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CORRELATION FLOWMETER (CAPACITANCE TYPE) FOR PULVERIZED COAL

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1 INTRODUCTION

This flowmeter is a mass flowmeter which detects concentration and velocity of powder being transported and measures only powder volume of solid/gas 2-phase flow.

Measurement of mass flow of powder being transported through a pipe line is one of the most difficult flow measurements because in a solid/gas 2-phase flow, various parameters such as mesh of solid, specific gravity, solid-gas ratio, gas flow velocity and pressure, cause behavior of the flow to change complicatedly. For this reason, it is extremely difficult to apply the conventional method which obtaines flow from a physical value that expresses a flow, and none of them has been realized practically.

The flowmeter introduced in this paper detects flow and concentration independently as shown in *Fig. 1*, and obtains a mass from the multiplication. Since this flowmeter is a capacitance type and have no obstructive part inside the pipe, the flowmeter has the following features:

1) The pipe line is not clogged.
2) No pressure loss occurs.
3) Long service life and high reliability
4) Maintenance free

The hardware consists of a detector, transmitter and shielded cable which joins the detector and transmitter.

2 DETECTOR

As a method to detect concentration of powder flowing through a pipe, the detector uses a capacitance method. The capacitance sensing electrode is installed on a part of ceramic pipe exterior by means of a metalization as shown in *Fig. 2*. The ceramic pipe is outstanding for the electrical insulation, wear resistance and heat resistance, and further,

Fig. 2 Sensor geometry

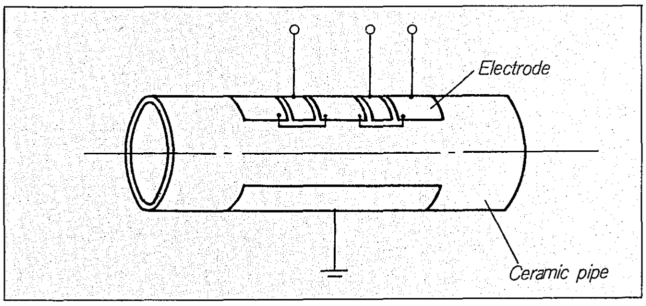


Fig. 1 Principle of measurement

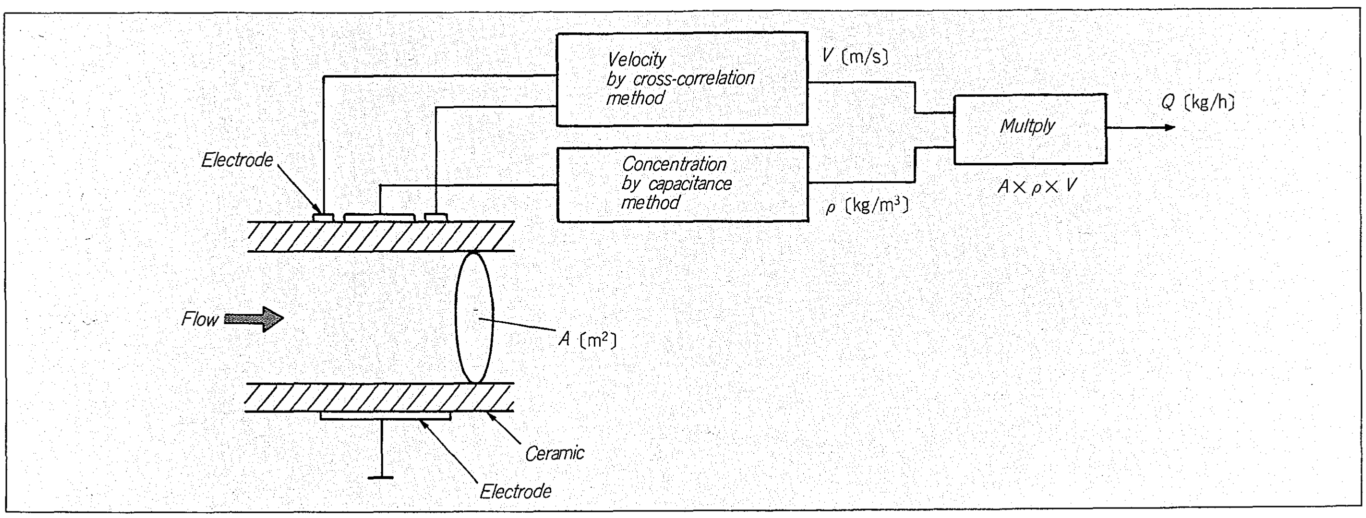
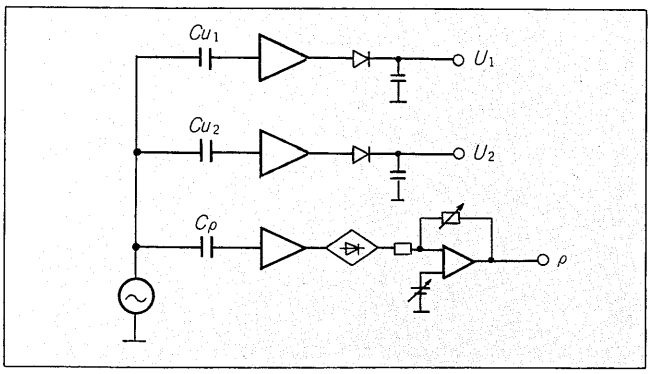


Fig. 3 Diagram of detector unit



this material has such a feature as that the moisture absorption is almost none. The ceramic pipe composes a part of the flow line.

The concentration sensing electrode detects capacitance changes caused by concentration of powder as a change of mean value. For this reason, taking a large area. The velocity sensing electrodes in two points are formed in a pertinent area so that flow fluctuating pattern can be detected sensitively. Further, the electrodes in the other side of the capacitance and flow velocity sensing electrodes are used commonly.

Detected capacitance is converted to voltage signals by the detector circuit accommodated in the case on the ceramic pipe protecting metal pipe, and the voltage signals are sent to the transmitter through the shielded cable. The detector circuit applies high frequency sine-wave voltage to the detected capacitance, and thus, detects charge current. *Fig. 3* shows the principle configuration. In addition, *Fig. 9* shows external dimensions of the detector unit.

3 TRANSMITTER

The transmitter consists of a flow velocity circuit, concentration circuit, multiplier circuit and signal converter circuit, and outputs 4 to 20 mA dc unified signals which proportion to mass flow of the powder. Moreover, as an output signal, frequency signals can also be handled, and it is also possible to take out flow velocity and concentration in the form of a dc voltage signal. *Fig. 4* is a block diagram for the transmitter circuits.

1. Operating Principle of the Flow Velocity Circuit

Fluctuations generated on sensors A and B which are installed toward the axial direction of the pipe in a predetermined distance L as shown in *Fig. 5* successively change as shown in *Fig. 6*. The upstream signal U_1 appears to be the downstream signal U_2 τ_0 seconds later in the similar

Fig. 5 Detector configuration

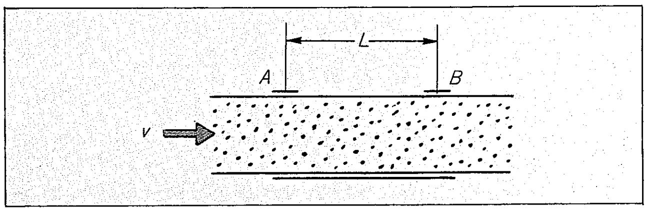


Fig. 6 Signal wave form

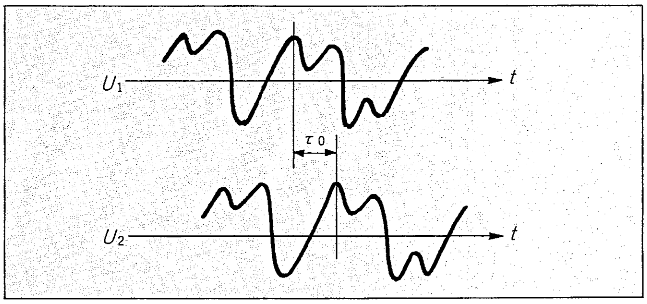


Fig. 7 Correlation curve

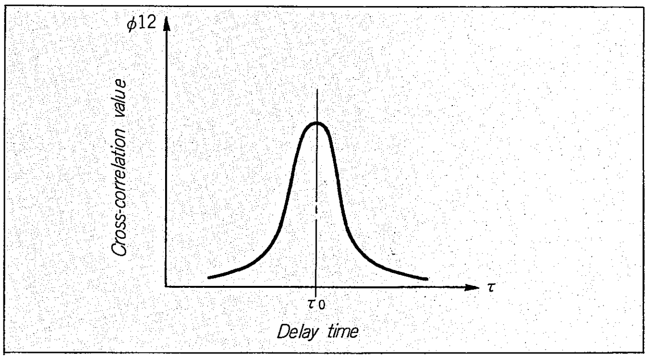


Fig. 4 Diagram of transmitter

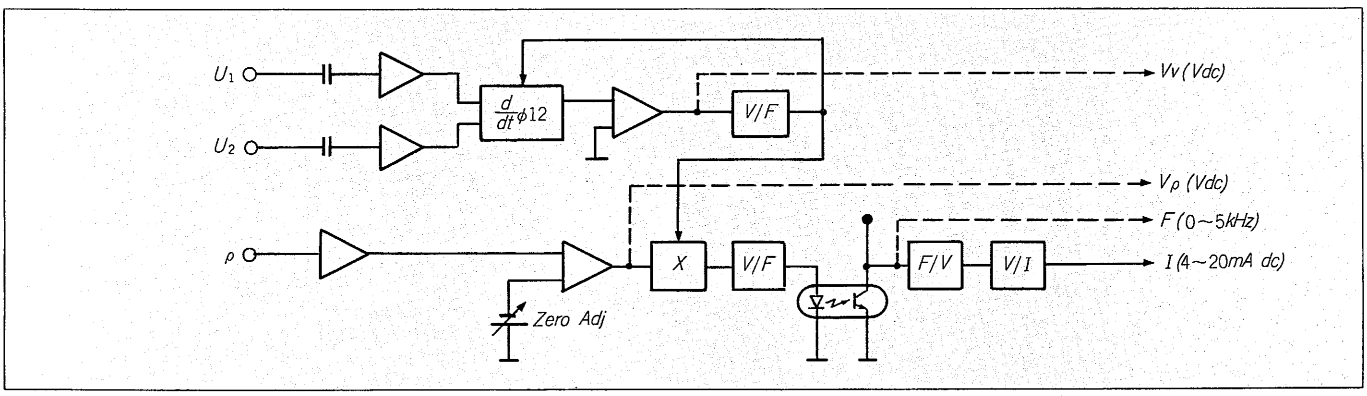


Fig. 8 Principle of cross-correlation circuits (Peak-point automatic tracking circuits)

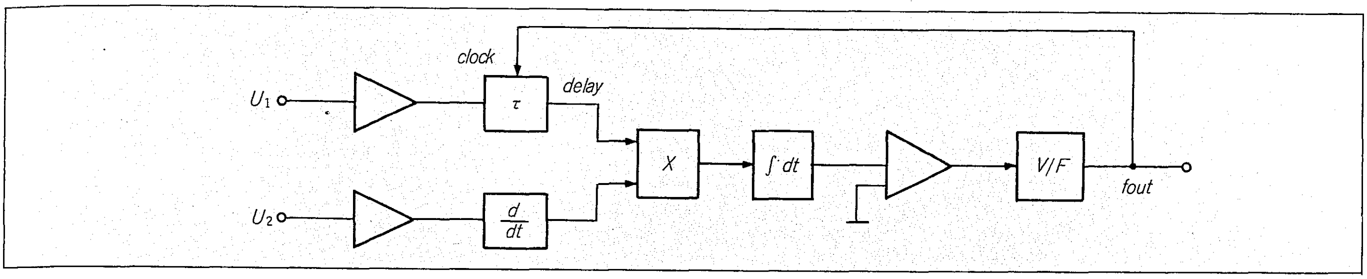


Fig. 9 Outline of detector

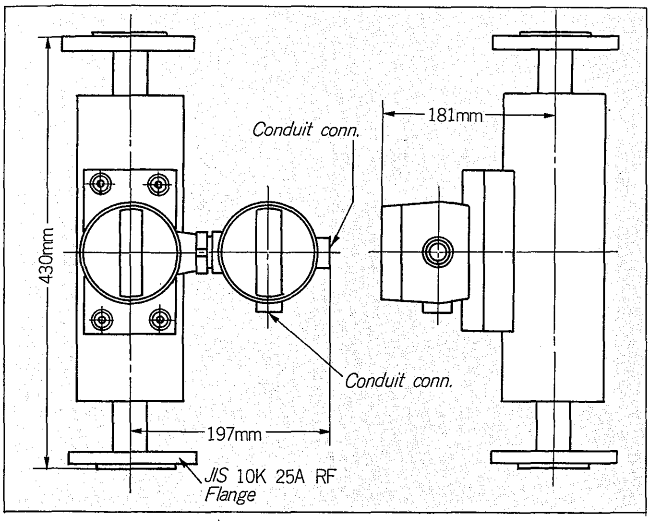
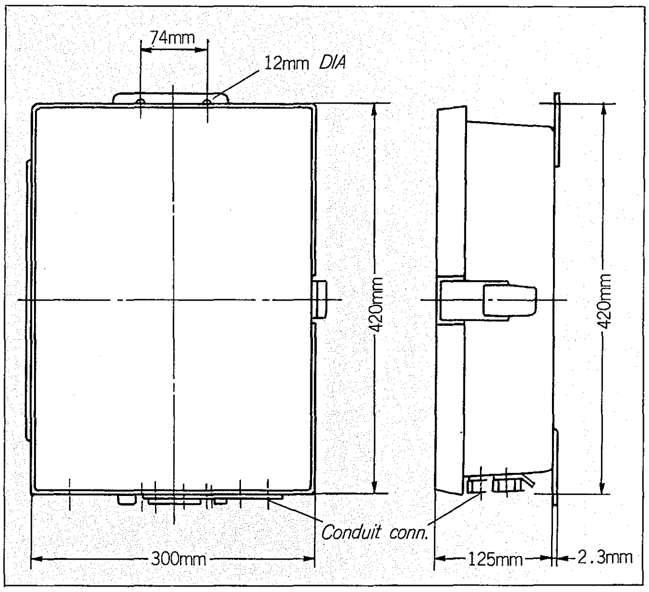


Fig. 10 Outline of transmitter



form. Hence, relationship $U_2(t) = U_1(t - \tau_0)$ is established, and the relative curve between U_1 and U_2 reaches the peak at $\tau = \tau_0$ as shown in *Fig. 7*. When this τ_0 is obtained, flow velocity V can be obtained as $V = L/\tau_0$ [m/sec].

As a method to automatically trace peak of the relative curve, there is a method to obtain differential of the relative value $\phi 12$. To be more specific, the point where the solution of the following equation becomes zero is the peak of the relative value $\phi 12$.

$$\frac{d}{d\tau}\phi 12 = \frac{1}{T}\int_0^T U_1(t-\tau)\cdot\frac{d}{dt}\,U_2(t)dt$$

This flow velocity circuit realizes the above equation, and delay time τ is controlled so that the result of an integration is zero. *Fig. 8* shows the operating principle of the flow velocity circuit.

4 EXTERNAL DIMENSIONS AND SPECIFICATIONS

Figs. 9 and *10* respectively show the external dimensions of the detector and transmitter, and *Table 1* indicates the major specifications.

Table 1 Specification (for the use of measuring relative flow)

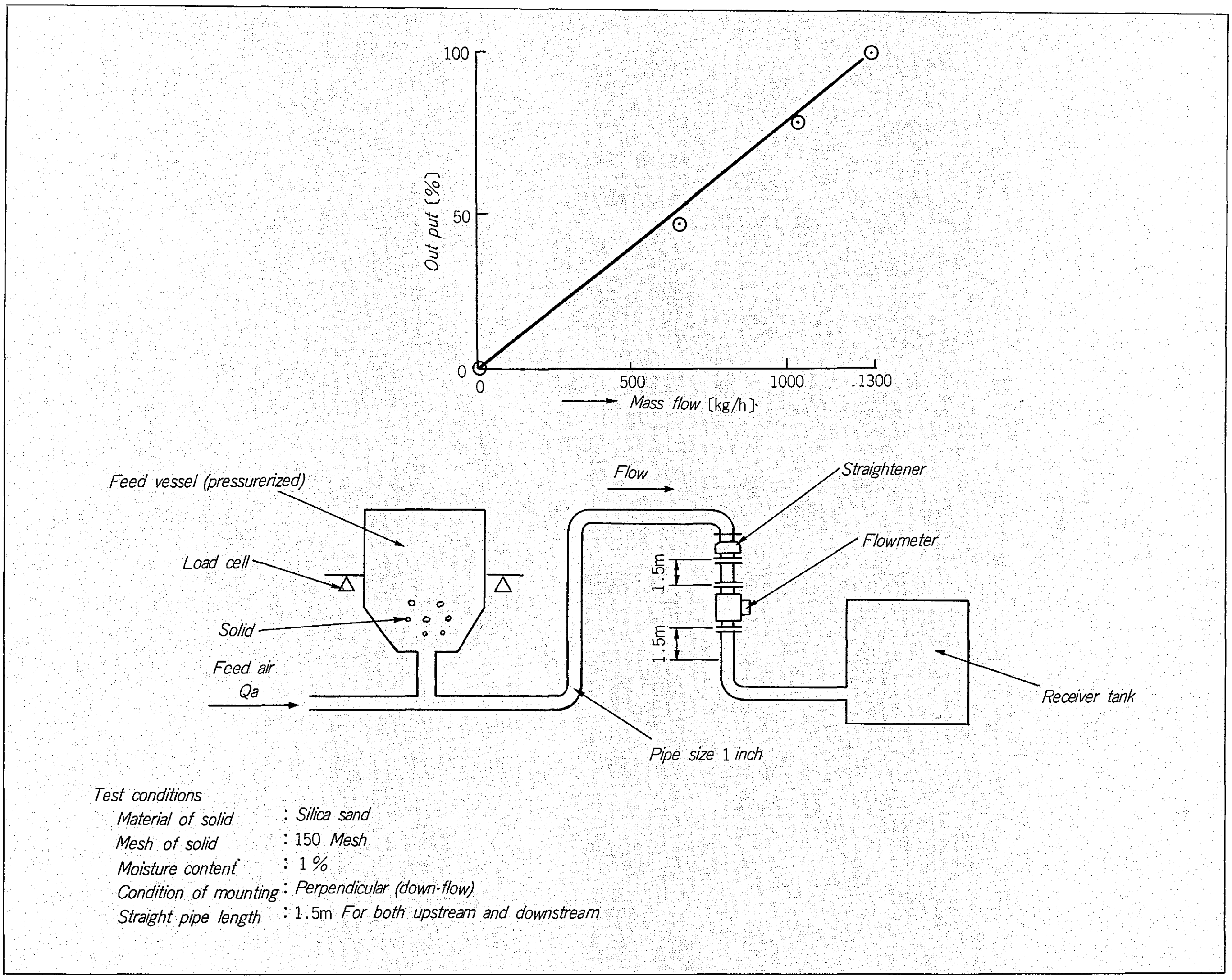
Measuring fluid	: Pulverized coal and coke grain size: 200 mesh moisture content: less than 3% (weight) properties: adhesionless to the inner surface of the pipe
Fluid temperature	: Normal temperature – +80°C
Fluid pressure	: Atomspheric pressure – 10 kg/cm²G
Flow rate	: Max. 1000 kg/h
Pipe size (Pipe material)	: 1 inch (Metallic pipe)
Connection	: Flange JIS 10 K
Mounting the detector	: Vertical direction
Straight pipe length (pipes and detector must be grounded)	: More than 40 D (1 m)
Accuracy by factory calibration	: ±5% of full scale
Materials	
– Sensor	: Ceramics
– Case	: Cast-aluminium
Power supply	: AC100/115/220 V ±10%, 50/60 Hz
Output	: DC 4-20 mA
Load	: 0-450 Ω
Ambient temperature and relative humidity	: Detector: –10-+80°C, 95% RH Transmitter: –10-60°C, 90% RH

5 CALIBRATION OF FLOWMETER

5.1 Factory Calibration

Using the reference unit, the detector and transmitter are calibrated independently. Further, as occasion demands the detector and transmitter are tested by actually flowing powder. For the factory test, the sample powder is supplied

Fig. 11 An example of flow test



from the customer. In this test, the flowmeter is evaluated for the powder flowing nature, adhesiveness, electrification, applicability of this flowmeter, transporting condition, piping condition, etc. *Fig. 11* shows an example of silica sand measurement using this system.

5.2 On-Site Calibration

At a field, flow of powder in each pipe line is not uniform. Therefore, the flowmeter must be calibrated under the actual operating condition prior to using it practically. As for the methods, there are a method to match the flowmeter output with output of the load cell used as a reference flowmeter, method to match the output of flowmeter installed on each branched pipe. Further, when the irregularities of the flow distribution are remarkable, a straightener must be installed in the upstream side. Furthermore, concentration is affected by dielectric constant, moisture content etc. of the powder, and therefore, a compensation is required on the system when they cannot be disregarded, provided that when measuring relative flow of each distributed pipe, no compensation is required because the influential value is equal.

6 POSTSCRIPT

As indicated in the *Table 1,* the measured object and applicable pipe diameter of this flowmeter are limited. This means that the flowmeter has proved the specifications. To expand the range of the specifications, experience must be accumulated one by one, and we are intending to realize it by using various samples supplied by the custmers.