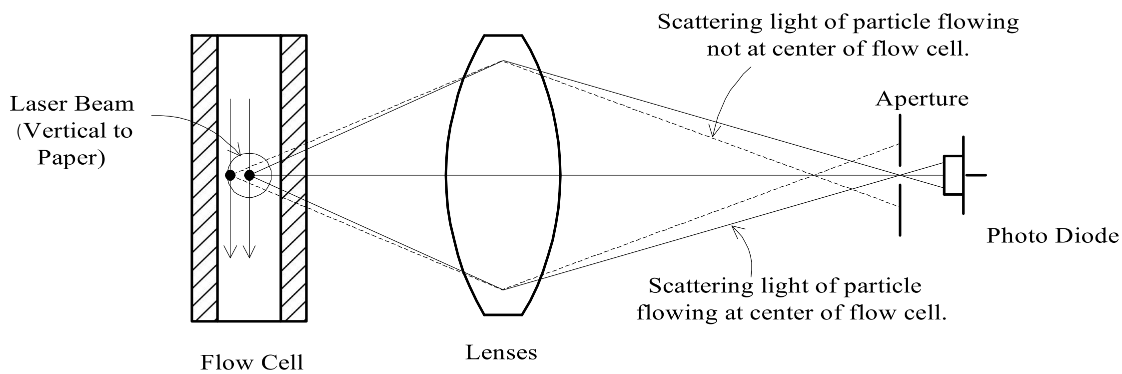
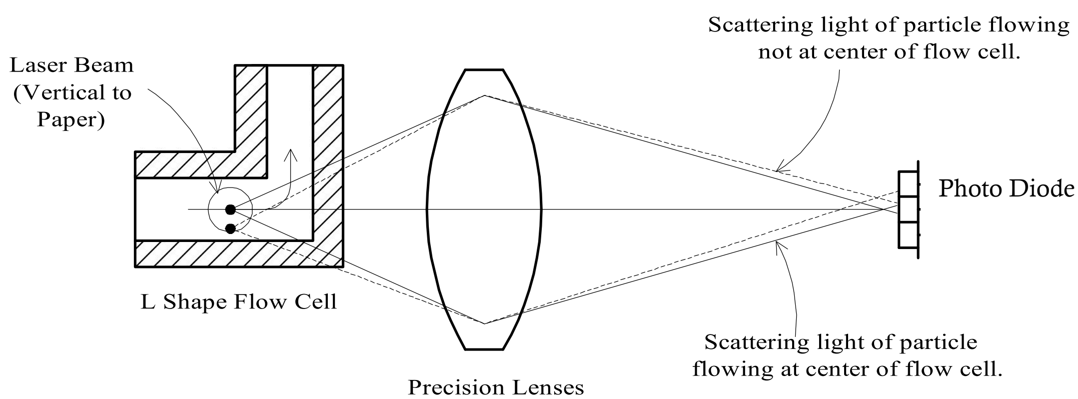


Figure 3 Tow types of Flow cell and Laser beam for Liquid-borne Particle Counters

Overview of Optical System



Conventional Optical System



KS-17 Optical System

Figure 4 Optical system for the Pure Water Particle Counter KS-17 and conventional optical system

4. Display

4-1 XP-L4 Display

Figure 5 shows the display unit for the XP-L4. This display unit is the Sensor Controller KZ-70, which includes both the display and the sensor controller. Figure 6 shows an example of the screen display.

The main data shown is as follows:

(1) **SENSOR:** Shows the sensor status, including the sensor name, sample flow rate and flow cell status.

(2) **MEAS.MODE:** Shows the measurement mode information, including automatic measurements, repeats, measurement time and rest intervals.

(3) **DATA:** Shows the measurement data, including the raw data, calculated values (concentration), particle size and particle count.

(4) **LAST DATA:** Shows the last data recorded before the current measurements.

(5) **The current operation status** is shown by LD indicators.

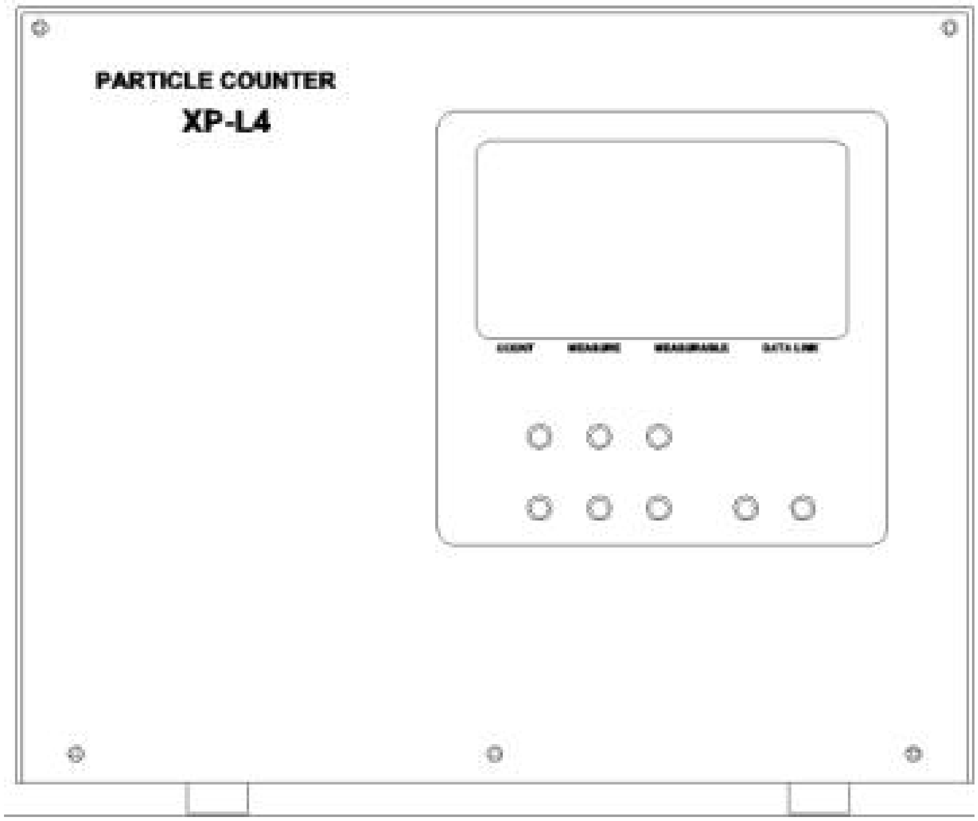


Figure 5 Display unit for the XP-L4 (Front view of the XP-L4)

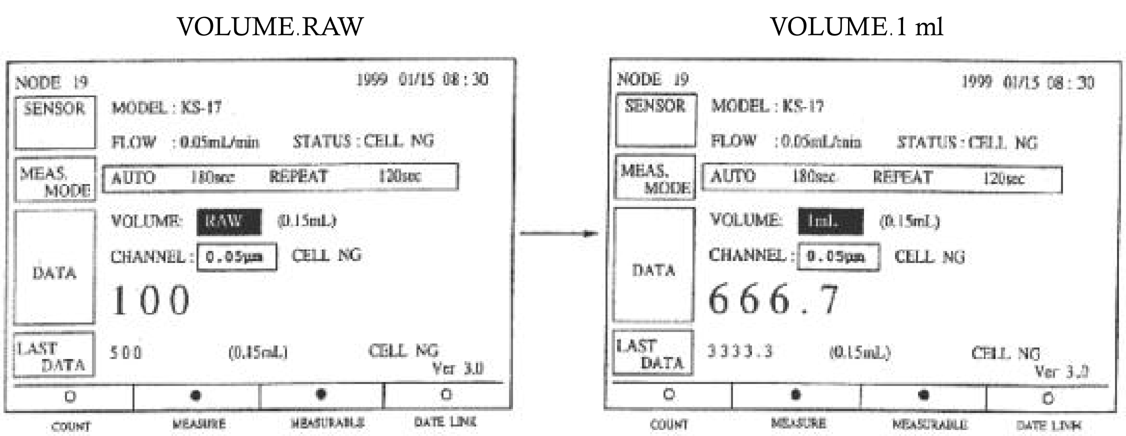


Figure 6 Example of the screen display

4-2 Printer Output

By connecting the optional DPU-414 printer to the XP-L4, you can print out the measurement results.

Figure 7 shows a sample printout.

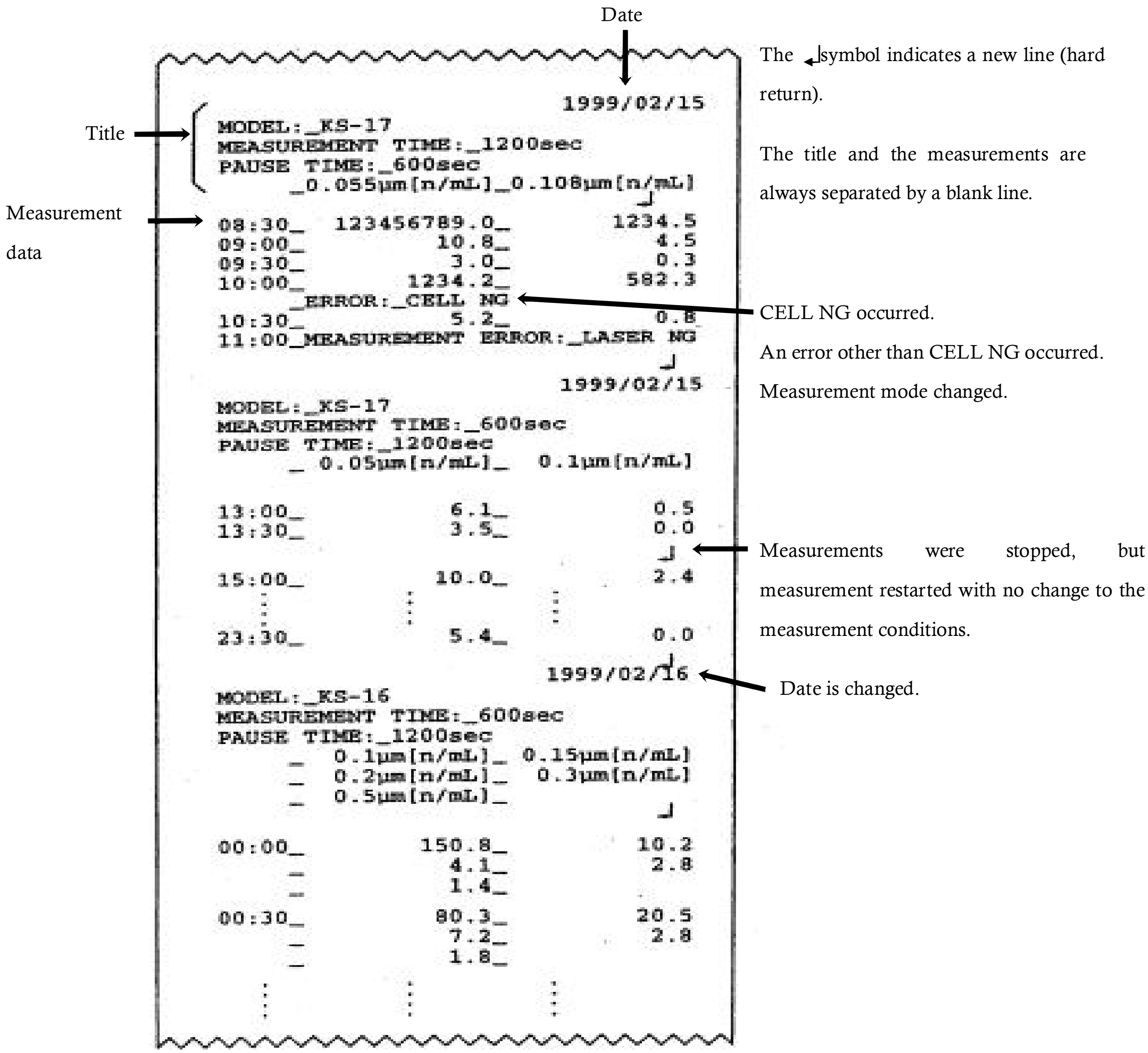


Figure 7 Sample printout from DPU-414 printer (optional)

5. Electrical Output

The electrical outputs offered by the Liquid-borne Particle Counter for Pure Water XP-L4 are printer output, alarm output, D/A-converted current output and serial output. Figure 8 shows the output terminals on the XP-L4.

(1) Printer output

Connects to the DPU-414 printer (optional) for printed output.

(2) Alarm output

Used to output warnings issued when the particle count exceeds a set value. Values between 0.1 and 999 P/ml can be set.

(3) D/A-converted current output

A current output of 4 to 20 mA in response to a set level of particle concentration. Depending on the settings, either raw data or a running average value can be output.

(4) Serial output

RS-232C serial output. This allows the XP-L4 to be connected to a computer for data downloading using the optional RP-Monitor K9461 monitoring software. Note that the Sensor Controller KZ-70 must be switched off when you are using the serial output port.

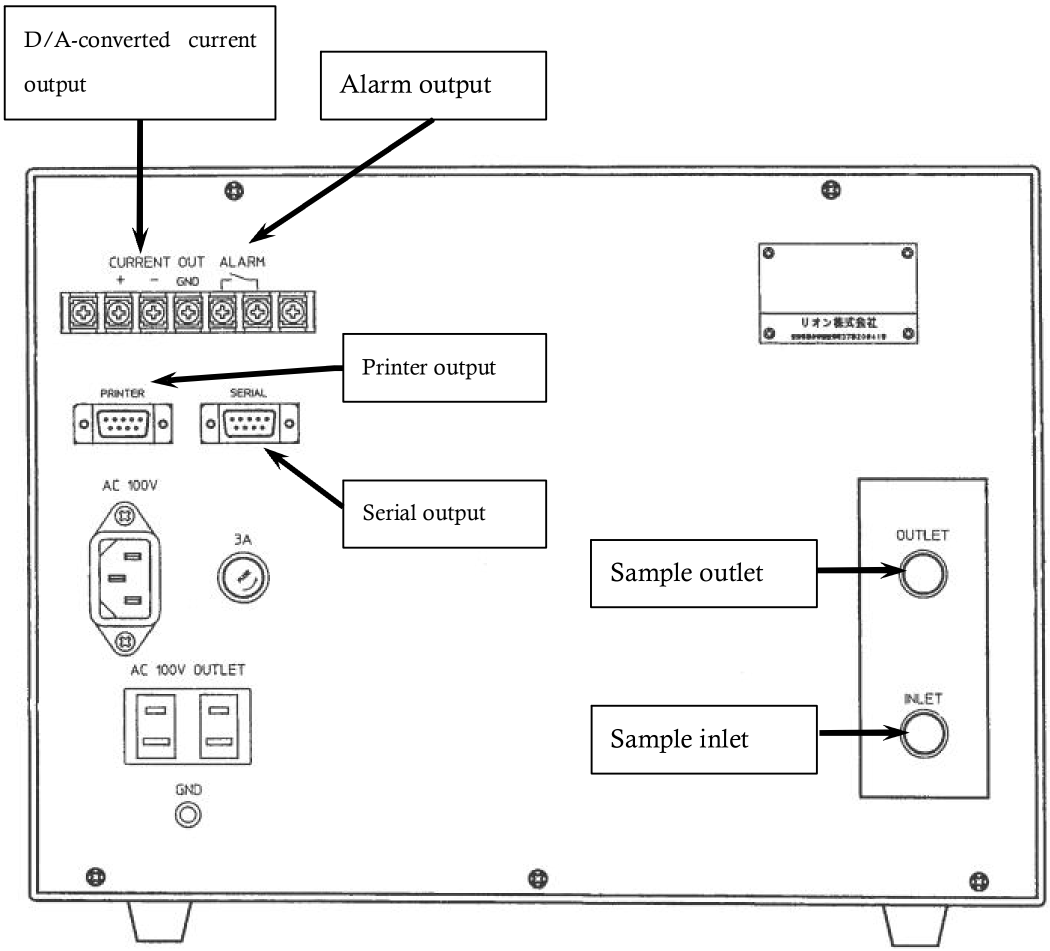


Figure 8　Output terminals on the XP-L4 (Rear view of the XP-L4)

6. Maintenance and Calibration

The recommended maintenance interval for Liquid-borne Particle Counter for Pure Water XP-L4 is one year. This maintenance comprises two parts: checking and calibration.

Checking: Confirms that the XP-L4 is operating normally by performing operation checks on the electrical and fluid systems. Any problems found are repaired (for an additional fee).

Calibration: Standard particles are passed through the sensor and the threshold voltage setting and noise level are checked. If any errors are found, the parameters are reset.

6-1 Outline of Maintenance Procedures

The maintenance procedures are summarized below.

(1) Cleaning on arrival

(1) The fluid system is cleaned internally with pure water.

(2) The tubing is checked for leaks.

(3) The indicator lamps are checked to ensure that they are operating normally.

(2) Data creation on arrival. (If an error in the indicator lamps, etc., is shown, measurement is not performed.)

(1) A reference unit is connected to the device being measured and the flow rate is adjusted.

(2) A count comparison test is conducted using a diluent containing standard particles.

(3) Noise level measurement

The noise level is measured in the stopped state with pure water used as the test fluid.

(4) Calibration using standard particles

(1) The flow rate is adjusted.

(2) A fluid content analyzer is used for measurement of a diluent containing standard particles and the response voltage is obtained.

(3) The S/N ration is checked.

(5) Threshold voltage setting

The threshold voltage is set for each particle size.

(6) Count comparison testing

Once calibration is completed, the on-arrival testing is performed again to yield equivalent data.

(7) Leak testing

A helium leak tester is used to perform leak testing.

(8) Function checks

A range of operation and display tests are performed.

(9) Document generation

6-2 Documents for ISO

The ISO-compliant documents (available for an additional fee) are the trace ability charts and a calibration certificate. For example:

(1) Calibration certificate

(2) Particle counter trace ability flowchart for quantity of electricity

(3) Particle counter trace ability flowchart for physical quantity

Appendix

KS-17 Liquid-borne Particle Detector with 0.05-µm Detection

T. Matsuda, RION Co., Ltd., Environmental Measurement Instruments Division

1. Introduction

In the electronics industry generally and particularly in the field of semiconductor fabrication, improvements in micro processing techniques have led to increasingly higher levels of integration. By the same token, the product yields that can be obtained are affected by smaller and smaller contaminant particles. The current contaminant level in ultra pure water is a maximum of 1 particle of 0.1 µm or larger per milliliter. But there are calls for the measurement and removal of even smaller particles. This report describes the development of the KS-17 particle counter, which is capable of detecting particles as small as 0.05 µm in size.

2. Conventional Detection Principles

Liquid-borne particle counters are broadly classified into high-detection types that use a wide pattern of laser beams and partial-detection types that use a narrower laser beam pattern, as shown in Figure 1.

In partial-detection counters, the light energy concentration is increased to achieve better particle detection resolution. Partial detection also reduces the level of optical noise since less light is scattered from the surfaces of the flow cell walls. The KS-17 sensor uses this partial detection method to allow measurement of the smallest possible particles.

The drawback of conventional partial-detection particle counters is that, because the light energy concentration in the flow cell is not uniform, the measurement resolution varies from place to place in the flow of particles. When large particles flow through areas with low light intensity, they may be mistakenly recorded as small particles. In addition, the probability that relatively small particles will be detected decreases. In short, particle counting efficiency becomes dependent on particle size.

In the KS-17, this problem was resolved by improving the partial detection system used.

3. Design Used to Resolve Detection Problems

The KS-17 restricts its particle signal detection to the area immediately around the center of the detection area, thereby minimizing the differences in illumination light intensity in that area and increasing the particle discrimination accuracy even when the light intensity is not distributed uniformly over the illuminated area. Three specific measures are used to achieve this.

1) The flow cell is bent into an L shape so that the flow direction in the illuminated area is aligned with the incident light axis. In this way, particle discrimination errors are eliminated in the area around the incident light axis. See Figure 2.

2) In order to detect the positions of particles moving in a perpendicular direction to the flow direction and incident light axis, three channel photodiodes were used to divide the illuminated plane into 3 parts. The signals for particles that pass directly through the center appear only in channel b. Signals that are shifted slightly away from the center appear in both a and b or in both b and c. Signals shifted still further away from the center appear in either a only or c only. Information on the locations of passing particles can then be obtained from the proportions of the signals appears in the three channels. At the same time, we can use these photodiodes to detect the amount of light scattered by the particles. The information on the particle positions and the amount of scattered light can then be used to identify the particle sizes with excellent precision.

3) A high-precision condensing lens group with low aberration was designed so as to accurately detect particle flow location data.

4. Dependency of Counting Efficiency on Particle Size

Figure 3 shows the change in counting efficiency relative to particle size. Conventional partial-detection counters made by other manufacturers show the failing discussed above, with a large variation in counting efficiency relative to particle size. The KS-17 on the other hand shows an almost perfectly consistent counting efficiency of 1% for particle sizes of 1 μm or larger. For particles around 0.05 μm in size, the efficiency drops to around half that level, demonstrating ideal characteristics for a particle counter. Figure 4 shows the measurement data for a polydispersoid sample. Concurrent measurements were taken with the KS-17 and a high-detection-type 0.1-μm particle counter, and the results clearly show the continuity of the data.

5. Conclusion

To summarize, the KS-17 offers 0.05-μm particle detection, low dependency between particle counting efficiency and particle-size, and a lightweight and compact unit at a low cost. Future markets will demand still smaller minimum particle detection sizes and even better counting efficiency, and those are the issues that remain to be addressed.