

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS B 7554 : 1997

Electromagnetic flowmeters

ICS 17.120.10

Descriptors : flowmeters, electromagnetically-operated devices, magnetic field effects, electric field effects, electromagnetism

Reference number : JIS B 7554 : 1997 (E)

B 7554:1997

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of International Trade and Industry through deliberations at Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law. Consequently, JIS B 7554:1993 is replaced with JIS B 7554:1997.

Date of Establishment: 1984-11-01

Date of Revision: 1997-11-20

Date of Public Notice in Official Gazette: 1997-11-20

Investigated by: Japanese Industrial Standards Committee
Divisional Council on Precision Machinery

JIS B 7554:1997, First English edition published in 1998-06

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

© JSA 1998

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

Printed in Japan

Electromagnetic flowmeters

Introduction This Japanese Industrial Standard was made on the basis of **ISO 6817** *Measurement of conductive liquid flow in closed conduits — Method using electromagnetic flowmeters* published in 1992 as the first edition and **ISO 9104** *Measurement of fluid flow in closed conduits — Methods of evaluating the performance of electromagnetic flowmeters for liquids* published in 1991 as the first edition without changing the technical contents as for the corresponding parts. The items (inspection, selection, measurement, maintenance and check, and simple method of performance test) not specified in the corresponding International Standard are added to this Standard.

1 Scope This Japanese Industrial Standard specifies the principle, construction and function, method of performance test and using method of the electromagnetic flowmeters for industrial use ⁽¹⁾ (hereafter referred to as "flowmeter"). This Standard does not apply to the flowmeters for medical use, for measuring liquid metal and for measuring water flow in open conduits.

Note ⁽¹⁾ Flowmeter which creates a magnetic field perpendicular to the flow, so enabling the flow-rate to be deduced from the induced electromotive force produced by the motion of a conducting liquid in the magnetic field.

Remarks: The following are the corresponding International Standards to this Standard.

ISO 6817 *Measurement of conductive liquid flow in closed conduits — Method using electromagnetic flowmeters*

ISO 9104 *Measurement of fluid flow in closed conduits — Methods of evaluating the performance of electromagnetic flow-meters for liquids*

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. The most recent editions of the standards indicated below shall be applied.

JIS B 2238 *General rules for steel pipe flanges*

JIS B 2239 *General rules for cast iron pipe flanges*

JIS C 0903 *Electrical apparatus for explosive atmospheres in general industry*

JIS C 0920 *Tests to prove protection against ingress of water and degrees of protection against ingress of solid objects for electrical equipment*

JIS G 3101 *Rolled steels for general structure*

JIS G 3451 *Fittings of coated steel pipes for water service*

JIS G 4303 *Stainless steel bars*

JIS G 5527 *Ductile iron fittings*

JIS H 4553 *Nickel and nickel alloy rod and bar*

JIS H 4650 *Titanium rods and bars*

JIS H 4701 *Tantalum flat mill products, rod and wire*

JIS Z 8103 *Glossary of terms used in instrumentation*

3 Definitions For the purpose of this Standard, the definitions given in **JIS Z 8103** and the following definitions apply.

- a) **electromagnetic flowmeter** The electromagnetic flowmeter shall consist of the following detector (primary device) and converter (secondary device).
 - 1) **detector (primary device)** Device consisting of an electrically insulating meter tube through which the conductive fluid to be metered flows, one or more pairs of electrodes, diametrically opposed, across which the signal generated in the fluid is measured, and exciting and core for producing a magnetic field in the meter tube. The detector produces a signal proportional to the flow-rate.
 - 2) **converter (secondary device)** Equipment which extracts only the flow signal from the electrode signal of detector and converts it to a output signal directly proportional to the flow-rate. This equipment may be mounted on the detector.
- b) **meter tube** Pipe section of the detector through which the fluid to be measured flows. Its inner surface is electrically insulating. Bore and face to face distance of the meter tube are as follows:
 - 1) **bore** Nominal diameter of counterpart piping with which the detector is coupled. It may be expressed with the nominal diameter of the coupling flange.
 - 2) **face to face distance** Dimension between the coupling faces of the flanges of the detector in the direction of pipe axis. It includes the thickness of the lining and liquid-contacting ring, if equipped.
- c) **electrode** One or more pairs of conductors or capacitor plates by means of which the signal electromotive force is induced.
- d) **lining** Relatively thick insulating film coated on the inner surface of the meter tube of the detector contacting directly with the fluid to be metered. Insulating meter tube is included.
- e) **liquid-contacting ring** Ringed electric conductor for making the detector and the fluid to be metered the equivalent electric potential.
- f) **electrode voltage** Total potential difference between the electrodes, consisting of the flow signal and the signals not related to flow such as in-phase noise, flux differential noise (quadrature phase noise), common mode noise.
 - 1) **signal electromotive force** Voltage proportional to the flow-rate between the electrodes.
 - 2) **in-phase noise** Electrode voltage component which is the same phase as the flow signal but does not vary with the flowrate.
 - 3) **flux differential noise** That part of the electrode voltage which is 90° out of phase with the flowrate signal. In the commercial frequency excitation, it is called quadrature phase noise.

- 4) **common mode noise** Voltage which exists equally between each electrode and a reference potential.
- g) **output signal** Signal proportional to the flow-rate and transmitted from the converter.
- h) **detector constant** Signal electromotive force when making the exciting current constant at the flow velocity 1 m/s or the constant inherent to the detector corresponding to the exciting current generating a constant electromotive force.
- i) **full-scale flowrate** Flow-rate corresponding to the maximum output signal.
- j) **full-scale flow velocity** Flow-velocity corresponding to the maximum output signal.
- k) **precision rating** Limit of error allowed in accordance with the type of electromagnetic flowmeters under the standard operational conditions.

4 Principle of measurement

4.1 General When a liquid moves in a magnetic field, electromotive forces are generated in accordance with Faraday's law (see Fig. 1). If the field is perpendicular to an electrically-insulated pipe which contains the moving liquid and if the electrical conductivity of the liquid is not too low, a voltage may be measured between two electrodes on the wall of the pipe. This voltage is proportional to the magnetic flux density, the average velocity of the liquid and the distance between the electrodes. Thus the velocity and hence the flow-rate of the liquid may be measured.

4.2 Quantity symbols and units Quantity symbols and units shall be as follows:

Quantity symbol	Physical quantity	Unit
B	Magnetic flux density	T
D	Inside diameter of meter tube	m
$\bar{v}$	Mean axial liquid velocity	m/s
E	Signal electromotive force	V
k	Constant	—
Q	Volume flow-rate	m ³ /s

4.3 Basic equation In accordance with Faraday's law, the strength of the induced voltage is given by the following equation.

$$E = kBD\bar{v} \dots\dots\dots (1)$$

The volume flow-rate in the case of a circular meter tube is

$$Q = \frac{\pi D^2}{4} \cdot \bar{v} \dots\dots\dots (2)$$

This equation is combined with the equation (1) resulting in the following equation (3);

$$Q = \frac{\pi D}{4kB} \cdot E \dots\dots\dots (3)$$

If the magnetic flux density is made constant, the flow-rate in the pipe is obtained by measuring the signal electromotive force.

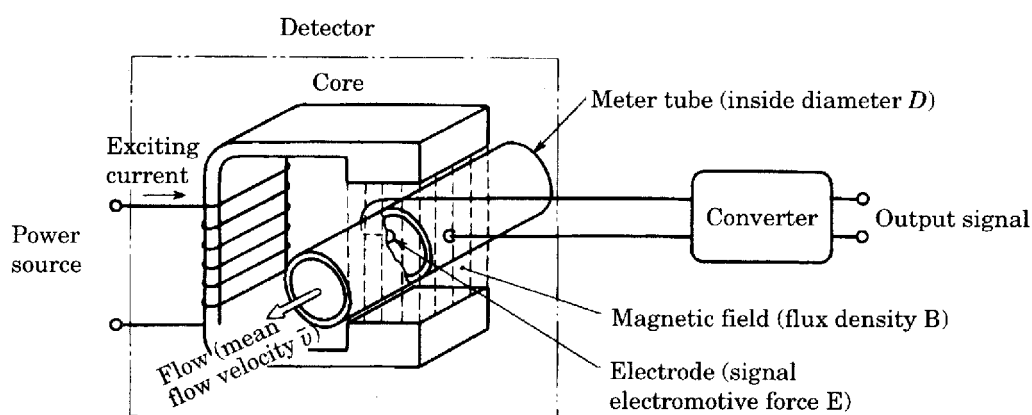


Fig. 1 Principle of measurement

5 Construction and function

5.1 Basic construction The flowmeters are classified into two types of separate type and one-body type as shown in Fig. 2 according to the construction of detector and converter. The separate type is that the detector and the converter are set separately and a cable the length of which is restricted by the conductivity of the liquid to be metered contacts between them. The one-body type is that the detector and converter are set as an unified body. In the flowmeter of this type, the range of working temperature is limited with respect to the liquid temperature and ambient temperature compared with the separate type.

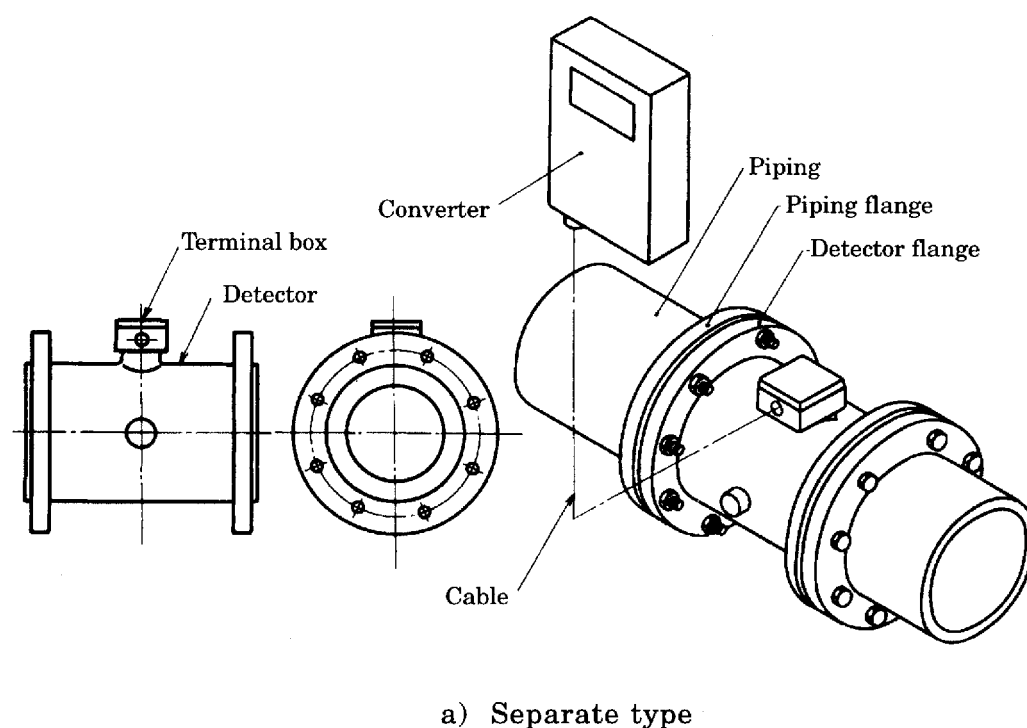
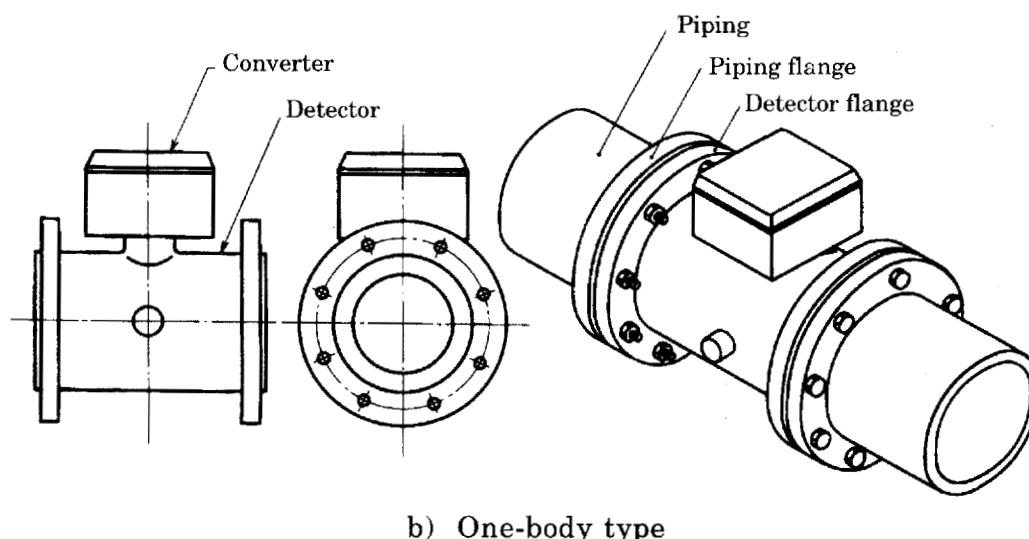


Fig. 2 Combination of detector and converter



b) One-body type

Fig. 2 Combination of detector and converter (concluded)

5.2 Construction and function of detector

5.2.1 Name and function of main parts The name and function of the main parts of the flowmeter shall be as follows (see Fig. 3).

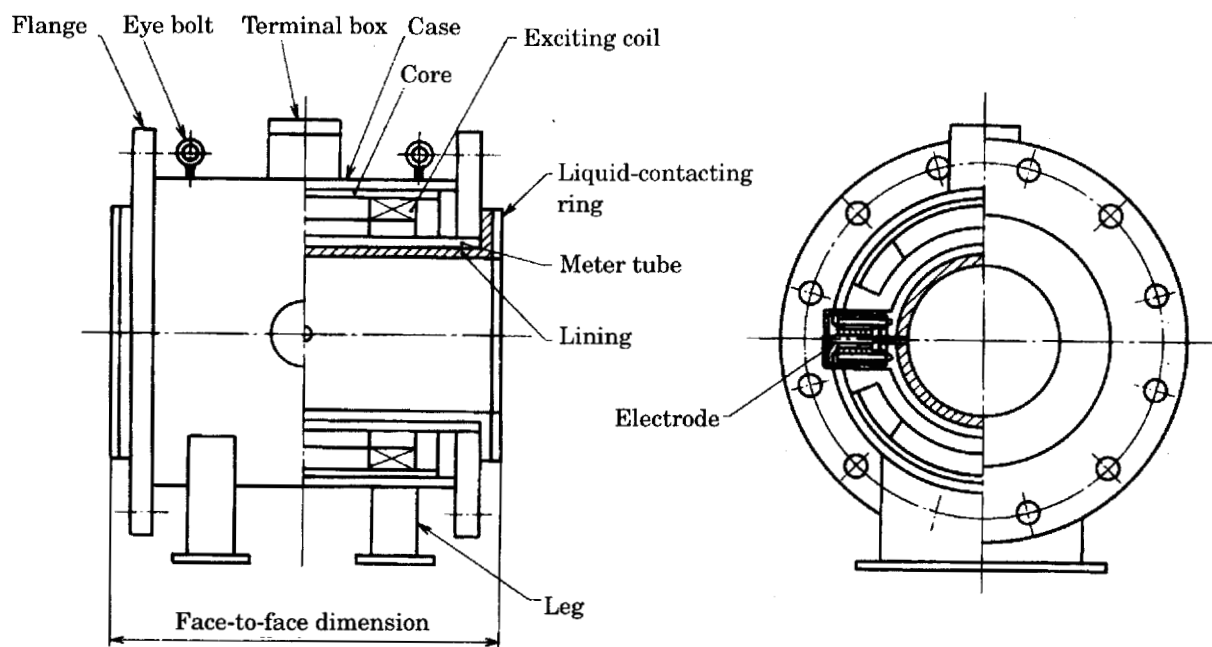


Fig. 3 Example of constructional layout of detector

- a) **Case** Preventing the exciting coil, core, electrode lead line, etc. in the detector from mechanical damage and protecting them from the ambient environment. It shall have mechanically sufficient strength and be of the construction to prevent the entrance of water, dust, etc. and the damage of internal part and endure the ambient atmosphere of setting place.

- b) **Meter tube** It shall be of the construction forming a conduit to flow the liquid to be measured and enduring mechanically the liquid pressure.
- c) **Lining** Insulation lined in the meter tube to prevent the signal electromotive force from electrical short circuit. The material for lining which contacts with the liquid to be measured shall endure fully abrasion and corrosion. The materials are shown in Table 1.

In addition, the lining has the upper limit of liquid temperature according to the materials used.

- d) **Electrode** It is mounted on the wall of the meter tube to take out the electrode voltage. The materials for electrode shall endure fully the abrasion and corrosion by the liquid to be measured. The materials are shown in Table 1.
- e) **Liquid-contacting ring** The detector and the liquid to be measured shall be brought to equipotential. It may play a role to protect the lining on the flange surface. The material shall be endure fully abrasion and corrosion. They are shown in Table 1.
- f) **Exciting coil and core** They make the magnetic flux density proportional to the exciting current from the converter within the meter tube.

Table 1 Materials used for liquid-contacting part

Appellation	Material
Lining	Fluorocarbon resin PTFE (Poly tetra fluoro ethylene) PFA (Per fluoro alkoxyether) FEP (Fluorinated ethylene propylene) Chloroprene rubber Polyurethane rubber Ceramics
Electrode	Stainless steel, SUS316, SUS316L (specified in JIS G 4303) Platinum (Pt) Platinum-iridium (Pt-Ir) Tantalum (Ta) (specified in JIS H 4701) Titanium (Ti) (specified in JIS H 4650) Hastelloy B and hastelloy C (specified in JIS H 4553) Monel (specified in JIS H 4553)
Liquid-contacting ring	Rolled steel for general structure SS400 (specified in JIS G 3101) Stainless steel SUS 304, SUS316, SUS 316L (specified in JIS G 4303) Platinum (Pt) Platinum-iridium (Pt-Ir) Tantalum (Ta) (specified in JIS H 4701) Titanium (Ti) (specified in JIS H 4650) Hastelloy B and hastelloy C (specified in JIS H 4553) Monel (specified in JIS H 4553) Conductive fluorocarbon resin

5.2.2 Use The use and construction of the flowmeter shall be as shown in Table 2.

Table 2 Use and construction

Classification	Use	Construction
General use	Used under ordinary service circumstances (including measurement of flowrate of drainage)	As specified in JIS C 0920
Sanitary use	Used under ordinary service circumstances and used for service related to foods	The materials not harmful in food sanitation shall be used and there shall be no residue on the liquid-contacting part.
For explosion proof	Used in explosive atmosphere	As specified in JIS C 0903
For use in water	Used in submerged condition	Under water type specified in JIS C 0920

5.2.3 Piping coupling The classification of the system for coupling the flowmeter with piping shall be as shown in Table 3.

Table 3 Coupling system

Classification	Composition
Flange connection system	System connecting the flange of the detector with the flange of piping [Fig. 4 a)]
Flange insertion system	System inserting the detector without flange into the flange pipe of piping [Fig. 4 b)]
Sanitary coupling system	System connecting the detector with IDF ⁽²⁾ clamp with the wiring with IDF clamp using the clamp used only for its purpose [Fig. 4 c)]
Screw connection system	System connecting the detector with screw threads with the piping with screw threads by screwing in [Fig. 4 d)]

Note ⁽²⁾ International Dairy Farming Standards

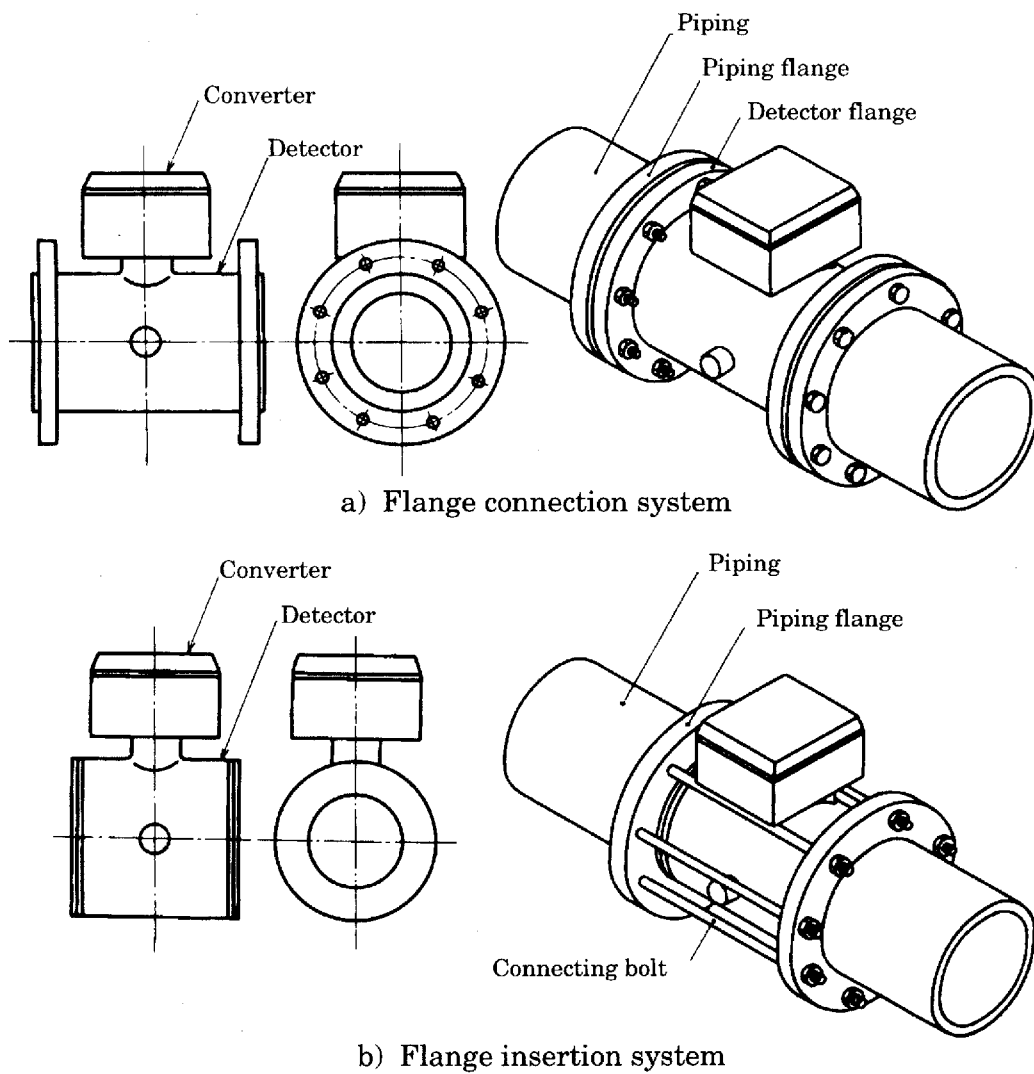


Fig. 4 Systems for coupling flowmeter

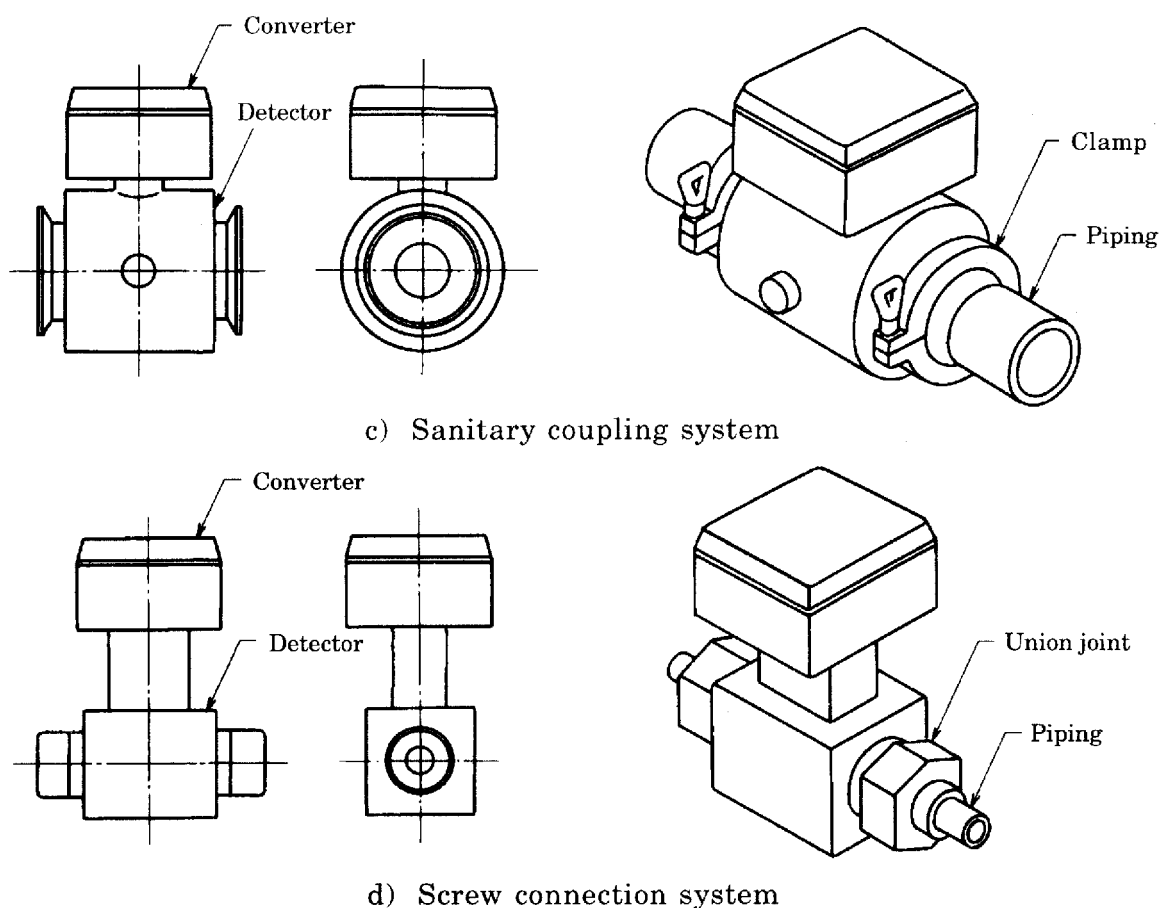


Fig. 4 Systems for coupling flowmeter

5.2.4 Bore The bore of the detector shall be as given in Table 4.

Table 4 Bore of detector

Unit: mm

Bore	Bore	Bore
10	300	1 350
15	350	1 500
20	400	1 600
25	500	1 800
40	600	2 000
50	700	2 200
80	800	2 400
100	900	2 600
150	1 000	
200	1 100	
250	1 200	

5.3 Composition and function of converter

5.3.1 Function Main function of the converter shall be as follows:

- a) to make the exciting current to flow into the coil of the detector;
- b) to amplify the signal electromotive force and convert to the display of output;
- c) to set up the full-scale flow-rate (or flow speed) and adjust the zero point;
- d) to remove the influence by in-phase noise, flux differential noise and common mode noise during the electrode voltage;
- e) to remove the influence by variation of the voltage and frequency of the power source;
- f) to remove the influence by variation of the magnetic field.

5.3.2 Composition The converter shall, in order to attain the function in 5.3.1, be composed as shown in the block diagram of Fig. 5.

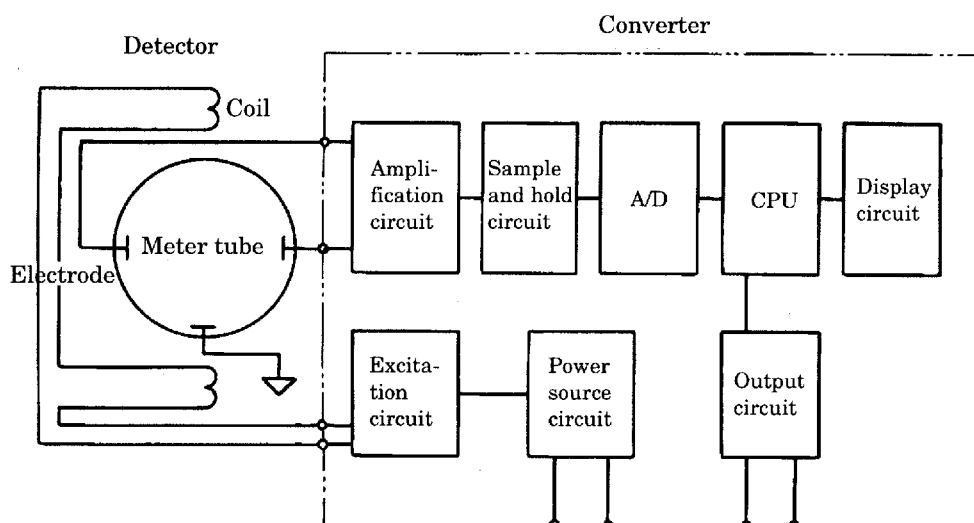
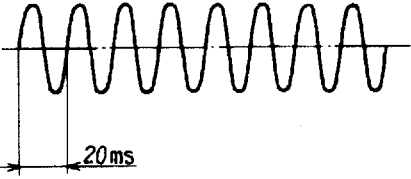
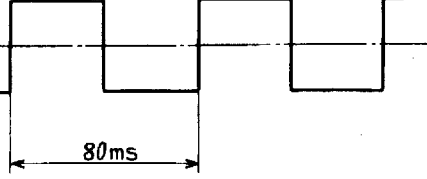


Fig. 5 Example of block diagram of converter

5.3.3 Excitation The excitation system for making the flow into the coil of the detector is in general the commercial frequency excitation and square-wave excitation. The example is shown in Table 5. The commercial frequency excitation system that the coil is directly excited by the commercial power source is excellent in responsiveness and hardly affected by the in-phase noise of low frequency. On the other hand, the square-wave excitation system that the coil of the detector is excited by the square form pulse equal to one of the fragments divided by even number of the commercial frequency is made by the converter which is excellent in the stability of zero point and capable of realizing the low power consumption because the sampling interval is adjusted to the cycle of commercial induction noise.

Table 5 Example of type of excitation system

Commercial frequency excitation	Square-wave excitation
 • Commercial frequency • Sine wave	 • Frequency of one of even number divisions of commercial frequency • Square wave

5.3.4 Output signal As the output signal of the converter, one or more can be selected from among the following signals:

- analog direct current signal;
- analog direct voltage signal;
- pulse signal in the form of scaled or unscaled;
- digital communication signal.

6 Performance test method The evaluation of the performance of this flowmeter shall be made in accordance with the method of performance test specified in Annex 1 or Annex 2. Annex 1 gives the test method in details and Annex 2 does the simple test method. These methods for performance test both apply to the case where the synthetic evaluation of flowmeters is the purpose and do not apply to the test method for general shipment inspection the manufacturer carries out.

7 Measurement error and flow-rate characteristic

7.1 Measurement error The measurement error of the electromagnetic flowmeters shall be expressed with the error in contrast to the indicated value (indicated value error) or the error to the full scale flow-rate (full scale error).

The error e to the indicated value is determined by the following formula:

$$e = \frac{I - Q}{Q} \times 100 (\%)$$

where, e : error to the indicated value

I : value indicated by the flowmeter

Q : actual flow-rate obtained by reference calibration instrument or reference calibration equipment

and the error e_F to the full scale flow-rate is expressed by the following formula:

$$e_F = \frac{I - Q}{I_{\max}} \times 100 (\%)$$

where, e_F : error to the full scale flow-rate

$I_{\max}$: full scale flow-rate of the flowmeter

7.2 flow-rate characteristic In the case of the actual flow calibration test in 6, the following flow-rate characteristic is defined. Taking the flow speed on the horizontal axis and the indicated value error on the vertical axis, and example of the measurement result is shown in Fig. 6.

The flow-rate characteristic of flowmeter is shown by the curve connecting the average values of the indicated value errors at each flow-rate measuring point. Even in the case of using the full scale error, it is desirable to obtain the flow-rate characteristic by converting to the indicated value error.

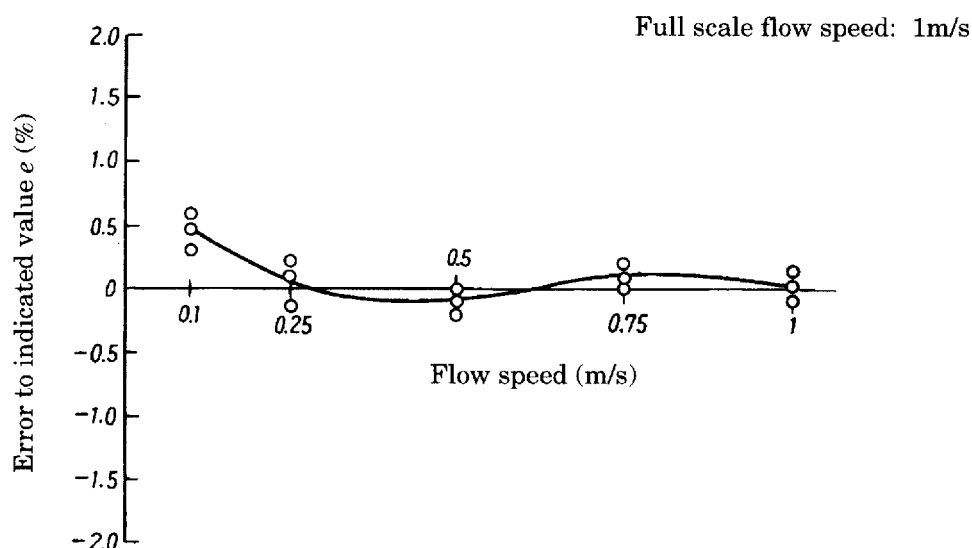


Fig. 6 Example of flow-rate characteristic

8 Inspection The inspection of the flowmeters shall be as follows:

- a) **Appearance** Appearance shall be inspected visually and conform to the specification in 5.2.1.
- b) **Dimension** Dimension shall be measured by means of vernier calipers, measuring type, etc. The dimension of main portion, i.g. between the faces, shall be done so in accordance with the designation of manufacturer.
- c) **Precision rating** Actual flow test shall be carried out and the result shall be in conformance with the specified precision rating. The full scale flow speed for carrying out the actual flow calibration inspection shall be the value the user designates or 2 m/s and the value of flow-rate be points at the neighbourhood of 0 %, 50 % and 100 % of it. For the flowmeters indicating the precision rating of the indicated value error down to the smaller value smaller than 50 %, the measurement shall be made at that flow-rate value.
- d) **Durability of detector against water pressure** When applying for 5 min either the water pressure of 1.5 times the maximum working pressure or of the maximum working pressure + 0.5 MPa which is larger, there shall be no leakage.
- e) **Insulating property** The value of insulation resistance between the power source terminal and the earthing terminals shall be not less than 10 MΩ.
- f) **Construction** The conformity with the specification in 5.2.1 shall be confirmed visually.

- g) **Package** The flowmeters which passed the inspection should be packaged appropriately with vinyl bag, cover, wooden frame, etc. to prevent the lining, electrode and connecting surface of piping taking the conditions of transportation and storage into consideration.

9 Marking The following information shall be marked on a place easy to be seen on the flowmeter.

a) **Detector**

- 1) type and serial number designated by manufacturer;
- 2) rated pressure and temperature;
- 3) power source: voltage, frequency, electric power (in the case where the power source is supplied independently to the detector or the case of one-body type);

On the detector, the following matters should be preferably marked;

- 4) grade of protective construction;
- 5) nominal bore;
- 6) quality of material of lining;
- 7) quality of material of electrode;
- 8) direction of flow;
- 9) constant of detector;
- 10) mass.

b) **Converter**

- 1) type and serial number designated by manufacturer;
- 2) power source: voltage, frequency and electric power;
- 3) output signal;
- 4) limited load impedance.

In the case of the one-body type flowmeters, in addition to the marking item of a), 3) and 4) in b) shall be marked.

10 Selection Flowmeter shall be selected taking the following general items into account in compliance with the working conditions.

- a) **Full scale flow-rate** Select the full scale flow-rate so as not to be lower than the maximum value of expected flow-rate. The service flow-rate is desirable to exceed 50 % of the full scale flow-rate.
- b) **Bore** Select in general the flowmeter of the same bore as the conduit. Moreover, it is preferable to change the bore where appropriate taking the following conditions into account.
- 1) **Abrasion** Make the flow speed smaller if liable to be abraded.
 - 2) **Adhesion of precipitate and foreign substance** When likely to generate accumulation of deposit and adhesion of foreign substance, make the flow speed larger.