FV-500
VORTEX FLOWMETERS

Operator's Manual

OMEGA
ENGINEERING, INC.
An OMEGA Group Company

WARRANTY

OMEGA warrants this unit to be free of defects in materials and workmanship and to give satisfactory service for a period of 13 months from date of purchase. OMEGA Warranty adds an additional one (1) month grace period to the normal one (1) year product warranty to cover handling and shipping time. This ensures that our customers receive maximum coverage on each product. If the unit should malfunction, it must be returned to the factory for evaluation. Our Customer Service Department will issue an Authorized Return (AR) number immediately upon phone or written request. Upon examination by OMEGA, if the unit is found to be defective it will be repaired or replaced at no charge. However, this WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive current, heat, moisture, vibration, or misuse. Components which wear or which are damaged by misuse are not warranted. These include contact points, fuses, and triacs.

THERE ARE NO WARRANTIES EXCEPT AS STATED HEREIN. THERE ARE NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND OF FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL OMEGA ENGINEERING, INC. BE LIABLE FOR CONSEQUENTIAL, INCIDENTAL OR SPECIAL DAMAGES. THE BUYER'S SOLE REMEDY FOR ANY BREACH OF THIS AGREEMENT BY OMEGA ENGINEERING, INC. OR ANY BREACH OF ANY WARRANTY BY OMEGA ENGINEERING, INC. SHALL NOT EXCEED THE PURCHASE PRICE PAID BY THE PURCHASER TO OMEGA ENGINEERING, INC. FOR THE UNIT OR UNITS OR EQUIPMENT DIRECTLY AFFECTED BY SUCH BREACH.

Return Requests/Inquiries

Direct all warranty and repair requests/inquiries to OMEGA Customer Service Department, telephone number (203) 359-1660. Before returning any instrument, please contact the OMEGA Customer Service Department to obtain an authorized return (AR) number. The designated AR number should then be marked on the outside of the return package.

To avoid processing delays, also please be sure to include:

1. Returnee's name, address, and phone number.
2. Model and Serial numbers.
3. Repair instructions.

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1. HANDLING CAUTIONS.

The OMEGA® FV-500 Series Vortex Flowmeter and remote flow converters are thoroughly tested at the factory before shipment. When these instruments are delivered, perform a visual check to ascertain that no damage occurred during shipment.

This section describes important cautions in handling these instruments. Read carefully before using them.

If you have any problems or questions, contact OMEGA Engineering Customer Service Department at (203) 359-1660.

1-1. Model Type and Specifications.

The model type and important specifications are indicated on the data plate attached to the case. Verify that they are the same as those specified in the original order, referring to paragraph 2.2. In any correspondence, always give model (MODEL), serial number (NO) and calibrated range (RANGE) from the data plate.

1-2. Transportation Cautions.

To avoid damage, the vortex flowmeter should be unpacked only after arriving at the customer's site.

1-3. Storage Cautions.

To avoid deterioration of insulation in the vortex converter amplifier, corrosion of metal parts, etc., the instrument should be installed soon after it is delivered. If the instrument is stored, observe the following:

(1) Where possible, store the vortex flowmeter without unpacking.

(2) Select a storage area that is
- protected against precipitation and moisture.
- relatively free from mechanical vibration or impact shock.
- at a temperature between −40 to 80°C(−40 to 176°F), preferably around 25°C (77°F).
- at a humidity 5 to 100%, preferably near 50%.

(3) Before storing a used vortex flowmeter, completely remove fluid from the flowmeter pipe and sensor assembly.

(4) If the instrument is stored outdoors, its performance may be affected. The flowmeter should be installed as soon as it is delivered to the installation site.

1-4. Installation Area Selection.

The vortex flowmeter is designed to operate under even severe conditions. However, to ensure its stable and accurate operation for many years, the following cautions must be observed in selecting an installation area.

(1) Ambient temperature.
Avoid an area which has wide temperature variations. When the installation area is subjected to heat radiation from process plant, ensure adequate heat prevention or ventilation.

(2) Ambient air.
Avoid installing the vortex flowmeter in a corrosive atmosphere. When the vortex flowmeter must be installed in a corrosive atmosphere, adequate ventilation must be provided.

(3) Mechanical vibration and impact.
The vortex flowmeter is of sturdy construction, but select an area subject to minimum mechanical vibration or impact shock. If the flowmeter is subject to vibrations, provide pipeline supports as shown in Figure 1-1.

(4) Other.
Provide sufficient room around the vortex flowmeter for:
- periodic maintenance.
- ease of wiring and piping.

1-5. Piping Connection.

(1) Verify that the process connector bolts are tightened firmly.
(2) Verify that no leak exists in the process connection pipeline.
(3) Do not apply a pressure higher than the specified maximum working pressure.
(4) Do not loosen or tighten the flange mounting bolts when the assembly is pressurized.
(5) Handle the vortex flowmeter carefully when measuring dangerous liquids, so that the liquids do not splash into eyes or on face. When using dangerous gases, be careful not to inhale them.

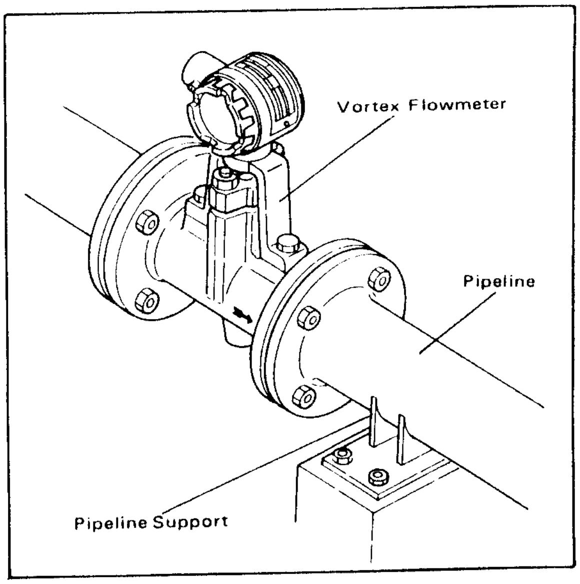


Figure 1-1. Recommended Pipeline Support.

2. GENERAL.

2-1. Outline.

The FV-500-R Series Vortex Flowmeter is used with the remote flow converter.

This vortex flowmeter measures liquid, gas and steam flow rates and converts them to a 4 to 20 mA DC output or pulse output signal. A special cable is used between these instruments.

Since the converter is mounted independently from the flowmeter, it permits remote flow measurements of high temperature liquid, steam, etc.

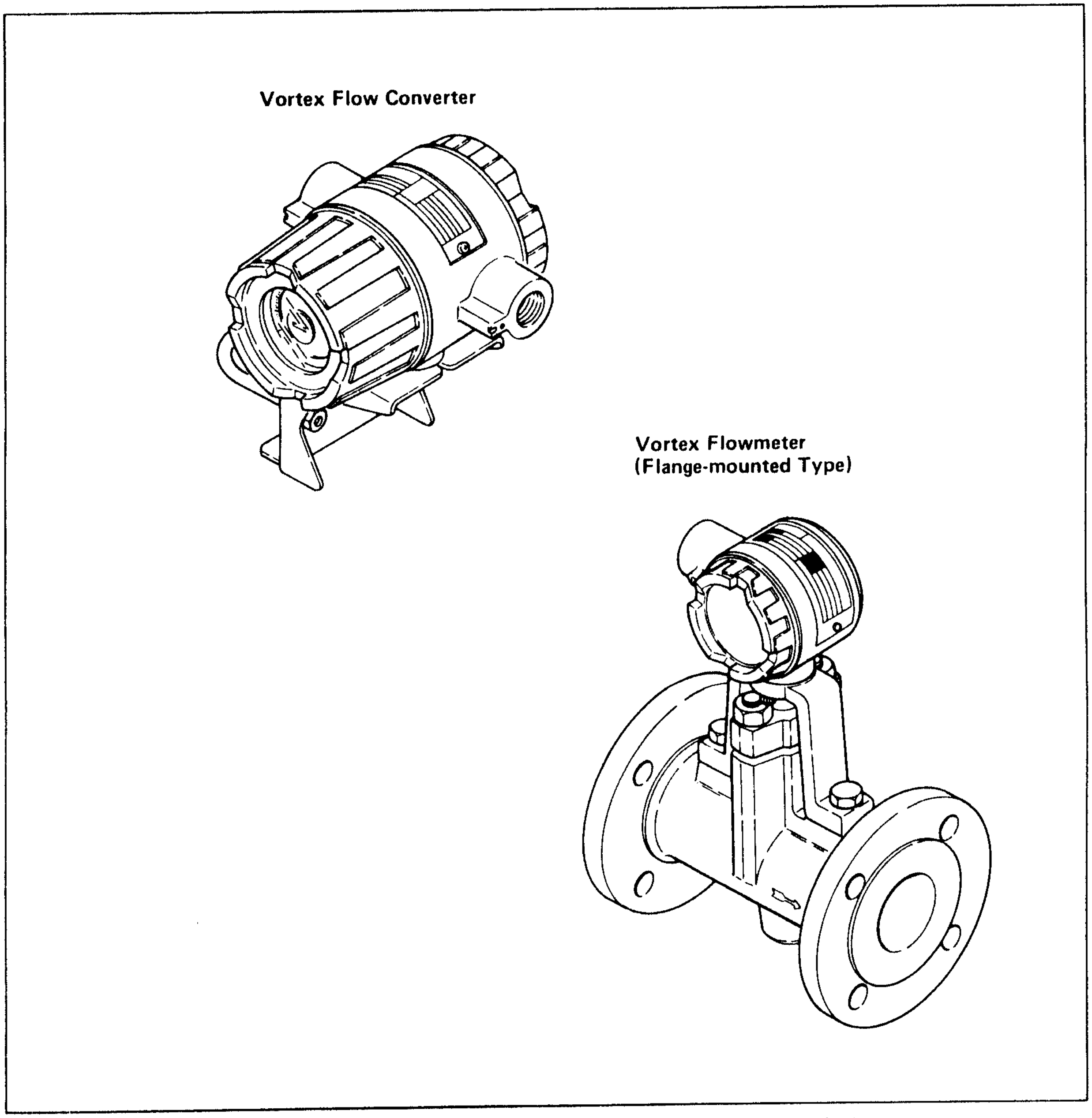


Figure 2-1. Vortex Flowmeter and Vortex Flow Converter – External Views.

2-2. Specifications.

- **FV-500 Series Vortex Flowmeter.**

Fluid to be Measured: Liquid, Gas or Steam.

Linear Flow Rates: Reynolds number of 20000 to 7000000 (40000 to 7000000 for 6- and 8-inch flowmeter). The relationship between the flow velocity and kinematic viscosity is shown in Figure 5-1. The relationship between the minimum measurable flow rate and specific weight is shown in Figure 5-2.
If the flow rate corresponds to a Reynolds number between 5×10^3 and 7×10^6, refer to section 6-2.

Accuracy:
Analog output; ±0.8% of reading plus ±0.1% of full scale for liquid service. ±1.5% of reading plus ±0.1% of full scale for gas or steam service.
Pulse output; ±0.8% of reading for liquid service. ±1.5% of reading for gas or steam service.

Ambient Temperature Limits: −40 to 80°C (−40 to 176°F).

Process Temperature Limits: −40 to 300°C (−40 to 572°F).

Ambient Humidity Limits: 5 to 100% RH.

Process Pressure Limits: Less than flange ratings.

Enclosure Classification: NEMA Protection Type 4 Watertight and Dust-tight.

Electrical Classification: Dust-ignitionproof Class II, Groups E, F & G, Division 1 & 2. Suitable for Class III, Division 1 & 2. Temperature range T6.
Dust-ignitionproof Class II, Groups E, F & G, Division 1 & 2. Suitable for Class III, Division 1 & 2. Temperature Range T6.

Electrical Connection: ANSI ½NPT Female.

Wetted Parts Materials:
Body; ASTM A296 Grade CF8M (AISI 316) stainless steel or ASTM A216 Grade WCC carbon steel.
Vortex Shedder; AISI 329 stainless steel.

Terminal Box: Aluminum casting, finished with polyurethane paint. Deep green (Munsel 5.0 GY 3.6/1.3).

Weight: See external dimensions.

- **Remote Vortex Flow Converter.**

Input Signal: Signal from a remote converter type flowmeter.

Output Signal:
Analog output: 4 to 20 mA DC.
Pulse output:
Low level; 0 to 1 V.
High level; Vs (input supply voltage) −2 V.
Pulse rise time; Determined by the load capacitance (25 μs with 10000 pF).
Pulse width; Approx. 50% duty cycle.
See Table 2-3 for the nominal pulse rate.

Span Setting: For analog outputs, a screw-type span adjustment allows span to be adjusted in the following ranges.
Liquid; 0-1.1 to 0-7 m/s or 0-3.7 to 0-23 ft/s. 0-1.5 to 0-7 m/s or 0-5 to 0-23 ft/s for 6- and 8-inch flowmeter.
Gas or steam; 0-11 to 0-75 m/s or 0-37 to 0-250 ft/s. 0-15 to 0.75 m/s or 0-50 to 0-250 ft/s for 8-inch flowmeter.

Ambient Temperature Limits: −40 to 80°C (−40 to 176°F).
With integral indicator option; −20 to 60°C (−4 to 140°F).

Ambient Humidity Limits: 5 to 100% RH.

Power Supply and Load Resistance:
Analog output: See Figure 4-1.
Pulse output: Supply voltage 12 to 30 V DC.
Allowable ripple; ±1.5 V or less for the Vs of 13.5 to 30 V DC.
Minimum load resistance; 10 kΩ.
Maximum load capacitance; 0.22μF.

Enclosure Classification: NEMA Protection Type 4 Watertight and Dust-tight.

Electrical Classification: Dust-ignitionproof Class II, Groups E, F & G, Division 1 & 2. Suitable for Class III, Division 1 & 2. Temperature Range T6.
Dust-ignitionproof Class II, Groups E, F & G, Division 1 & 2. Suitable for Class III, Division 1 & 2. Temperature Range T6.

Mounting: 2 inch pipe mounting.

Electrical Connection: ANSI ½NPT Female.

Converter Case: Aluminum casting, finished with polyurethane paint. Deep green (Munsel 5.0 GY 3.6/1.3).

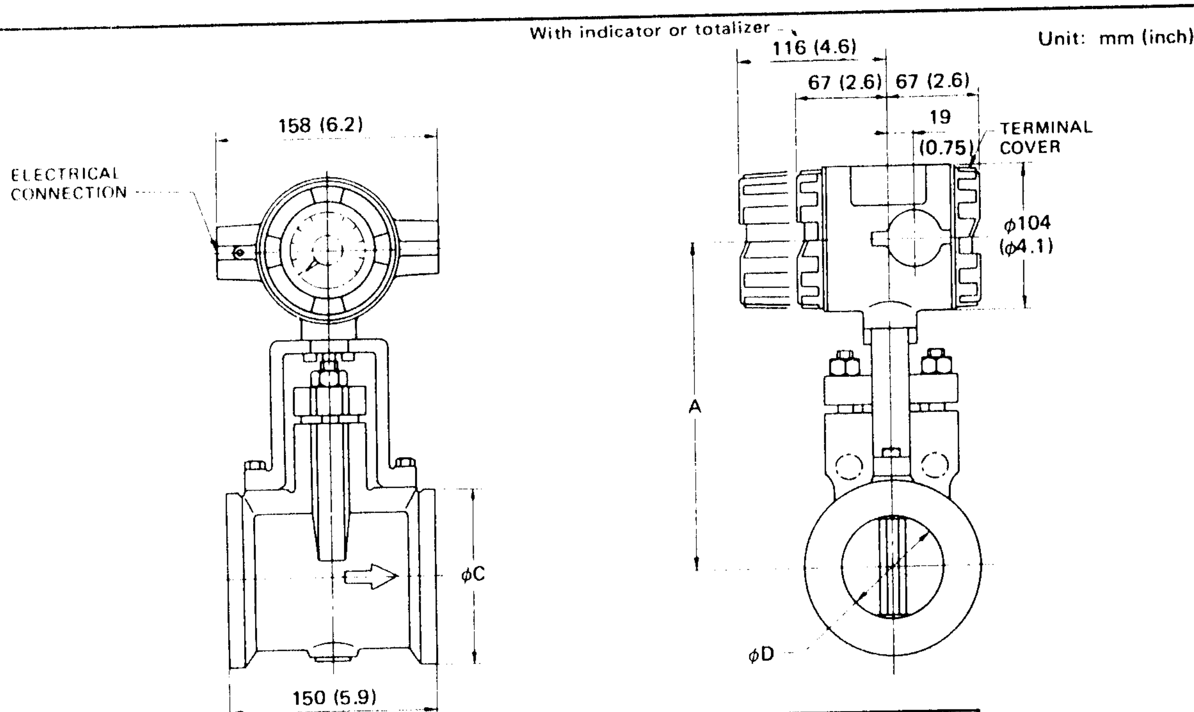
Weight: 2.6 kg (5.7 lb).

2-3. Options.

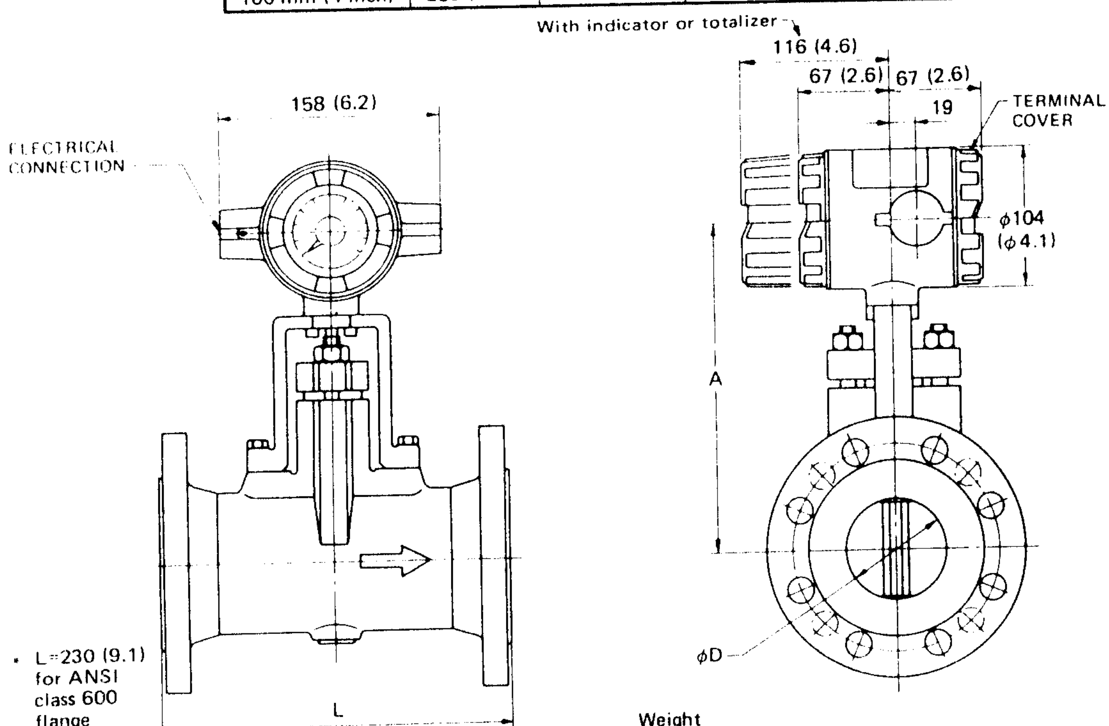
Analog Display (suffix M on model number)

Pulse Output (suffix P on model number)

2-4. External Dimensions.



Size	A	C	D	Weight
50 mm (2 inch)	221 (8.7)	92 (3.62)	51.1 (2.01)	7.4 kg (16 lb)
80 mm (3 inch)	238 (9.4)	127 (5.00)	71.0 (2.80)	12 kg (26 lb)
100 mm (4 inch)	253 (10)	157.2 (6.19)	93.8 (3.69)	15 kg (33 lb)



• L=230 (9.1) for ANSI class 600 flange

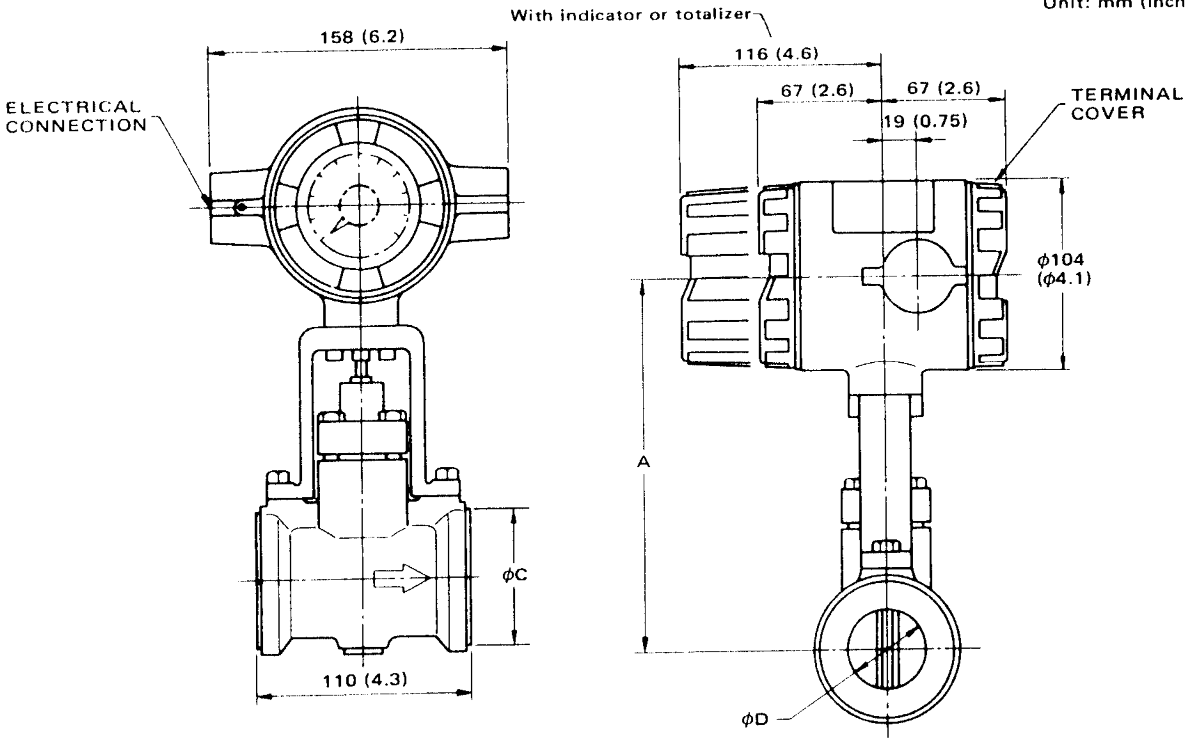
Size	A	D	L
2 inch	221 (8.7)	51.1 (2.01)	200 (7.9)*
3 inch	238 (9.4)	71.0 (2.80)	250 (9.8)
4 inch	253 (10)	93.8 (3.69)	260 (10.2)

Weight

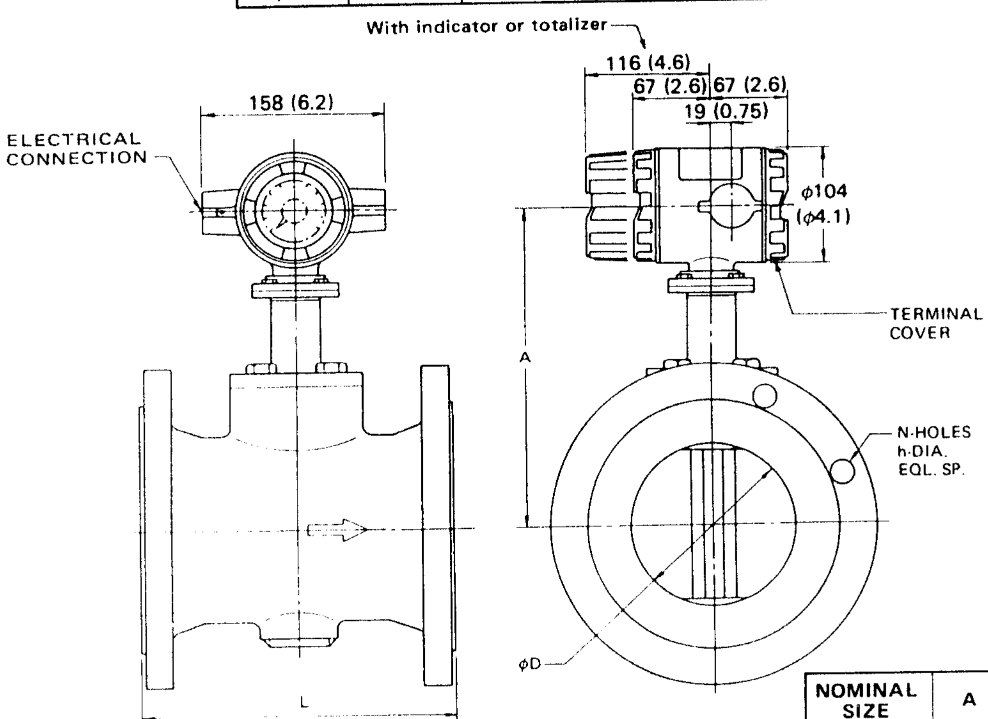
Size	Class 150	Class 300	Class 600
2 inch	12 kg (26 lb)	13 kg (29 lb)	15 kg (33 lb)
3 inch	21 kg (46 lb)	24 kg (53 lb)	28 kg (62 lb)
4 inch	30 kg (66 lb)	37 kg (81 lb)	52 kg (114 lb)

Figure 2-2. Vortex Flowmeter — External Dimensions.

Unit: mm (inch)



Size	A	C	D	Weight
1 inch	192 (7.6)	50.8 (2.00)	25.7 (1.01)	4.7 kg (10 lb)
1-1/2 inch	199 (7.8)	73 (2.87)	39.7 (1.56)	5.3 kg (12 lb)



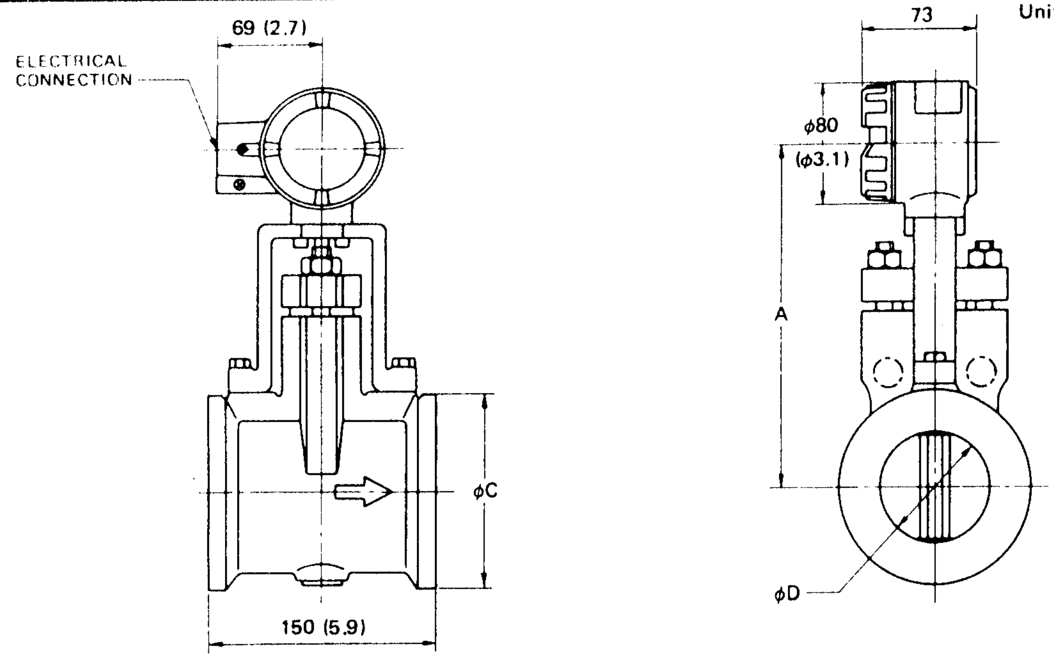
Weight

	Class 150	Class 300	Class 600
6 inch	37 kg (81 lb)	55 kg (120 lb)	85 kg (190 lb)
8 inch	56 kg (123 lb)	81 kg (179 lb)	—

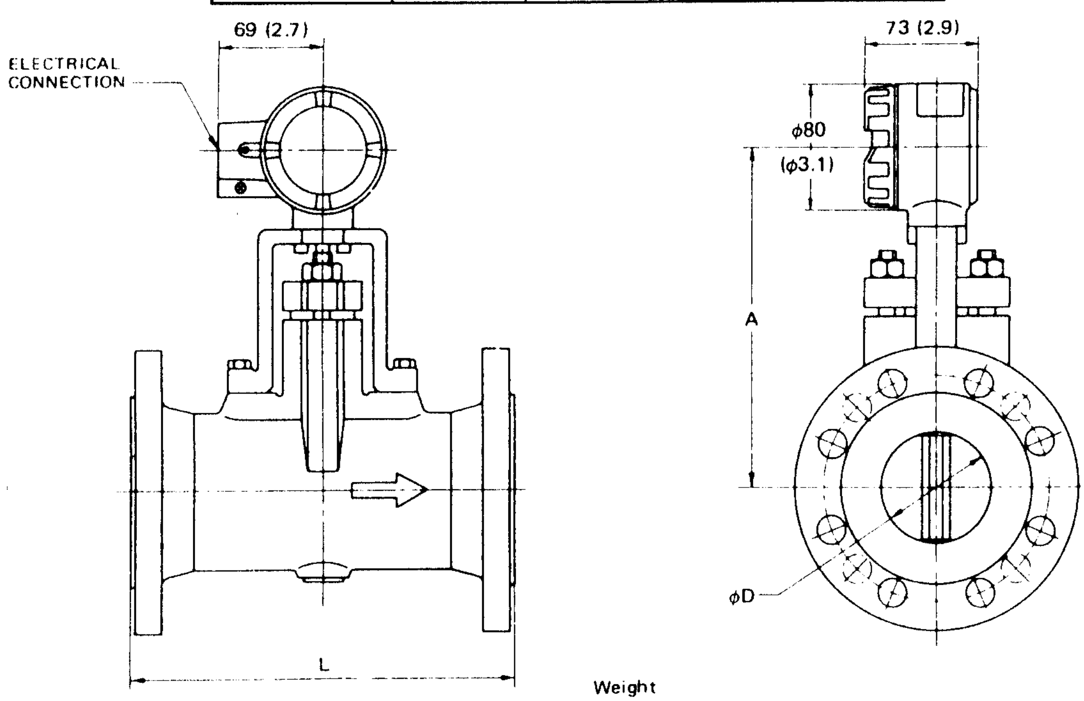
NOMINAL SIZE	A	φD	L
150 (6 in)	272 (10.7)	138.8 (5.46)	270* (10.6)
200 (8 in)	304 (12.0)	185.6 (7.31)	310 (12.2)

* L=310 (12.2) for ANSI Class 600 or JIS 40 kg/cm²

Figure 2-3. Vortex Flowmeter — External Dimensions.



Size	A	C	D	Weight
50 mm (2 inch)	209 (8.2)	92 (3.62)	51.1 (2.01)	6.4 kg (14 lb)
80 mm (3 inch)	226 (8.9)	127 (5.00)	71.0 (2.80)	11 kg (24 lb)
100 mm (4 inch)	241 (9.5)	157.2 (6.19)	93.8 (3.69)	14 kg (31 lb)



Size	A	D	L
2 inch	209 (8.2)	51.1 (2.01)	*200 (7.9)
3 inch	226 (8.9)	71.0 (2.80)	250 (9.8)
4 inch	241 (9.5)	93.8 (3.69)	260 (10.2)

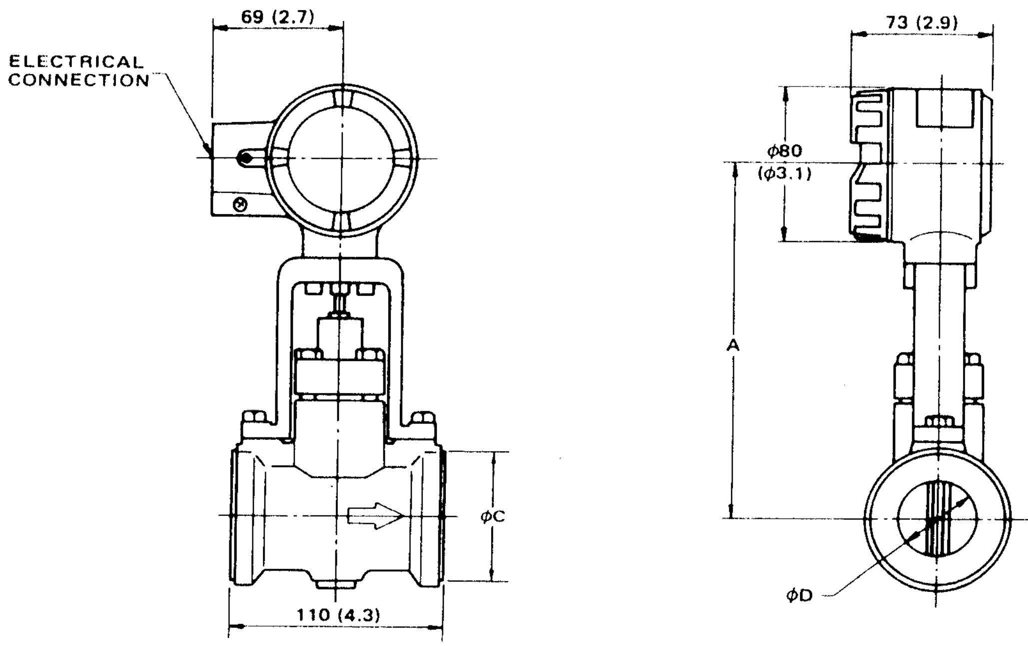
* L = 230 (9.1) for ANSI class 600 flange.

Weight

Size	Class 150	Class 300	Class 600
2 inch	11 kg (24 lb)	12 kg (26 lb)	14 kg (31 lb)
3 inch	20 kg (44 lb)	23 kg (51 lb)	27 kg (59 lb)
4 inch	29 kg (64 lb)	36 kg (79 lb)	51 kg (112 lb)

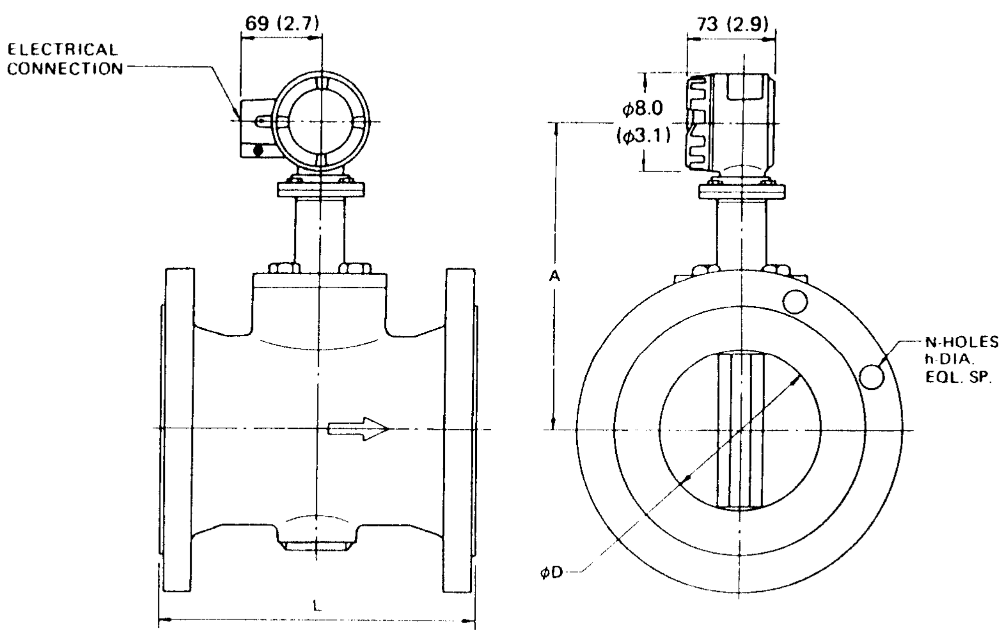
Figure 2-4. Vortex Flowmeter — External Dimensions.

Unit: mm (inch)



Size	A	C	D	Weight
1 inch	180 (7.1)	50.8 (2.00)	25.7 (1.01)	3.7 kg (8.1 lb)
1-1/2 inch	187 (7.4)	73 (2.87)	39.7 (1.56)	4.3 kg (9.5 lb)

UNIT: mm



Weight

	Class 150	Class 300	Class 600
6 inch	36 kg (79 lb)	54 kg (120 lb)	84 kg (180 lb)
8 inch	55 kg (121 lb)	80 kg (176 lb)	–

NOMINAL SIZE	A	ϕD	L
150 (6 in)	260 (10.2)	138.8 (5.46)	270* (10.6)
200 (8 in)	292 (11.5)	185.6 (7.31)	310 (12.2)

* L=310(12.2) for ANSI Class 600 or JIS 40 kg/cm²

Figure 2-5. Vortex Flowmeter — External Dimensions.

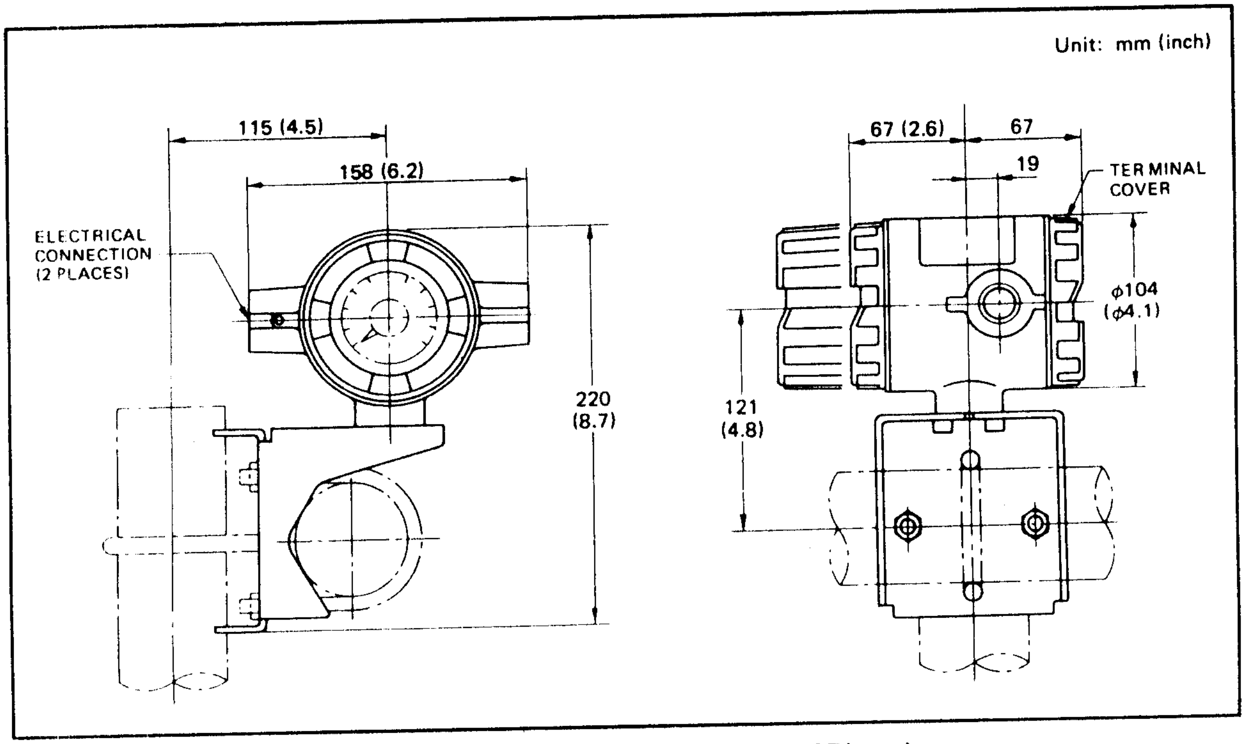


Figure 2-6. Vortex Flowmeter Converter — External Dimensions.

2.5 Description of Components.

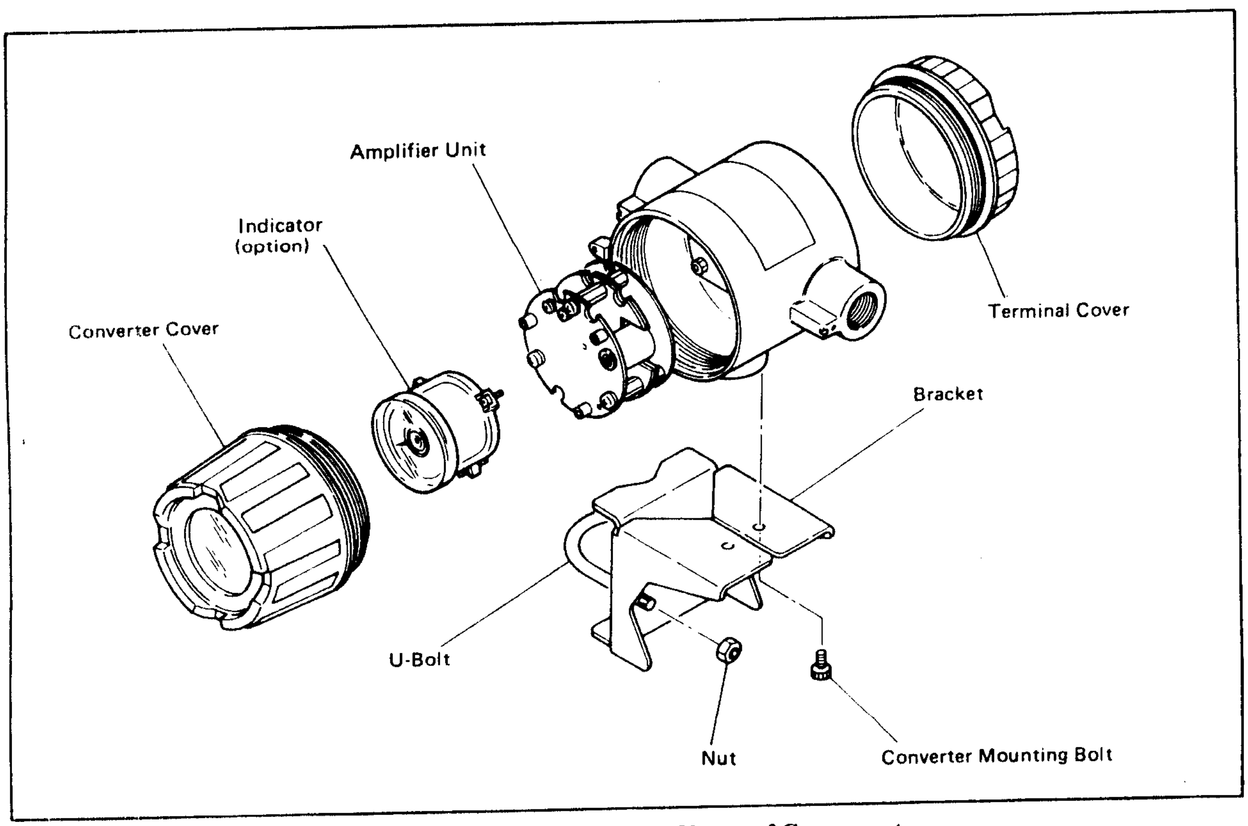


Figure 2-7. Vortex Flow Converter — Names of Components.

3. INSTALLATION.

When installing the vortex flowmeter, refer to paragraph 1-4, Installation Area Selection, and paragraph 2-2, Standard Specifications.

3-1. Piping.

(1) If a single elbow or reducer is installed in the upstream of the pipeline, provide a straight pipe 10 times as long as the inner pipe diameter upstream of the vortex flowmeter and five times as long as the inner pipe diameter downstream of the vortex flowmeter. If there is an elbow in the pipe, the flowmeter and vortex shedder should be in the same plane as the elbow.

(2) If a shut-off valve is located upstream of the flowmeter, provide a straight pipe – if possible more than 40* times as long as the pipe inside diameter – between it and the flowmeter.

* At least 20 times as long as the pipe inside diameter.

(3) The process pipeline inner diameter should be slightly larger than the vortex flowmeter inner diameter, Schedule 40 or lower pipes should be used for 1 to 2 inch flowmeters and schedule 80 or lower pipes for 3 to 8 inch flowmeters.

(4) The vortex flowmeter is of NEMA4 waterproof construction. However, it cannot be used under water.

(5) The flowmeter can be installed vertically, horizontally or at any other angle. However, for liquid measurement, the instrument pipe must be filled with the fluid. In a vertical flowmeter, fluid should flow upward.

(6) Pressure and Temperature Taps.
For pressure measurements (when required), locate the pressure tap 3.5 to 5.5 inner pipe diameters downstream of the vortex shedder.
For temperature measurements (when required), the temperature tap should be located on 6 to 8 inner pipe diameter downstream of the vortex shedder. See Figure 3-1.

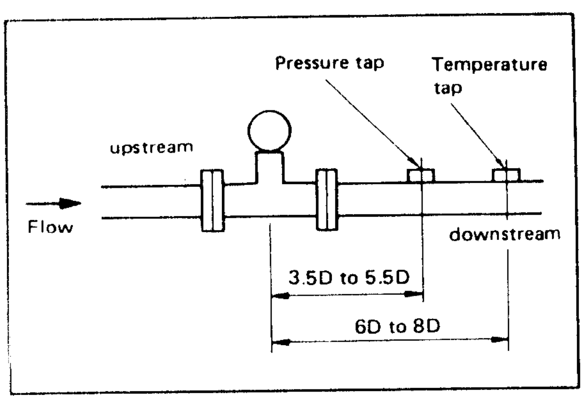


Figure 3-1. Pressure and Temperature Taps.

3-2. Installing the Vortex Flowmeter.

Before installing the instrument verify the following.

- The direction of flow should match the arrow mark on the instrument body. The instrument is shipped with arrow mark pointing from left to right, when viewed from terminal box cover. When changing the orientation of the terminal box, refer to Section 3-3.
- Before installing a number of flowmeters in one area, insure that they are correctly matched with their paired converters. The converters and flowmeters are matched with regard to serial numbers.

3-2-1. Installing Wafer Type Vortex Flowmeter.

When installing the wafer type vortex flowmeter, it is important to align the instrument bore with the inner diameter of the adjacent piping.

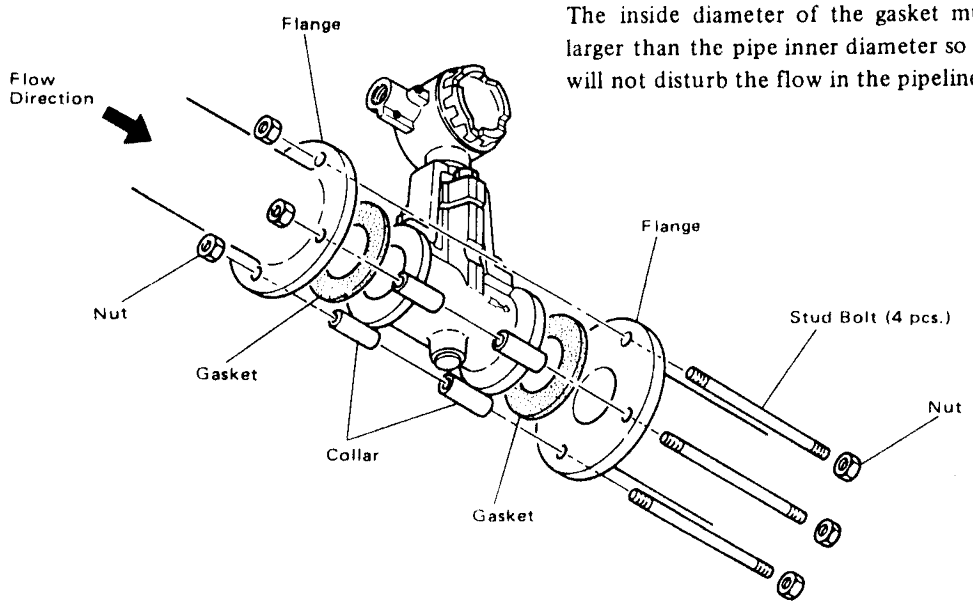
To establish alignment, use the four collars supplied with the instrument.

1. Four collars are supplied for ANSI Class 150 2-inch flanges or ANSI Class 150 3-inch flanges. Install the instrument as illustrated in Figure 3-2.
2. If the adjacent flanges have eight bolt holes, insert the stud bolts in the holes on the instrument shoulder. See Figure 3-3.
3. Two alignment plates are supplied for 1 inch flanges or 1-1/2 inch flanges. Install the instrument as illustrated in Figure 3-4.

Table 3-1. Recommended Stud Bolt Length for Wafer Type Vortex Flowmeters.

Nominal Size	Flange Rating	Stud Bolt Length mm (inch)
25 mm (1-inch)	ANSI Class 150	185 (7.3)
	ANSI Class 300, 600	200 (7.9)
40 mm (1-1/2 inch)	ANSI Class 150	190 (7.5)
	ANSI Class 300, 600	210 (8.3)
50 mm (2-inch)	ANSI Class 150	240 (9.5)
	ANSI Class 300, 600	250 (9.8)
80 mm (3-inch)	ANSI Class 150	250 (9.8)
	ANSI Class 300	270 (10.8)
	ANSI Class 600	270 (10.8)
100 mm (4-inch)	ANSI Class 150	255 (10)
	ANSI Class 300	270 (10.8)
	ANSI Class 600	290 (11.5)

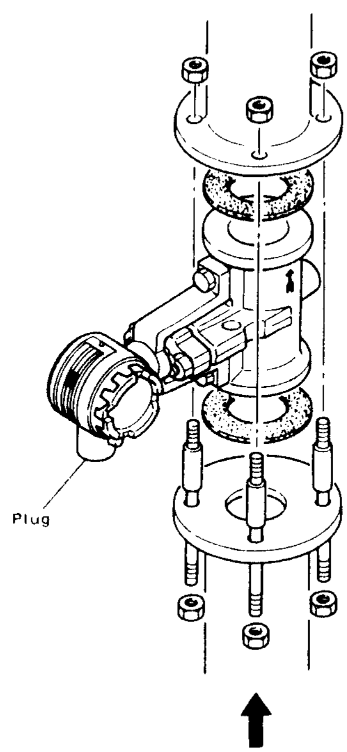
(A) Horizontal Installation



CAUTION

The inside diameter of the gasket must be larger than the pipe inner diameter so that it will not disturb the flow in the pipeline.

(B) Vertical Installation



The installation of vortex flowmeters applies to the following line sizes and flange ratings.

Nominal Size	Flange Rating
50 mm (2-inch)	ANSI Class 150
80 mm (3-inch)	ANSI Class 150

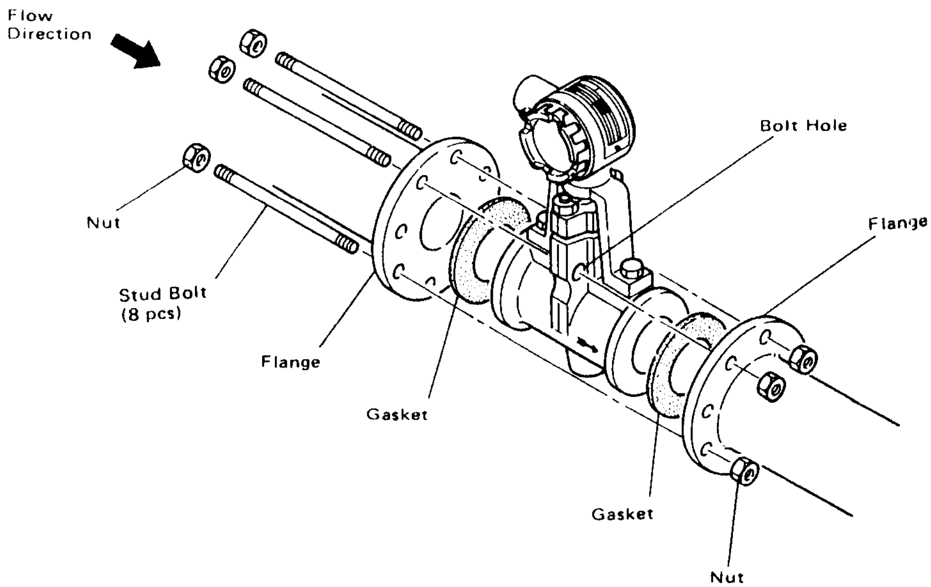
Four collars are supplied with the flowmeter to properly align the flowmeter bore with the inner diameter of the adjacent piping. These collars establish a predetermined spacing between the mounting bolts and the outside diameter of the flowmeter body. It is necessary that the bolts be of the proper diameter to establish alignment.

- **Installing the flowmeter horizontally.**
  Insert two each collars on each of the lower two bolts. Place the flowmeter body on the lower two bolts. See Figure (A). Tighten the four bolts (including upper two bolts) and nuts uniformly. Check for leakage from the flange connections.

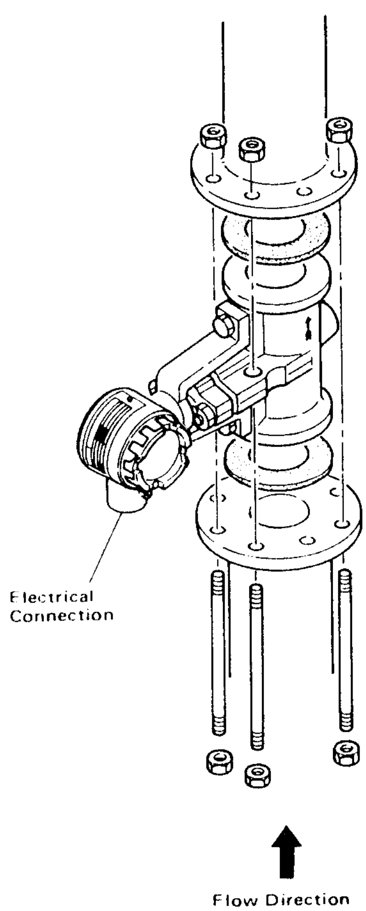
- **Installing the flowmeter vertically.**
  Insert four collars on each of the four bolts and check that all four collars contact the outside diameter of the flowmeter body. See Figure (B). Tighten the four bolts uniformly. Check for leakage from the flange connections.

Figure 3-2. Wafer Type Vortex Flowmeter Installation – 1.

(A) Horizontal Installation



(B) Vertical Installation



CAUTION

The inside diameter of the gasket must be larger than the pipe inner diameter so that it will not disturb the flow in the pipeline.

These installation examples apply to the flange rating listed below.

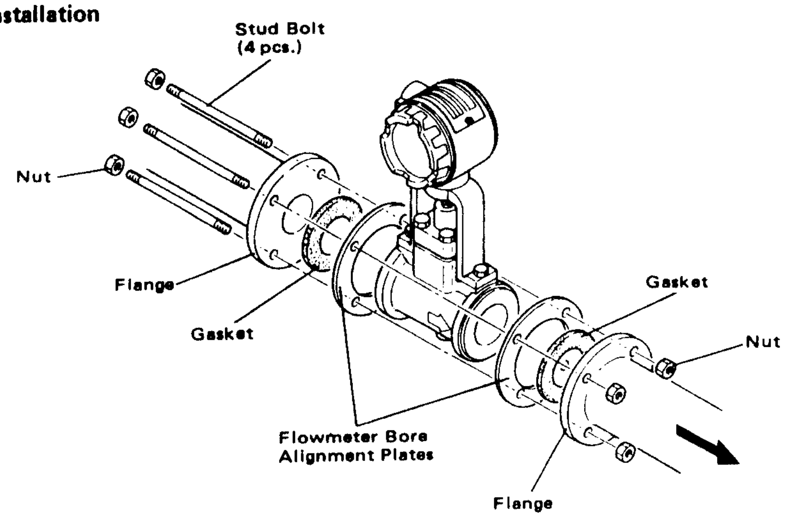
Nominal Size	Flange Rating
50 mm (2-inch)	ANSI Class 300, 600
80 mm (3-inch)	ANSI Class 300, 600
100 mm (4-inch)	ANSI Class 150, 300, 600

The following notes apply to both horizontal and vertical installations.

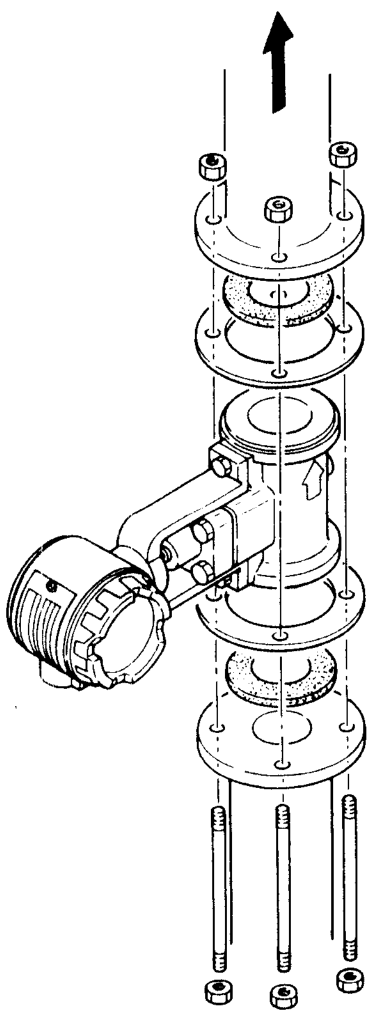
- Insert two stud bolts in the bolt holes on the flowmeter shoulder to align the instrument body with the inner diameter of the adjacent piping.
- Tighten all bolts uniformly and check that there is no leakage between the instrument and the flanges.

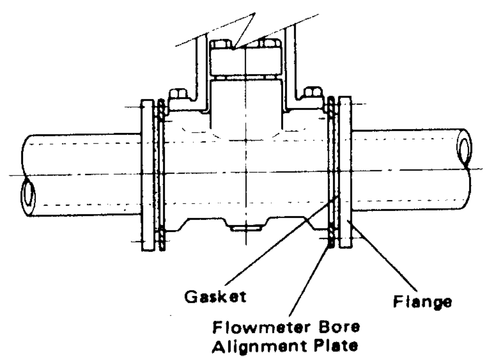
Figure 3-3. Wafer Type Vortex Flowmeter Installation – 2.

(A) Horizontal Installation



(B) Vertical Installation





The installation applies to the following line sizes.

Nominal Size
25 mm (1-inch)
40 mm (1-1/2-inch)

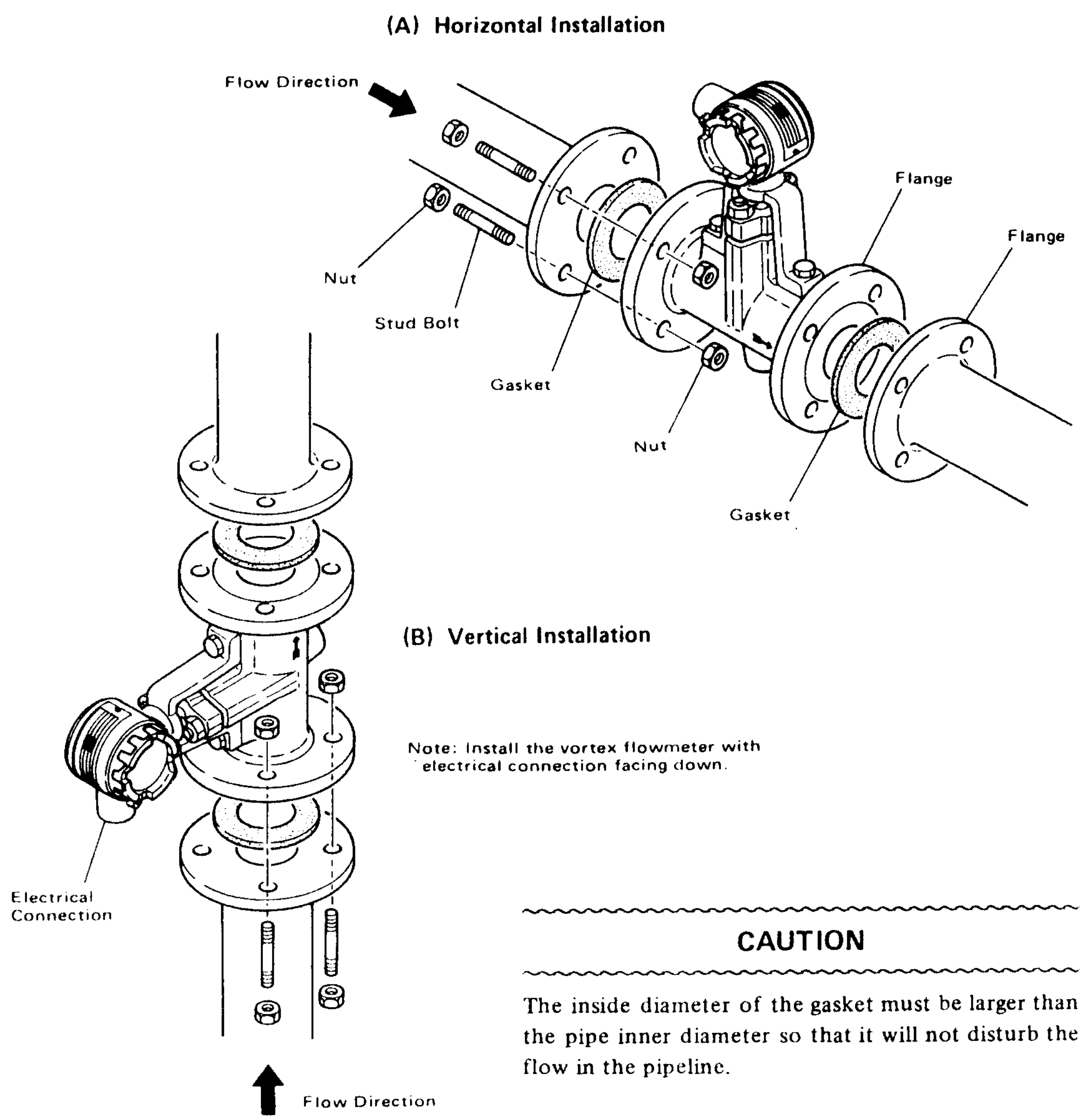
The following notes apply to both horizontal and vertical installation.

- Two flowmeter bore alignment plates are supplied with the vortex flowmeter. Insert these plates between the raised faces of the flowmeter and the process flanges as illustrated.
- Adjust the bore alignment plates around the periphery so that the centers of the plates coincide with those of the flanges before tightening the bolts.
  Tighten the bolts uniformly. The gasket bore must be slightly larger than the flowmeter bore and inside diameter of the adjacent process piping. (If the gasket bore is smaller, it will disturb the measurement accuracy.)
- After tightening the bolts, confirm that there is no leakage from the flowmeter connections.

Figure 3-4. Wafer Type Vortex Flowmeter Installation – 3.

3-2-2. Installing the Flanged Vortex Flowmeter.

Install the flowmeter as illustrated in Figure 3-5.



CAUTION

The inside diameter of the gasket must be larger than the pipe inner diameter so that it will not disturb the flow in the pipeline.

Figure 3-5. Flanged Vortex Flowmeter Installation.

3-3. Changing the Terminal Box Orientation.

The terminal box can be changed in four directions with respect to the flow direction. See Figure 3-6.

(1) Remove the terminal box cover.
(2) Disconnect the vortex shedder assembly leadwires from the terminal board.
(3) Remove the bracket mounting bolts and remove the terminal box and bracket from the flowmeter body. The bracket applies to the 1 to 4 inch flowmeters.
(4) Remove the four allen bolts securing the terminal box to the bracket.
(5) Turn the terminal box to the desired orientation. When reassembling the terminal box, reverse the above procedure.

3-4. Installing the Vortex Flow Converters.

A signal cable is used between the flowmeter and the converter. The maximum signal cable length is 20 m.

The converter is mounted on a 2-inch (60.5 mm outer dia.) stanchion or horizontal pipe. See Figure 3-7. Do not mount the converter on a vertical pipe. It makes wiring and maintenance difficult. The converter mounting orientation can be changed as illustrated in Figure 3-8.

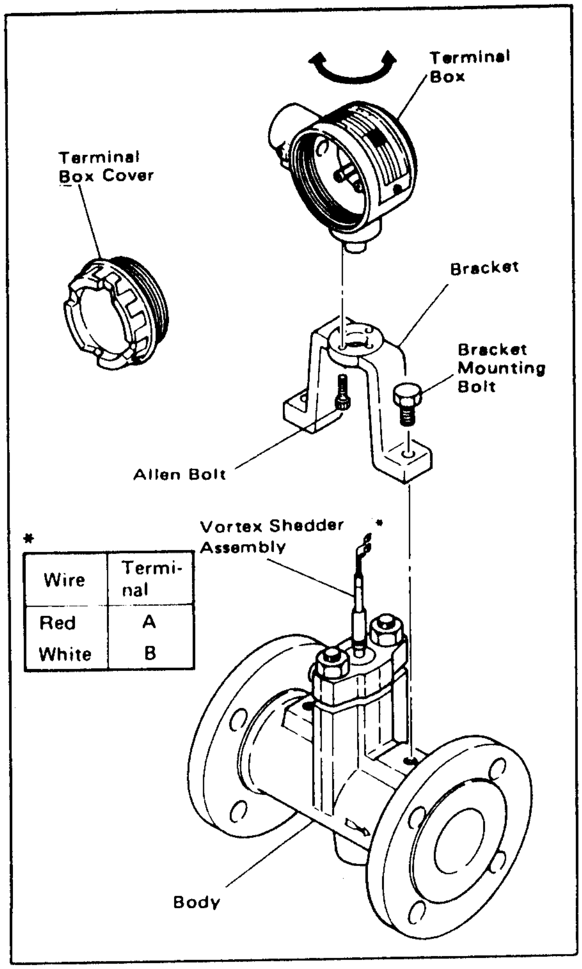


Figure 3-6. Changing the Terminal Box Orientation.

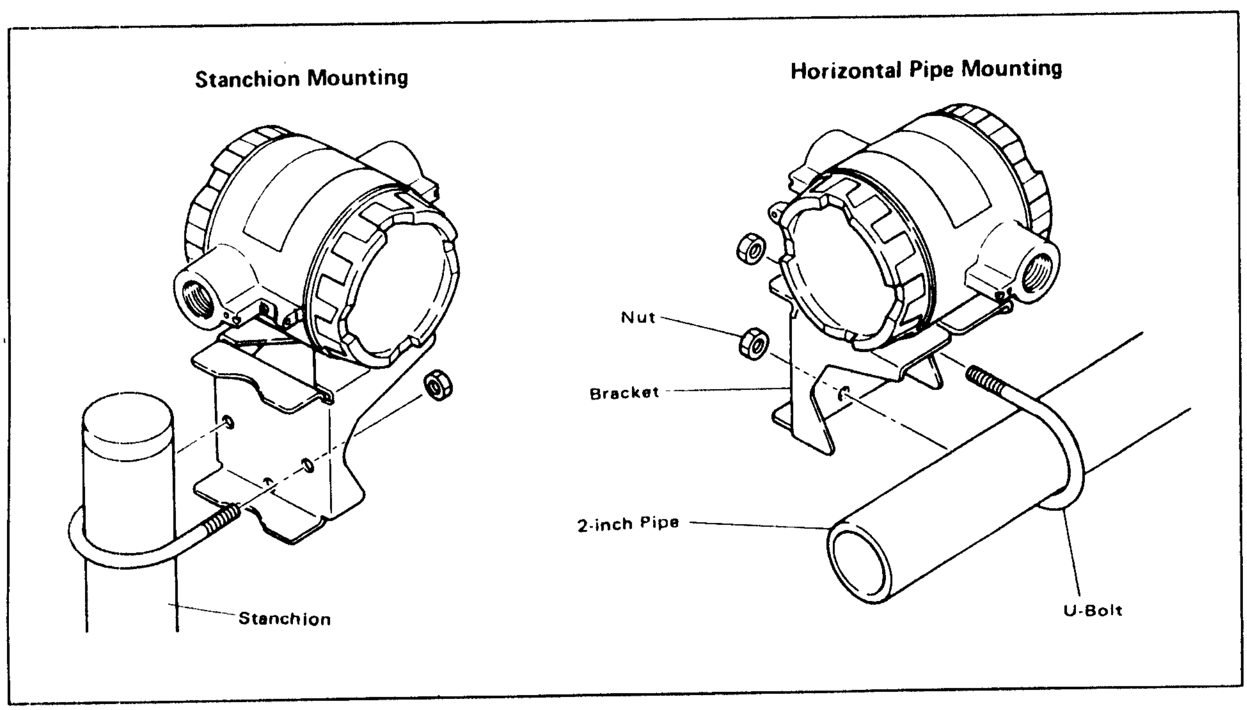


Figure 3-7. Vortex Flow Converter Installation.

3-5. Changing the Converter Orientation.

The vortex flow converter orientation can be changed by rotating it 90°. See Figure 3-8.

- If the power and signal cables are connected, turn the power OFF and disconnect these cables from the instrument.
- Remove two allen converter mounting bolts.
- Move the converter to the desired orientation and tighten the bolts.

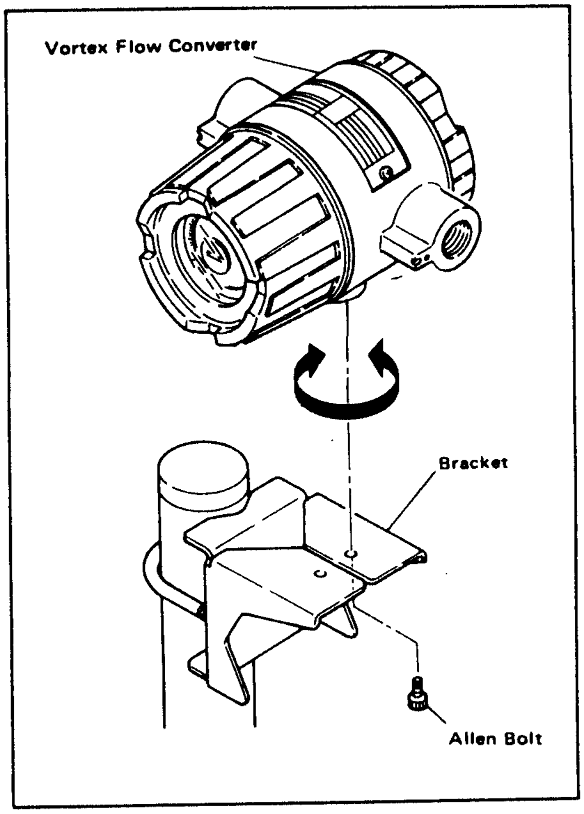


Figure 3-8. Changing the Converter Orientation.

4. WIRING.

4-1. Power Supply and Load Resistance.

The remote converter type vortex flowmeter is used with the external converter. To connect these instruments, use the special cable. See Figure 4-4. 20 m (65 feet) is the maximum length.

(1) Analog output (4 to 20 mA DC) converter.
This converter uses the same two wires for both the signal and power supply. A DC power supply is required in a transmission loop. The total lead-wire resistance including the instrument load and power distributor (supplied by the user) must conform to a value in the permissible load resistance range (see Figure 4-1). Figure 4-2 shows typical wiring connections.

(2) Pulse output converter.
This version uses three wires between the converter and the power supply. 12 to 30 V DC power (allowable ripple ±1.5 V or less) is required.
The minimum load resistance of the pulse output loop is 10 kΩ (maximum capacitance 0.22μF) and leadwire resistance must be 50Ω or less.

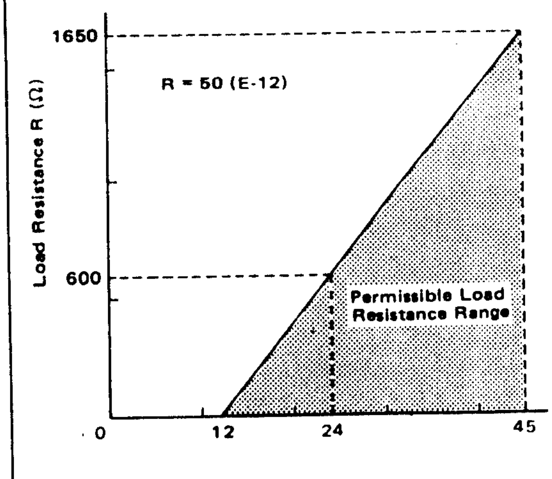


Figure 4-1. Relationship between Power Supply Voltage and Load Resistance. (4 to 20 mA DC output version).

4-2. Wiring Cables and Wires.

The following should be taken into consideration when selecting cables for use between the converter and distributor.

(1) Use 600 V PVC insulated wire or equivalent standard wire or cable.

(2) Use shielded wire in areas susceptible to electrical noise (both analog and pulse output versions).

(3) In areas with high or low ambient temperatures, use wires or cables suitable for such temperatures.

(4) In atmospheres where oils or solvents, corrosive gases or liquids may be present, use suitable wires or cables.

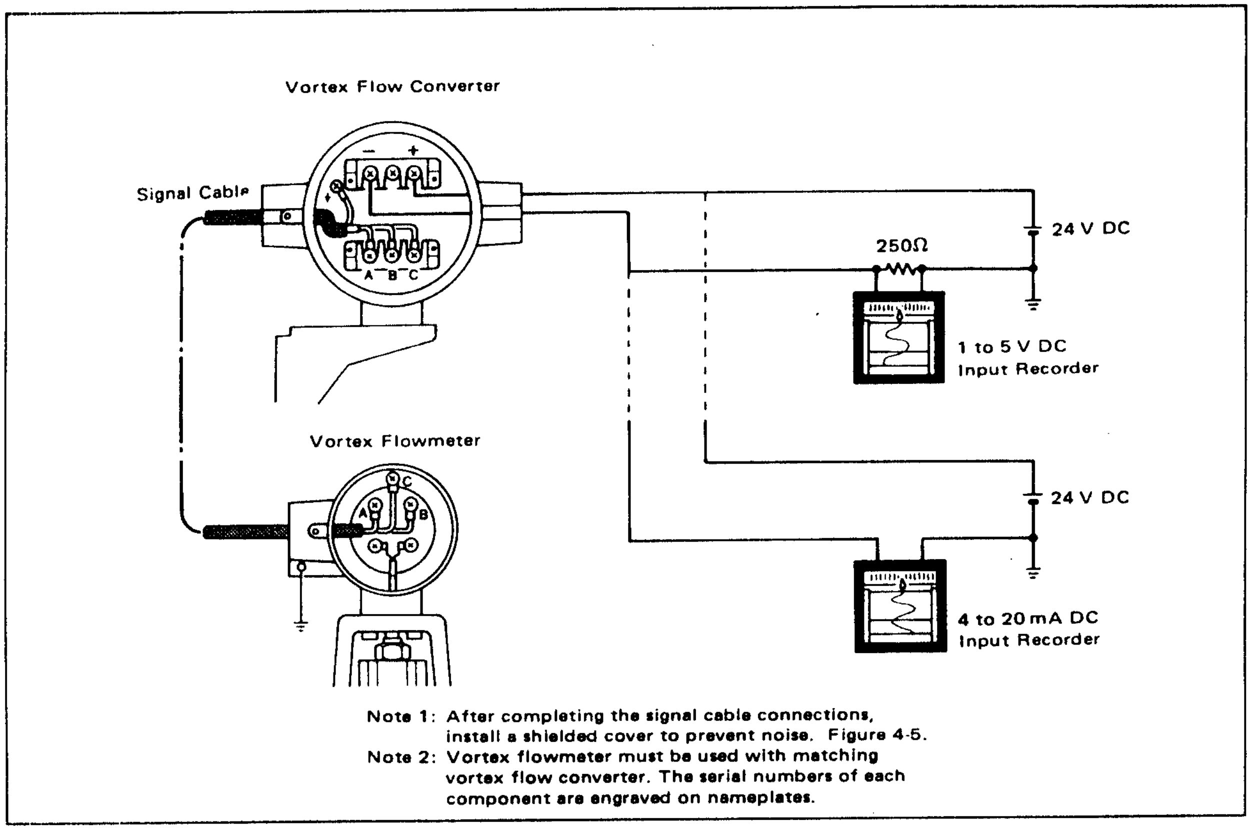


Figure 4-2. Vortex Flowmeter Wiring Connections (Analog Output Version).

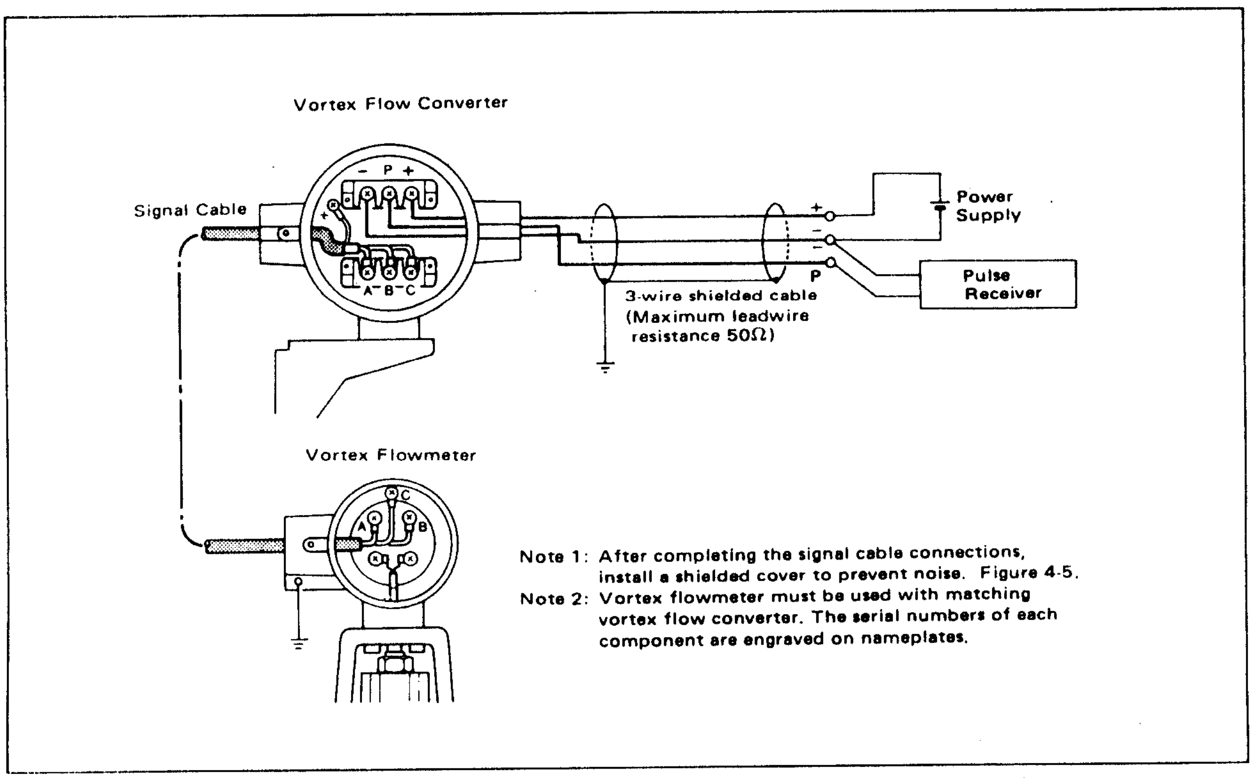


Figure 4-3. Vortex Flowmeter Wiring Connections (Pulse Output Version).

5. PREPARATIONS FOR OPERATION.

5-1. Determining Flow Range.

The vortex flowmeter has been calibrated at the factory before shipment, and recalibration is not required. When changing the flow range, calculate the new range using the following method and recalibrate the flowmeter in accordance with paragraph 6-2-2.

The vortex flowmeter flow range corresponds to the Reynolds number range 2×10^4 to 7×10^6 (4×10^4 to 7×10^6 for 6- and 8-inch flowmeter). The flow velocity is restricted to those given in Figures 5-1 and 5-2.

The Reynolds number can be obtained from the following equation.

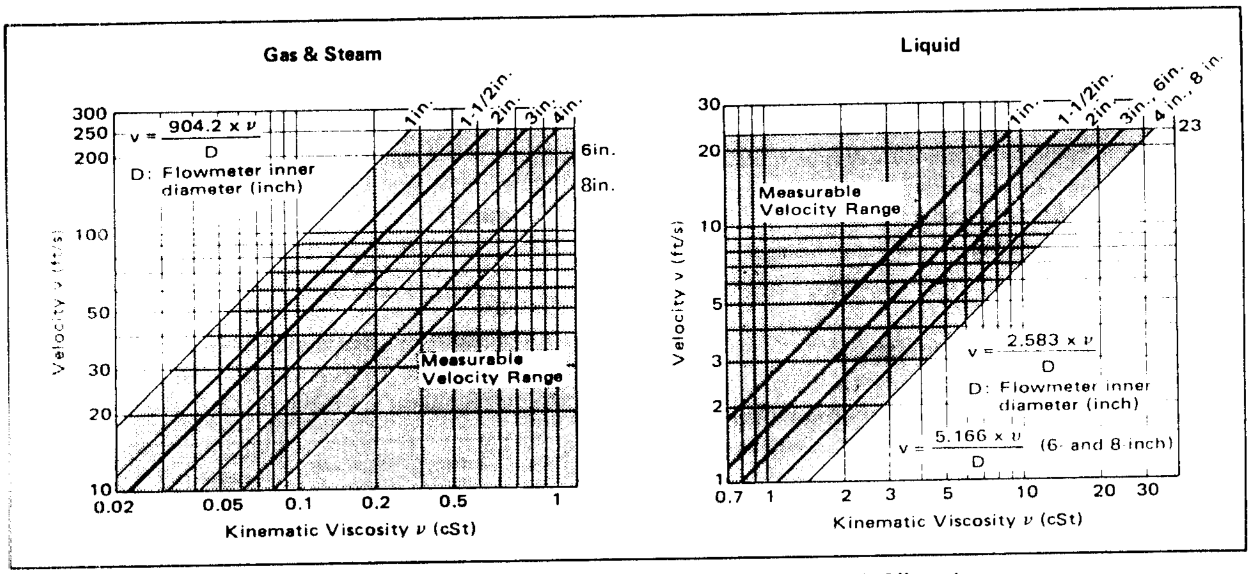


Figure 5-1. Relationship between Velocity and Kinematic Viscosity.

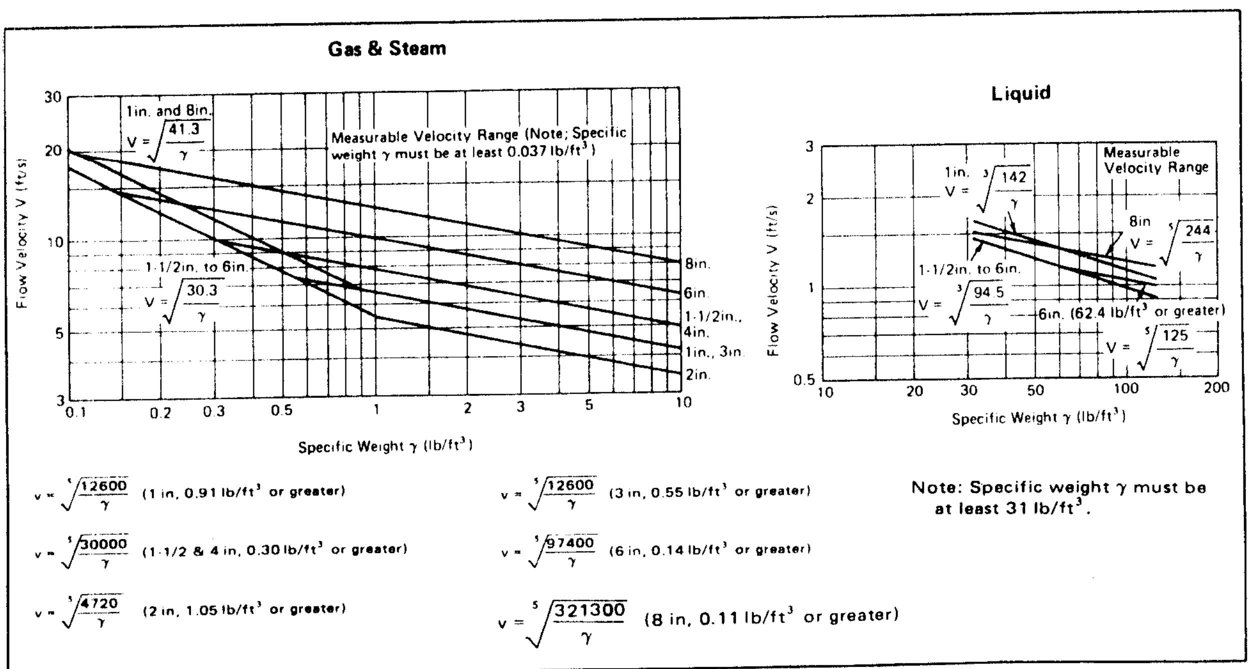


Figure 5-2. Relationship between Minimum Velocity and Specific Weight.

$$R_e = \frac{52.77 \times Q_1}{D \times \nu}$$

or

$$R_e = \frac{394.7 \times Q_2}{D \times \nu}$$

Where, Q_1: Flow rate (US gph)
Q_2: Flow rate (ft^3/h)
D: Flowmeter diameter (inch)
ν: Kinematic viscosity (cSt)

The measurable flow range which varies depending on the fluid condition is determined by multiplying the velocity (obtained from Figures 5-1 or 5-2) by the cross-sectional area of the flowmeter tube. As long as this value meets the customer's specification, a flow measurement is possible.

Even when the flow rate is outside this value, flow measurements are possible although accuracy may be adversely affected. See Table 6-2.

- The Reynolds number is within the range of 5×10^3 to 7×10^6.

5-2. Selecting Flowmeter Size.

To keep a vortex flowmeter in good operating condition, a pipeline should be selected taking the following into consideration.

1. Select the vortex flowmeter size that gives large values to flow span and velocity.
2. Confirm that the line pressure is high enough for small flowmeter size so that no cavitation occurs, and pressure loss is minimal.
   The optimum line pressure can be obtained from the following equation.

$$\Delta p = 2.33 \times 10^{-4} \times \gamma \times v^2$$

$$p \geqslant 2.7 \cdot \Delta p + 1.3 \cdot p_0$$

where
Δp: Pressure loss (psi)
p: Minimum pipeline pressure (psia)
γ: Liquid specific weight (lb/ft^3)
v: Flow velocity (ft/s)
p_0: Saturation liquid vapor pressure (psia)

Table 5-2. shows water pressure loss at 15°C (59°F) and minimum line pressure.

Table 5-2. Pressure Loss and Minimum Line Pressure at 15°C (59°F) Water.

Flow Velocity ft/s	Pressure Loss psi	Min. Line Pressure psia
3	0.13	0.67
5	0.36	1.29
10	1.45	4.24
15	3.27	9.15
20	5.8	16.0
23	7.7	21.1

[Example 1]

Fluid: Liquid
Maximum Flow Rate: 180 U.S. gpm
Normal Flow Rate: 130 U.S. gpm
Kinematic Viscosity: 2.04 cSt
Specific Weight at Operating Conditions: $61.15\ lb/ft^3$
Pressure: $3\ kg/cm^2$ (42.7 psi)
Temperature: 100°C (212°F)

[Solution]

Calculate Reynolds numbers at maximum flow rate and normal flow rate and confirm that these Reynolds numbers are between 2×10^4 and 7×10^6.

Pipe size (inch)	Inner dia. (inch)	Pipe cross-sectional area (ft^2)	Reynolds number at maximum flow rate	Reynolds number at normal flow rate
1	1.01	0.0056	2.77×10^5	2.00×10^5
1-1/2	1.56	0.0133	1.79×10^5	1.29×10^5
2	2.01	0.022	1.39×10^5	1.00×10^5
3	2.80	0.043	9.98×10^4	7.21×10^4
4	3.69	0.074	7.57×10^4	5.47×10^4
6	5.46	0.163	5.12×10^4	3.70×10^4
8	7.31	0.291	3.82×10^4	2.76×10^4

The flow velocity ranges for all flowmeter sizes are obtained from Figure 5-1.

5.22 to 32 ft/s for 1 inch pipe
3.38 to 32 ft/s for 1-1/2 inch pipe
2.62 to 32 ft/s for 2 inch pipe
1.89 to 32 ft/s for 3 inch pipe
1.43 to 32 ft/s for 4 inch pipe
1.93 to 32 ft/s for 6 inch pipe
1.44 to 32 ft/s for 8 inch pipe

The minimum flow velocity of 1.32 ft/s (1 and 8 inch pipes) and 1.16 ft/s (1-1/2 to 6 inch pipes) can be obtained from Figure 5-2. Thus, the measurable flow velocity ranges are below.

5.22 to 32 ft/s for 1 inch pipe
3.38 to 32 ft/s for 1-1/2 inch pipe
2.62 to 32 ft/s for 2 inch pipe
1.89 to 32 ft/s for 3 inch pipe
1.43 to 32 ft/s for 4 inch pipe
1.93 to 32 ft/s for 6 inch pipe
1.44 to 32 ft/s for 8 inch pipe

Multiplying these velocities by the cross-sectional area of the inner flow tube, the flow rates for each flowmeter can be obtained.

e.g. 1 inch pipe flowmeter

Minimum flow rate

$5.22 \times 0.0056 \times 60 = 1.75\ ft^3/min.$

$1.75 \times 7.481 = 13.1$ U.S. gpm

Maximum flow rate

$32 \times 0.0056 \times 60 = 10.7\ ft^3/min.$

$10.7 \times 7.481 = 80$ U.S. gpm

Both the minimum and maximum flow rates for 1-1/2 to 8 inch pipes can be calculated in the same way.

13.1 to 80 U.S. gpm for 1 inch pipe
20.2 to 191 U.S. gpm for 1-1/2 inch pipe
25.9 to 315 U.S. gpm for 2 inch pipe
36.5 to 617 U.S. gpm for 3 inch pipe
47.5 to 1062 U.S. gpm for 4 inch pipe
141 to 2341 U.S. gpm for 6 inch pipe
188 to 4179 U.S. gpm for 8 inch pipe

Since the maximum or normal flow rate in the above example exceeds the ranges of the 1, 6 and 8 inch pipes, any of the 1-1/2 to 4 inch flowmeters can be used to measure the flow conditions in the above example. Determine a suitable pipeline size referring to paragraph 5-2.

[Example 2]

Fluid: Saturated steam
Maximum Flow Rate: 650 acfm*
Normal Flow Rate: 450 acfm
Kinematic Viscosity: 8.54 cSt
Specific Weight: 0.102 lb/ft³
Pressure: 2 kg/cm² (28.5 psi)
Temperature: 134°C (273°F)

[Solution]

Calculate Reynolds numbers at maximum flow rate and normal flow rate and confirm that these Reynolds numbers are between 2×10^4 and 7×10^6.

Pipe size (inch)	Inner dia. (inch)	Pipe cross-sectional area (ft²)	Reynolds number at maximum flow rate	Reynolds number at normal flow rate
1	1.01	0.0056	1.78×10^6	1.24×10^6
1-1/2	1.56	0.0133	1.16×10^6	8.00×10^5
2	2.01	0.022	8.97×10^5	6.21×10^5
3	2.80	0.043	6.44×10^5	4.46×10^5
4	3.69	0.074	4.88×10^5	3.38×10^5
6	5.46	0.163	3.30×10^5	2.29×10^5
8	7.31	0.291	2.47×10^5	1.71×10^5

The maximum flow velocity is 262 ft/s for all sizes. See Figure 5-1.

The minimum flow velocity of 20.1 ft/s (1 inch and 8 inch pipes) and 17.2 ft/s (1-1/2 to 6 inch pipes) can be obtained from Figure 5-2. Thus, the measurable flow velocity ranges are 20.1 to 262 ft/s for 1 inch and 8 inch pipes, and 17.2 to 262 ft/s for 1-1/2 to 6 inch pipes. Multiplying this velocity by the cross-sectional area of the inner flow tube, the following flow rates can be obtained.

e.g. 2 inch pipe flowmeter

$17.2 \times 0.022 \times 60 = 22.7$ acfm*

$262 \times 0.022 \times 60 = 345$ acfm*

6.75 to 88 acfm* for 1 inch pipe
13.7 to 209 acfm* for 1-1/2 inch pipe
22.7 to 345 acfm* for 2 inch pipe
44.4 to 675 acfm* for 3 inch pipe
76.4 to 1163 acfm* for 4 inch pipe
168 to 2562 acfm* for 6 inch pipe
351 to 4574 acfm* for 8 inch pipe

*Actual cubic feet per minute.

Since the maximum flow rate of 650 acfm in the above example exceeds the ranges of 1 and 2 inch pipes, any of the 3 to 8 inch flowmeters can be used to measure the flow conditions in the above example. Determine a suitable pipeline size referring to paragraph 5-2.

[Example 3]

Fluid:	Dry air
Maximum Flow Rate:	80 acfm
Normal Flow Rate:	50 acfm
Kinematic Viscosity:	6.37 cSt
Specific Weight:	0.194 lb/ft³
Pressure:	2 kg/cm² (28.5 psig)
Temperature:	60°C (140°F)

[Solution]

Calculate Reynolds numbers at maximum flow rate and normal flow rate and confirm that these Reynolds numbers are between 2×10^4 and 7×10^6.

Pipe size (inch)	Inner dia. (inch)	Pipe cross-sectional area (ft²)	Reynolds number at maximum flow rate	Reynolds number at normal flow rate
1	1.01	0.0056	2.94×10^5	1.84×10^5
1-1/2	1.56	0.0133	1.91×10^5	1.19×10^5
2	2.01	0.022	1.48×10^5	9.25×10^4
3	2.80	0.043	1.06×10^5	6.64×10^4
4	3.69	0.074	8.06×10^4	5.04×10^4
6	5.46	0.163	5.45×10^4	3.40×10^4
8	7.31	0.291	4.07×10^4	2.54×10^4

The maximum flow velocity is 262 ft/s for all sizes. See Figure 5-1.

The minimum flow velocity of 14.6 ft/s (1 inch pipe), 12.5 ft/s (1-1/2 to 4 inch pipes), 13.8 ft/s (6 inch pipe) and 17.6 ft/s (8 inch pipe) can be obtained from Figure 5-2. Thus, the measurable flow velocity ranges are 14.6 to 262 ft/s for 1 inch pipe, 12.5 to 262 ft/s for 1-1/2 to 4 inch pipes, 13.8 to 262 ft/s for 6 inch pipe. 17.6 to 262 ft/s for 8 inch pipe. Multiplying this velocity by the cross-sectional area of the inner flow tube, the following flow rates can be obtained.

e.g. 2 inch pipe flowmeter
12.5 x 0.022 x 60 = 16.5 acfm
262 x 0.022 x 60 = 345 acfm
4.9 to 88 acfm for 1 inch pipe
10 to 209 acfm for 1-1/2 inch pipe
16.5 to 345 acfm for 2 inch pipe
32.3 to 675 acfm for 3 inch pipe
55.5 to 1163 acfm for 4 inch pipe
135 to 2562 acfm for 6 inch pipe
308 to 4574 acfm for 8 inch pipe

Since the maximum or normal flow rate in the above example exceeds the ranges of the 4, 6 and 8 inch pipes, any of the 1 to 3 inch flowmeters can be used to measure the flow conditions in the above example. Determine a suitable pipeline size referring to paragraph 5-2.

5-3. Zero Adjustment.

In normal operation the vortex flowmeter zero does not shift. Hence, the zero adjustment on this instrument has been locked with red paint.

5-4. Totalizer Setting.

Fot the flowmeter with integral totalizer, the user must set the scaler and (for pulse output) select scaled or unscaled pulse output as follows:

5-4-1. Scaler Setting.

To display totalizer value in any desired units, set the scaler as follows.

(1) Use equation ① below to obtain the scaling factor k.

(2) Substitute the scaling factor k in equation ② to obtain values of a_1, a_2, a_3, a_4 and N.

(3) Set the setting switches SW1, SW2, SW3, SW4 and the selector link position of CN4 to set the values a_1, a_2, a_3, a_4 and N respectively (see Figure 5-3).
Set the arrows on the setting switches – decade rotary switches – to the desired number. The correspondence between selector link position and value of N is shown in Figure 5-3.
Insert a shorting link at the position corresponding to the desired setting.

$$k = \frac{K_1}{K_t} \quad \text{......................} \quad ①$$

$$k = (a_1 \times 10^{-1} + a_2 \times 10^{-2} + a_3 \times 10^{-3} + a_4 \times 10^{-4}) \times 10^{-N} \quad \text{..............} \quad ②$$

N = 0 to 5

where
- k : Scaling factor
- Kt : K factor (operating conditions) (pulse/U.S.gal.)
- K_1 : Flow unit conversion factor

Calculating K_t

K factor (K_{59}) at 59°F is marked on the data plate. Obtain K factor (K_t) at normal operating conditions using K_{59}, and equations ③ and ④ below.

- When the body material is stainless steel,

$$K_t = K_{59} \{ 1 - 2.963 \times 10^{-5} \times (t - 59) \} \quad .. \quad ③$$

- When the body material is carbon steel,

$$K_t = K_{59} \{ 1 - 1.470 \times 10^{-5} \times (t - 59) \} \quad .. \quad ④$$

t: Fluid temperature (°F) at normal operating conditions.

Calculating K_1

Calculate K_1 as follows.

- Totalizer display at normal operating conditions (mainly for steam and liquid)

Display unit	Flow unit conversion factor (K_1)
U.S. gal	1
ACF	0.13368
lb	γ_1
lb	$0.13368 \times \gamma_2$
Btu	$0.13368 \times \gamma_2 \times h$

γ_1, γ_2 : Density or specific weight at normal operating conditions (γ_1: lb/U.S.gal, γ_2: lb/ft^3)
h : Specific enthalpy at normal operating conditions (h: Btu/lb)

- Totalizer display at reference conditions (mainly natural gas and general gas)

Display unit	Flow unit conversion factor (K_1)
U.S. gal	$\frac{P}{Pb} \times \frac{Tb + 460}{T + 460} \times C$
SCF	$0.13368 \times \frac{P}{Pb} \times \frac{Tb + 460}{T + 460} \times C$
lb	$0.13368 \times \gamma_b \times \frac{P}{Pb} \times \frac{Tb + 460}{T + 460} \times C$

- P : Fluid pressure (psia)
- P_b : Reference pressure (psia)
- T : Fluid temperature (°F)
- T_b : Reference temperature (°F)
- γ_b : Density or specific weight at reference conditions (lb/ft^3)
- C : $C = (F_{pv})^2$ .... for natural gas
  $C = \frac{1}{K}$ .... for general gas
- F_{pv} : Supercompressibility factor at normal operating conditions

K : Deviation factor at normal operating conditions

$$K = \frac{Z}{Z_b}$$

Z : Compressibility factor at normal operating conditions

Z_b : Compressibility factor at reference conditions

The following examples show how to calculate the scaler setting.

[Example 1]

Nominal size: 4 inch
Measured fluid: Liquid
Fluid temperature: 140°F
Body material: Stainless steel
K_{59} = 5.39 pulse/U.S.gal
To display the totalizer value in the units ACF.

[Solution]

$$K_t = 5.39\{1 - 2.963 \times 10^{-5} \times (140 - 59)\}$$
$$= 5.377 \text{ pulse/U.S. gal}$$
$$K_l = 0.13368 \text{ ACF/U.S. gal}$$
$$k = \frac{K_l}{K_t} = \frac{0.13368}{5.377}$$
$$= 0.2486 \times 10^{-1}$$

Then, a_1 = 2, a_2 = 4, a_3 = 8, a_4 = 6 and N = 1.

[Example 2]

Nominal size: 2 inch
Measured fluid: Dry air
Fluid temperature: 120°F
Fluid pressure: 140 psig
Body material: Stainless steel
K_{59} = 33.9 pulse/U.S. gal
C = 1.0
To display the totalizer value at reference conditions in the volumetric flow units SCF.

[Solution]

$$K_t = 33.9\{1 - 2.963 \times 10^{-5} \times (120 - 59)\}$$
$$= 33.84 \text{ pulse/U.S. gal}$$
$$K_l = 0.13368 \times \frac{140 + 14.7}{14.7} \times \frac{60 + 460}{120 + 460} \times 1$$
$$= 1.2613 \text{ SCF/U.S. gal}$$
$$k = \frac{K_l}{K_t} = \frac{1.2613}{33.84}$$
$$= 0.3727 \times 10^{-1}$$

Then, a_1 = 3, a_2 = 7, a_3 = 2, a_4 = 7 and N = 1.

[Example 3]

Nominal size: 3 inch
Measured fluid: Saturated steam
Fluid pressure: 140 psig
Body material: Stainless steel
K_{59} = 12.6 pulse/U.S. gal
To display the totalizer value in the gravimetric flow unit lb.

[Solution]

For saturated steam at pressure 140 psig, the specific weight is 0.04569 lb/U.S. gal, and the temperature t is 361°F,

$$K_t = 12.6\{1 - 2.963 \times 10^{-5} \times (361 - 59)\}$$
$$= 12.49 \text{ pulse/U.S. gal}$$
$$K_l = 0.04569 \text{ lb/U.S. gal}$$
$$k = \frac{K_l}{K_t} = \frac{0.04569}{12.49}$$
$$= 0.3658 \times 10^{-2}$$

Then, a_1 = 3, a_2 = 6, a_3 = 5, a_4 = 8 and N = 2.

Note 1. To slow the totalizer speed to one tenth, add 1 to N. For the example 3 above, add 1 to 2. Then N is 3. In this case, the display unit is 'x 10lb'. To multiply the totalizer speed by ten, subtract 1 from N. For example 3, subtract 1 from 2 – thus N is 1. In this case, the display unit is 'x 0.1 lb'.

Note 2. Span for analog output is not changed when the scaling factor setting is changed. Frequency of unscaled pulse output is also not affected (duty cycle is approx. 50%).

6. MAINTENANCE.

This section describes adjustment procedures, parts replacement, disassembly and reassembly relating to the maintenance.

6-1. Maintenance Service Instruments.

The instruments required for maintenance service are listed in Table 6-1.

6-2. Adjustments.

Adjustment procedures required for the converter range change are described. Adjustments are usually made in a service room where calibration instruments are readily available.

For pulse output, perform a TLA adjustment as per paragraph 6-2-4. Span adjustment is not required.

6-2-1. Zero Adjustment.

Zero adjustment is not required.

6-2-2. Span Adjustment.

This adjustment applies only to analog output. Before adjusting span, check that the flow range can be adjusted as per section 5-1.

(1) Connect instruments as shown in Figure 6-1. Warm up the instruments for at least five minutes. Use a 250 Ω or other readily available resistor whose resistance value is within the tolerances given in Figure 4-1.

(2) Set the sine wave generator to 2 to 5 V (rectangular wave may be used) and set the frequency obtained from the following equation.

$$f = Kt_1 \cdot Q_1$$
$$f = Kt_2 \cdot Q_2$$

where,

f: Frequency at maximum flow rate (Hz)

Q_1: Maximum flow rate (GPM)

Q_2: Maximum flow rate (ACFH)

Kt_1: Constants at flowing temperature (Hz/GPM)

$Kt_1 = M [1 - 2.963 \times 10^{-5} \times (t - 59)]$

$Kt_1 = M [1 - 1.470 \times 10^{-5} \times (t - 59)]$ for carbon steel body.

Kt_2: Constants at flowing temperature (Hz/ACFM)

$Kt_2 = L [1 - 2.963 \times 10^{-5} \times (t - 59)]$

$Kt_2 = L [1 - 1.470 \times 10^{-5} \times (t - 59)]$ for carbon steel body.

Table 6-1. Instruments Required for Maintenance.

Item	Remarks
Power Supply	Analog output: 24V DC±10% Pulse output: 10 to 30V DC
Load Resistance	4 to 20 mA DC version only
Voltmeter	4 to 20 mA DC version only
Sine Wave Generator	
Counter	5 to 10kHz, 4 or more digits.
Oscilloscope	

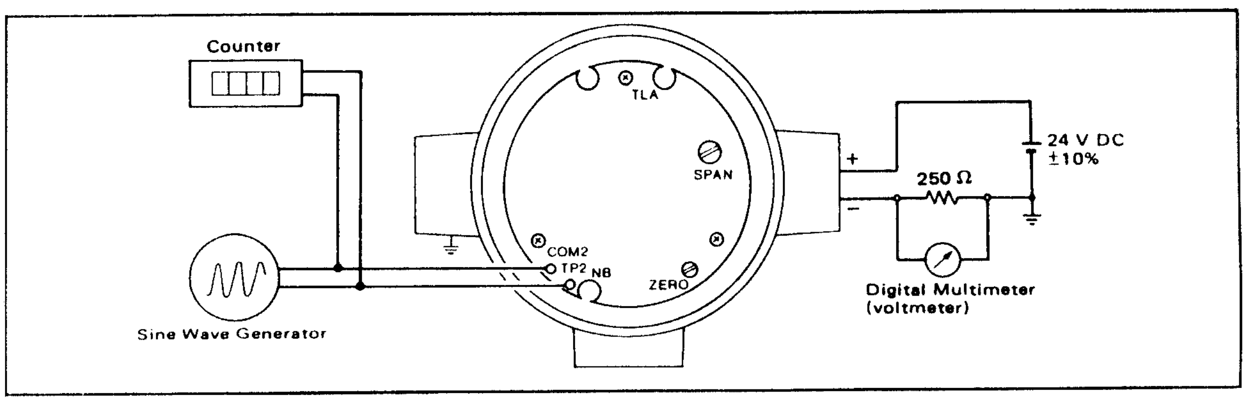


Figure 6-1. Span Adjustment Setup (Analog Output).

K_{59} : N (pulse/U.S. gal) (Constants)
(entered on data plate)
K_{59} : M (Hz/GPM) (Constants)
(M = 0.01667N Hz/GPM)
K_{59} : L (Hz/ACFH) (Constants)
(L = 0.002078N Hz/ACFH)
t : Flowing temperature (°F)

The following examples show frequency calculations within maximum flow rates.

[Example 1] See page 5-2.

Nominal Size: 2 inch
Fluid: Liquid
Maximum Flow Rate: 180 GPM
Flowing Temperature: 212°F
K-Factor: 33.83 pulse/gal

[Solution]

K_{59} = 33.83 pulse/gal
= 0.5639 Hz/GPM
K_{212} = 0.5639 [1 − 2.963 x 10^{-5} (212 − 59)]
= 0.5612 Hz/GPM
f = 0.5612 x 180
= 101.0 Hz

Hence, frequencies between 0 and 101.0 Hz are generated for flows in the range 0 to 180 GPM.

[Example 2] See page 5-3.

Nominal Size: 4 inch
Fluid: Saturated Steam
Maximum Flow Rate: 650 ACFM = 39,000 ACFH
Flowing Temperature: 273°F
K-Factor: 5.405 pulse/gal
Specific Weight: 0.102 lb/ft^3

[Solution]

K_{59} = 5.405 pulse/gal = 0.01123 Hz/ACFH
K_{273} = 0.01123 [1 − 2.963 x 10^{-5} (273 − 59)]
= 0.01116 Hz/ACFH
f = 0.01116 x 39,000
= 435.2 Hz

Thus, frequencies between 0 and 435.2 Hz are generated for flows in the range 0 to 650 ACFM.

Generally, specific volume is used for steam flow measurements.
Thus, Table 6-2 presents selected saturated steam specific volumes.

Note: Steam measurements are influenced by the moisture in the steam.

$$v = x \cdot v_g + (1 - x)\, v_f$$

v: Wet Steam Specific Volume
x: Dryness Fraction
v_g: Saturated Steam Specific Volume
v_f: Water Specific Volume
(1 − x): Wetness Fraction

The flowmeter can be adjusted to Kt at the factory before shipment if the flowing temperature is specified at order time.
As described in section 5-1, when measuring a flow having the Reynolds number range of 5 x 10^3 to 2 x 10^4, employ the compensation factor A obtained from the following equation.

f = Ka • Q
Ka = A x Kt

The flow compensation factors are given in Table 6-3.

Table 6-3. Flow Compensation Factor.

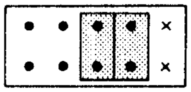
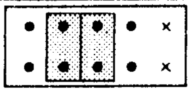
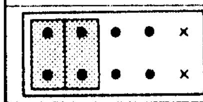
Reynolds Number (Re)	A
$5 \times 10^3 \leq Re \leq 6 \times 10^3$	1.12
$6 \times 10^3 < Re \leq 7 \times 10^3$	1.08
$7 \times 10^3 < Re \leq 8 \times 10^3$	1.065
$8 \times 10^3 < Re \leq 9 \times 10^3$	1.056
$9 \times 10^3 < Re \leq 1 \times 10^4$	1.047
$1 \times 10^4 < Re \leq 1.2 \times 10^4$	1.036
$1.2 \times 10^4 < Re \leq 1.5 \times 10^4$	1.023
$1.5 \times 10^4 < Re < 4 \times 10^4$	1.011

Table 6-2. Selected Saturated Steam Specific Volume.

Pressure psig	Temperature °F	Specific Volume ft^3/lb	Pressure psig	Temperature °F	Specific Volume ft^3/lb
0	212	26.82	120	350	3.344
10	240	16.49	140	361	2.926
20	259	12.00	150	366	2.756
30	277	9.460	160	371	2.605
40	287	7.833	180	380	2.351
50	298	7.229	200	388	2.141
60	308	5.842	220	395	1.965
70	316	5.118	240	403	1.814
80	324	4.670	260	409	1.683
90	331	4.249	280	416	1.571
100	338	3.895	300	422	1.474

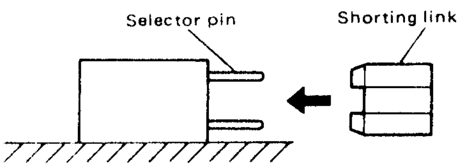
(3) Set the frequency selector link according to the span frequency obtained at the previous step (2) (see Table 6-4 and Figure 6-8)

Table 6-4. Frequency Selector Link Setting.

Position of shorting link	Range of span frequency	
	For liquid (Hz)	For gas or steam (Hz)
	7 to 30	70 to 300
	30 to 100	300 to 1000
	100 to 400	1000 to 4000

CAUTION

Insert the shorting link correctly as shown in the figure below.



(4) When the load resistance is 250 Ω, adjust span until the digital multimeter indicates 5 V. If a resistor other than 250 Ω is used, adjust span so the meter reads a R × 20 (mV).

(5) Next, apply a frequency corresponding to 50% of the range and confirm that the output is within the specified value.

(6) If the output is outside the limit, repeat steps (3) and (4).

(7) If the flowmeter is adjusted at the fluid flowing pipeline, remove terminal box cover and amplifier unit. Loosen the two sensor terminal screws and disconnect leadwires. After reinstalling the amplifier unit, adjust the span as per paragraphs (1) to (5) above.

6-2-3. NB (Noise Balance) Adjustment.

NB is adjusted at the factory before shipment. Hence, no further adjustments are normally required. By adjusting the vibration ratio in one of the two piezoelectric element outputs, a high S/N ratio can be obtained.

NB adjustment is required only when the indicator reads above zero where no fluid is flowing or the indicator reads a rather large value when only a small amount of fluid is flowing.

If the indication is not improved sufficiently when NB adjustment is carried out, carry out TLA adjustment according to par. 6-2-4.

(1) Use an oscilloscope to observe the signal waveform between terminals TP2 and COM2 (common). The best and also easiest adjustment can be performed when no fluid is flowing. However, if the fluid cannot be stopped, the best adjustment can be obtained from fluid velocity up to 0.5 m/s (1.6 ft/s) for liquid or up to 8 m/s (26 ft/s) for gas and steam. Adjust NB until the noise waveform between TP2 and COM2 is as shown in Figure 6-2.

(2) If no oscilloscope is available, adjust NB until the analog output indicator reads 4 mA DC or until the pulse output is zero (zero flow).

(3) Usually, NB adjustment is set to 3 to 4 as shown in Figure 6-2.

6-2-4. TLA Adjustment (Trigger Input Level Adjustment).

Carry out TLA adjustment after NB adjustment. The TLA adjustment sets the minimum measurable velocity. The TLA adjustment is set to 3 for liquid, or set to 4 for gas or steam before shipment (see Figure 6-3). For these settings, the minimum measurable velocity is about 1.4 times of that shown in Figure 5-2.

Adjust the TLA in the following cases;

- to decrease the minimum measurable velocity setting, (to measure flow velocities lower than the current minimum setting).

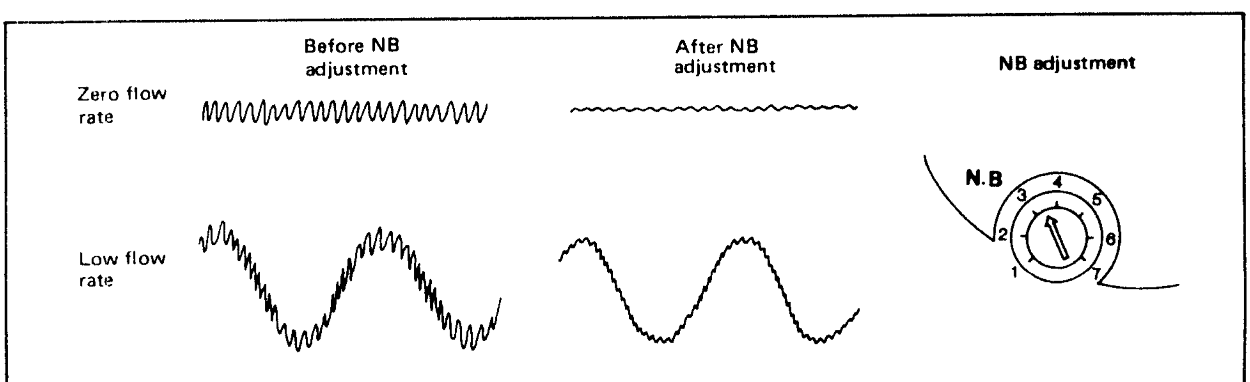


Figure 6-2. NB Adjustment.

- to increase the minimum measurable velocity setting, (when – due to pipe vibration – an erroneous velocity is displayed when fluid flow is very small or zero, despite NB adjustment).

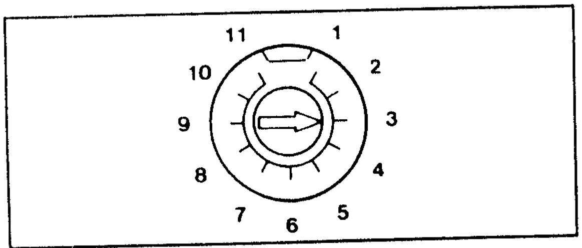


Figure 6-3. TLA Adjustment.

Turn the TLA adjustment clockwise to lower the trigger input level and to minimize noise influence. Turn it slowly and do not turn it past the limit. If the TLA adjustment is turned too far, the minimum velocity may change and affect accurate measurement (see Figure 7-5).

For "rule of thumb" TLA adjustment:

(1) If the pipe line is still vibrating after the fluid flow stops, gradually turn the TLA adjustment clockwise until output is 0%.
If an oscilloscope is provided, connect it between terminals PLS and COM1. Turn the TLA adjustment clockwise until the pulse waveform (Figure 6-4) disappears from the oscilloscope screen.

NOTE

It is recommended that a battery operated oscilloscope be used. If such oscilloscope is not available, an AC powered dual trace sweep scope must be used.

(2) If the fluid can not be stopped, turn the TLA adjustment until error becomes 0 at the minimum flow rate.

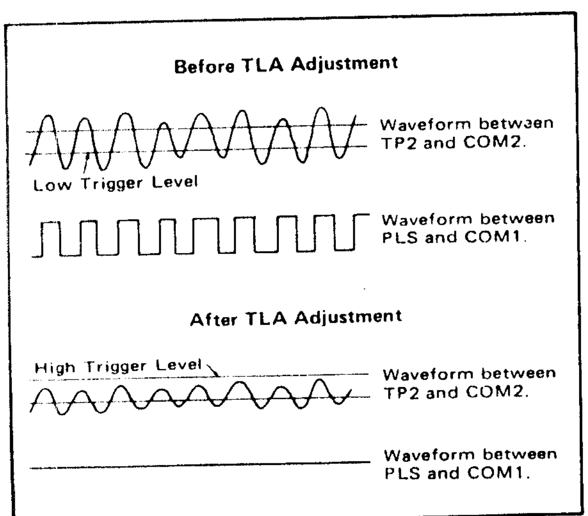


Figure 6-4. TLA Adjustment (at Zero Flow).

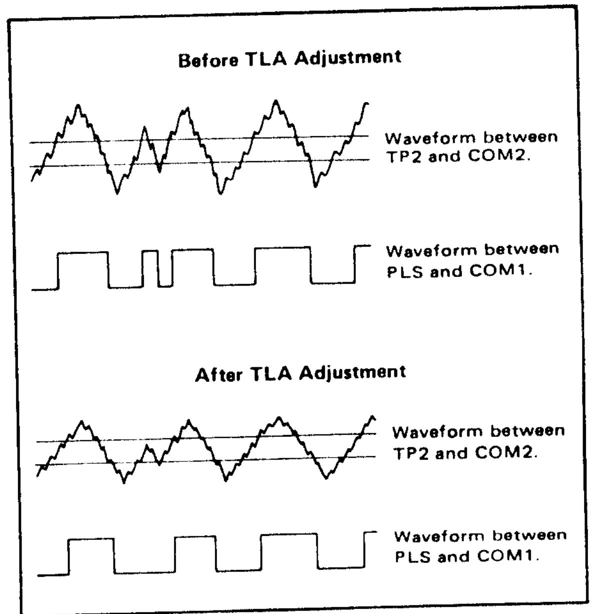


Figure 6-5. TLA Adjustment (at Low Flow).

CAUTION

Do not ground the COM1 terminal for analog output version.

The relationship between scale setting of the TLA adjustment and minimum flow velocity is shown in Tables 6-5 and 6-6.

Table 6-5. Minimum Flow Velocity of Liquid.

γ: Specific weight (lb/ft^3)

Nominal size (inch)	Minimum flow velocity (m/s)
1	$\mathrm{Vmin} = \sqrt[3]{\frac{142}{\gamma}} \times \{1 + 0.49 \times (\mathrm{scale} - 1)\}$
1-1/2 to 4	$\mathrm{Vmin} = \sqrt[3]{\frac{94.5}{\gamma}} \times \{1 + 0.49 \times (\mathrm{scale} - 1)\}$
6	$\mathrm{Vmin} = \sqrt[3]{\frac{94.5}{\gamma}} \times \{1 + 0.49 \times (\mathrm{scale} - 1)\}$ $\mathrm{Vmin} = \sqrt[5]{\frac{125}{\gamma}} \times \{1 + 0.49 \times (\mathrm{scale} - 1)\}$ When $\gamma < 62.4$ lb/ft^3, use the equation with the cube root. When $\gamma \geqq 62.4$ lb/ft^3, use the equation with the cube root or the one with the 5th root, whichever value of Vmin is greater.
8	$\mathrm{Vmin} = \sqrt[5]{\frac{244}{\gamma}} \times \{1 + 0.49 \times (\mathrm{scale} - 1)\}$

Table 6-6. Minimum Flow Velocity for Gas or Steam.

γ: Specific weight (lb/ft^3)

Nominal size (inch)	Minimum flow velocity (ft/s)
1	$Vmin = \sqrt{\frac{41.3}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$, $Vmin = \sqrt[5]{\frac{12600}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$ When $\gamma < 0.91\ lb/ft^3$, use the equation with the square root. When $\gamma \geqq 0.91\ lb/ft^3$, use the equation with the square root or the one with the 5th root, whichever value of Vmin is greater.
1-1/2	$Vmin = \sqrt{\frac{30.3}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$, $Vmin = \sqrt[5]{\frac{30000}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$ When $\gamma < 0.3\ lb/ft^3$, use the equation with the square root. When $\gamma \geqq 0.3\ lb/ft^3$, use the equation with the square root or the one with the 5th root, whichever value of Vmin is greater.
2	$Vmin = \sqrt{\frac{30.3}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$, $Vmin = \sqrt[5]{\frac{4720}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$ When $\gamma < 1.05\ lb/ft^3$, use the equation with the square root. When $\gamma \geqq 1.05\ lb/ft^3$, use the equation with the square root or the one with the 5th root, whichever value of Vmin is greater.
3	$Vmin = \sqrt{\frac{30.3}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$, $Vmin = \sqrt[5]{\frac{12600}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$ When $\gamma < 0.55\ lb/ft^3$, use the equation with the square root. When $\gamma \geqq 0.55\ lb/ft^3$, use the equation with the square root or the one with the 5th root, whichever value of Vmin is greater.
4	$Vmin = \sqrt{\frac{30.3}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$, $Vmin = \sqrt[5]{\frac{30000}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$ When $\gamma < 0.3\ lb/ft^3$, use the equation with the square root. When $\gamma \geqq 0.3\ lb/ft^3$, use the equation with the square root or the one with the 5th root, whichever value of Vmin is greater.
6	$Vmin = \sqrt{\frac{30.3}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$, $Vmin = \sqrt[5]{\frac{97400}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$ When $\gamma < 0.14\ lb/ft^3$, use the equation with the square root. When $\gamma \geqq 0.14\ lb/ft^3$, use the equation with the square root or the one with the 5th root, whichever value of Vmin is greater.
8	$Vmin = \sqrt{\frac{41.3}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$, $Vmin = \sqrt[5]{\frac{321300}{\gamma}} \times \{1 + 0.35 \times (scale - 1)\}$ When $\gamma < 0.11\ lb/ft^3$, use the equation with the square root. When $\gamma \geqq 0.11\ lb/ft^3$, use the equation with the square root or the one with the 5th root, whichever value of Vmin is greater.

CAUTION

Do not turn the TLA adjustment past the 7th scale division – whether for liquid, gas or steam.

6-3. Disassembly and Reassembly.

This section describes disassembly and reassembly procedures required for maintenance and parts replacement. For replacement parts, see the parts lists at the end of this manual.

Before disassembling the transmitter, turn off the power and release the pressure. Use proper tools when disassembling and reassembling.

6-3-1. Indicator or Totalizer Removal.

If necessary for servicing of amplifier, remove the indicator or totalizer (options) as follows (see Figure 6-6).

(1) Turn the power OFF.
(2) Remove the cover.
(3) For the totalizer, disconnect the cable connector from the amplifier unit (see Figure 6-8).
(4) Loosen the three indicator (totalizer) mounting screws using a Phillips screwdriver.
(5) Pull out the indicator (totalizer).
(6) Reinstall the indicator or totalizer in the reverse order to its removal (above) and secure the mounting screws.

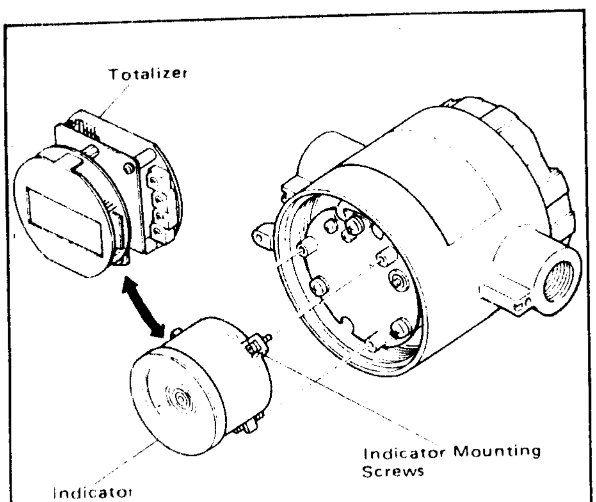


Figure 6-6. Removing and Reinstalling the Indicator (Totalizer).

6-3-2. Amplifier Unit Replacement.

Replace the amplifier unit as follows (see Figure 6-7).

(1) Turn the power OFF.
(2) Remove the converter cover.
(3) Remove the indicator or totalizer according to the procedures described in paragraph 6-3-1.
(4) Loosen the terminal screws and remove leadwires. (An analog output amplifier uses two leadwires and a pulse output amplifier uses three leadwires.)
(5) Loosen the three amplifier unit mounting screws and remove the amplifier unit as shown in Figure 6-7.

CAUTION

Do not turn the amplifier unit. The connector pins may be damaged.

(6) Set flowmeter size setting link and gain setting of a new amplifier unit as follows (see Figure 6-8 and Table 6-7).
(7) When reinstalling the amplifier unit in the converter, match the connector pin positions with the socket. Push the amplifier unit back to position.
(8) Tighten the amplifier mounting screws.
(9) Reconnect the leadwires to the amplifier unit. The leadwires must be connected to the proper terminals. See Figure 6-7 for the correct leadwire connections.
(10) Adjust span as per paragraph 6-2-2.

Terminal	Wire
+	Red
--	White
P*	Black

* Pulse out version only.

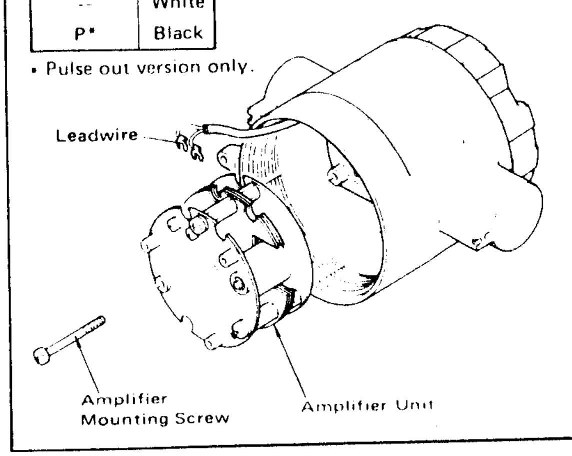
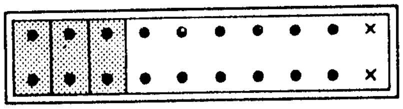
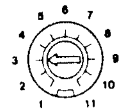
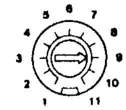
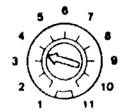
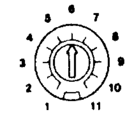
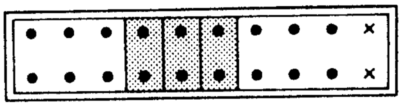
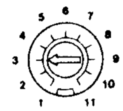
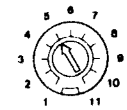
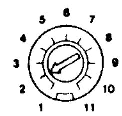
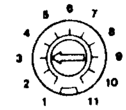
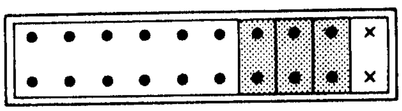
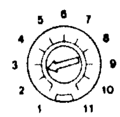
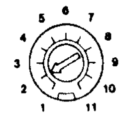
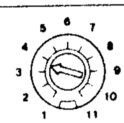
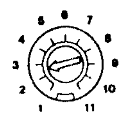
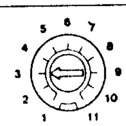
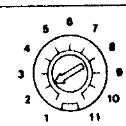


Figure 6-7. Removing Amplifier Unit.

Table 6-7. Setting Position of Flowmeter Size Setting Link and Gain Adjustment.

Nominal size (inch)	Position of size setting link	Setting position of gain adjustment	
		For liquid	For gas and steam
1			
1-1/2			
2			
3			
4			
6			
8			

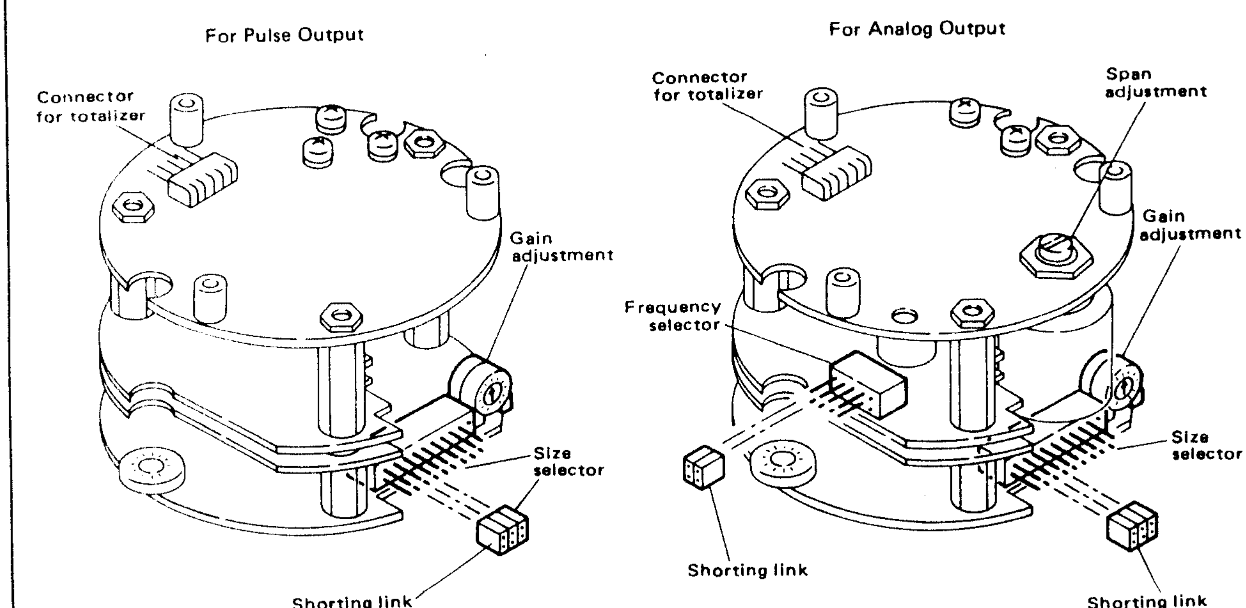
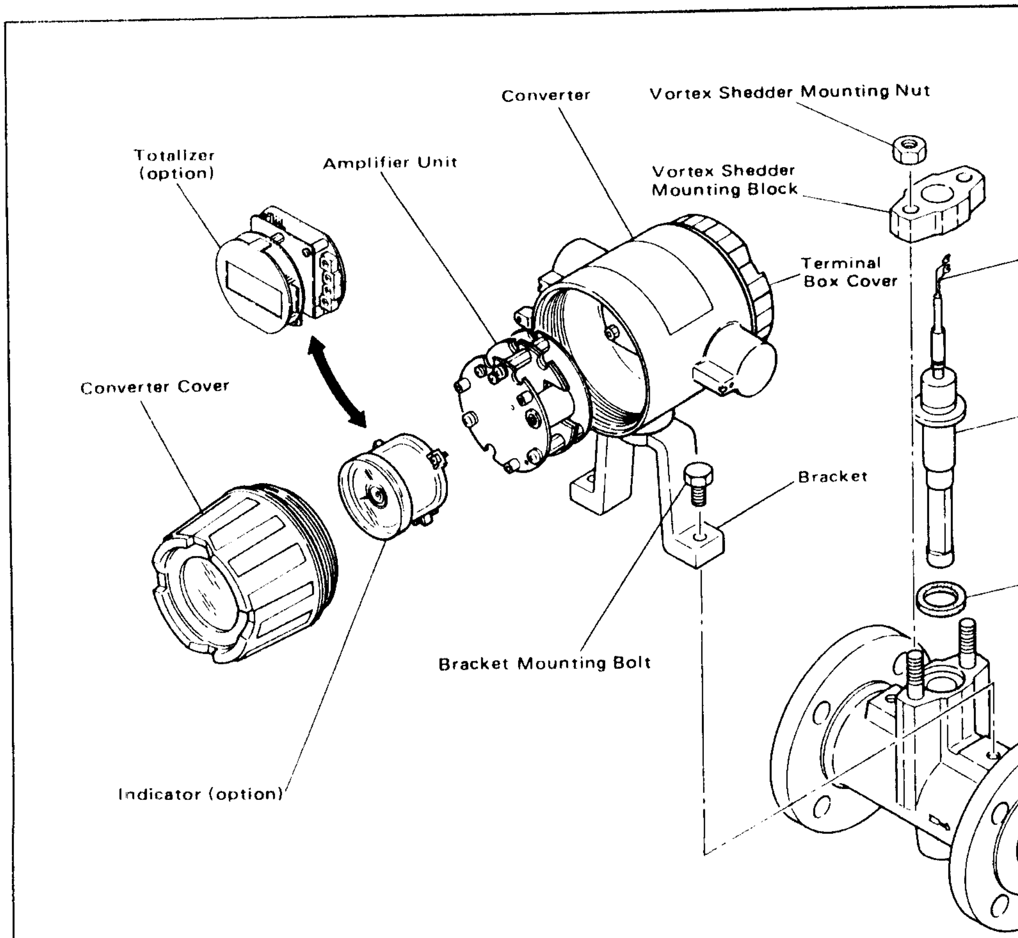


Figure 6-8. Flowmeter Adjustment and Settings.

6-3-3. Sensor Assembly Removal.

Disassemble the vortex flowmeter only when abnormality occurs in the instrument.



*

Wire	Terminal
Red	A
White	B

Figure 6-9. Disassembling and Reassembling the Vortex Shedder Assembly.

(1) Remove the converter cover.
(2) Loosen the two terminal screws and disconnect leadwires.
(3) Loosen the bracket mounting bolts and remove the terminal box together with the bracket. Be careful not to damage the leadwires connected to the vortex shedder assembly when removing the terminal box.
(4) Loosen the vortex shedder assembly mounting bolts or nuts and remove the vortex shedder assembly.
(5) When reassembling the vortex shedder assembly, reverse above procedure. Confirm the following.

a. In principle, a new gasket should be used.
b. The guide pin on the vortex shedder mounting block meets the guide pin hole. See Figure 6-11. The guide pin applies to the 1 to 4 inch flowmeters.
c. The vortex shedder assembly is installed as illustrated in Figure 6-10.
d. Tighten the sensor mounting nut with a torque wrench, applying the torque specified below.

105 in-lb (1.2 kg-m) for 1 and 1-1/2 inch flowmeters
350 in-lb (4 kg-m) for 2 inch flowmeter
520 in-lb (6 kg-m) for 3 inch flowmeter
870 in-lb (10 kg-m) for 4 inch flowmeter
435 in-lb (5 kg-m) for 6 inch flowmeter
610 in-lb (7 kg-m) for 8 inch flowmeter

e. Insert the leadwires through the terminal box bottom hole and lower the terminal box slowly until the bracket touches the flowmeter shoulder. Be sure to keep the leadwires vertical while lowering the terminal box.
f. After assembling, confirm that there is no leakage from the vortex flowmeter.

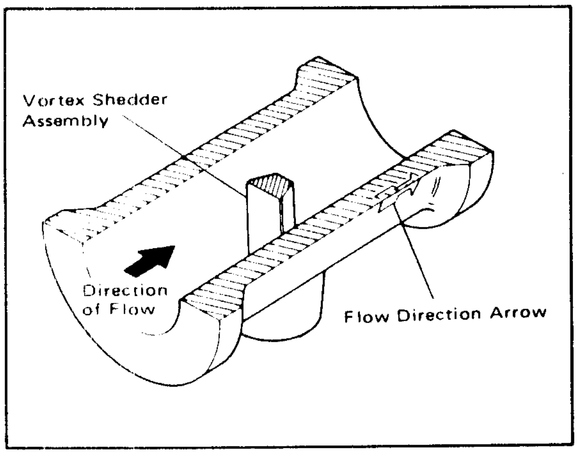


Figure 6-10. Mounting the Vortex Shedder Assembly.

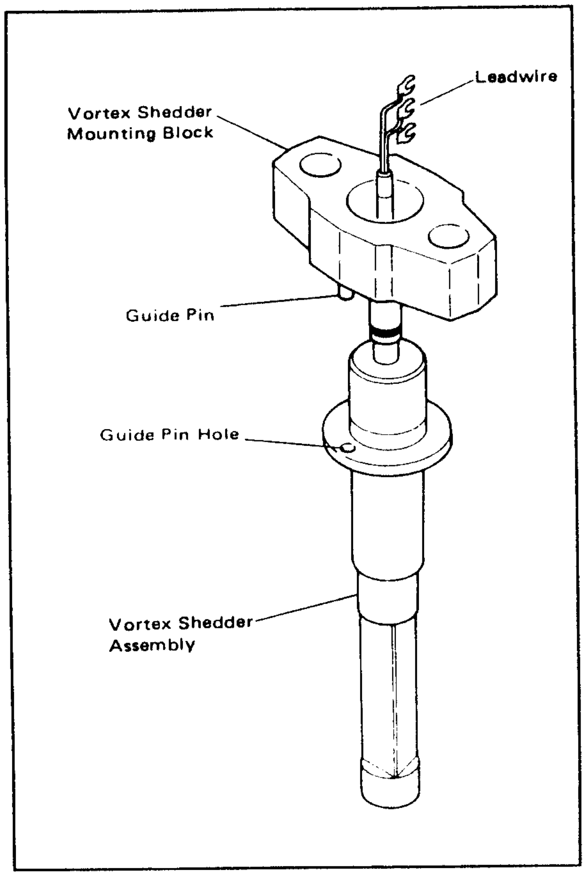


Figure 6-11. Vortex Shedder Assembly Positioning.

7. TROUBLESHOOTING.

If the vortex flowmeter does not operate properly, carefully check, isolate, and remedy troubles as per paragraph 7-3, Troubleshooting Flowcharts. If any troubles are difficult to remedy, contact OMEGA Engineering Customer Service Department at (203) 359-1660.

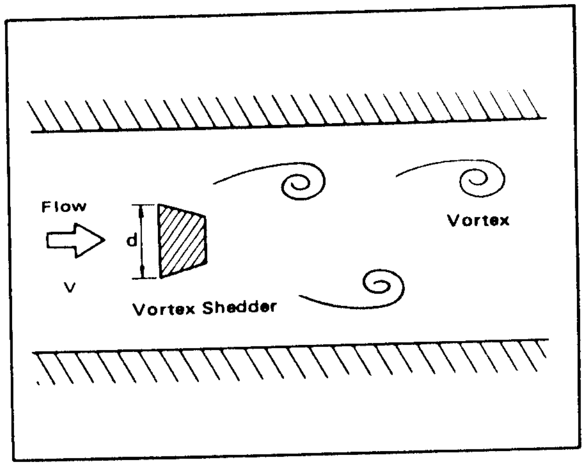


Figure 7-1. Karman Vortices.

7-1. Principles of Operation.

When an obstacle (vortex shedder) is installed in a pipeline, vortices are generated downstream of the obstacle when fluid flows in the pipeline. See Figure 7-1. These vortices are known as Karman Vortices. For a Karman Vortex Flowmeter, the following equation holds.

$$f = St \cdot v/d$$

Where f: Karman Vortex frequency
St: Constant (Strouhal number)
v: Velocity (fluid flow rate)
d: Width of vortex shedder

The Karman Vortex frequency f is proportional to the velocity v. Therefore it is possible to obtain the flow rate by measuring the Karman Vortex frequency.

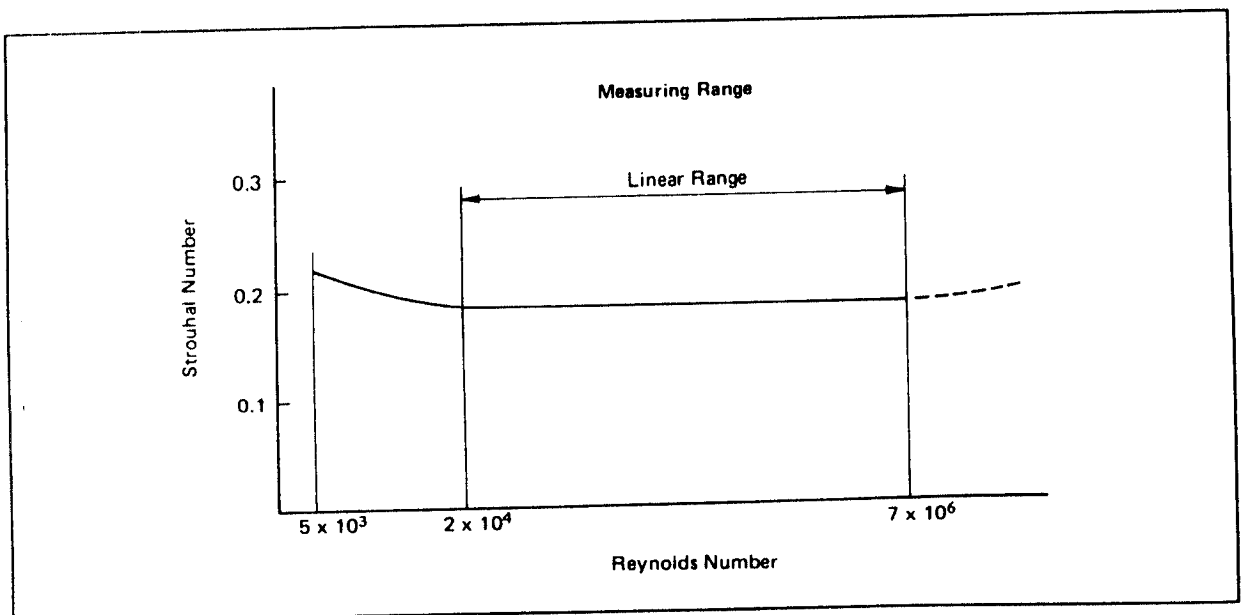


Figure 7-2. Relationship between Strouhal Number and Reynolds Number.

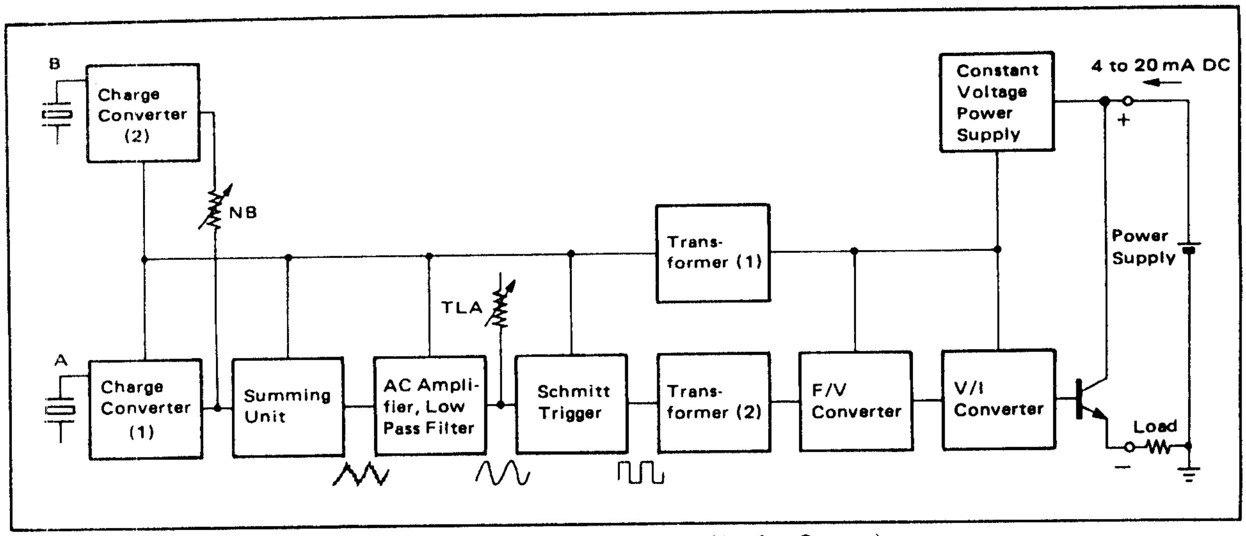


Figure 7-3. Circuit Configuration (Analog Output).

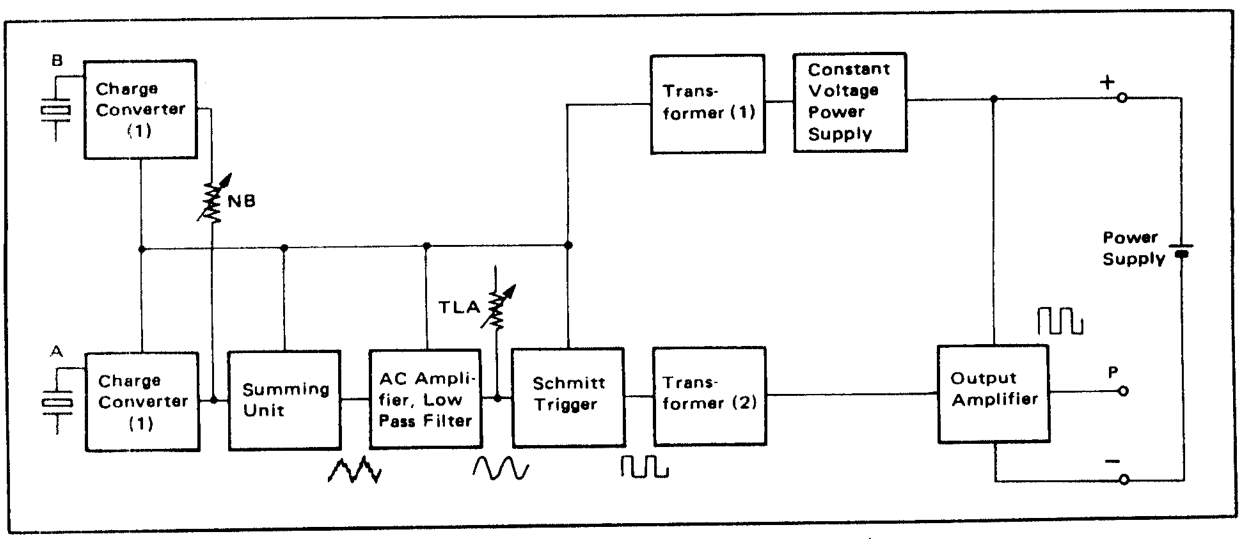


Figure 7-4. Circuit Configuration (Pulse Output).

The vortex flowmeter detects frequency f with a Sensor Assembly. The circuit configuration is shown in Figures 7-3 and 7-4. Individual sections function as follows:

(1) Charge converter (high impedance preamplifier)
An AC load output from a piezoelectric element is converted to a voltage proportional to the electric load applied to the circuit.

(2) Summing unit
The summing unit increases S/N ratio in the outputs from the two charge converters by summing up two output voltages with phase differences of 180°.

(3) AC amplifier and low pass filter
Amplifies the output signal and eliminates noise. The charge converter (high impedance preamplifier) output waveform is masked in high frequency noise when the fluid velocity is low. At high fluid flow rates, the output waveform contains a low frequency waveform. At a low fluid flow rate (low output voltage), high frequency noise is eliminated by a low pass filter. At high fluid flow rates (high output voltage), the low pass filter is reversed and rejects low frequency noise included in the output signal.

(4) Schmitt trigger
Converts a vortex frequency AC voltage to a constant signal level. The schmitt trigger circuit input/output has hysteresis to prevent chattering due to noise.

(5) F/V converter
Converts Schmitt output signal to an analog voltage which corresponds to the vortex frequency.

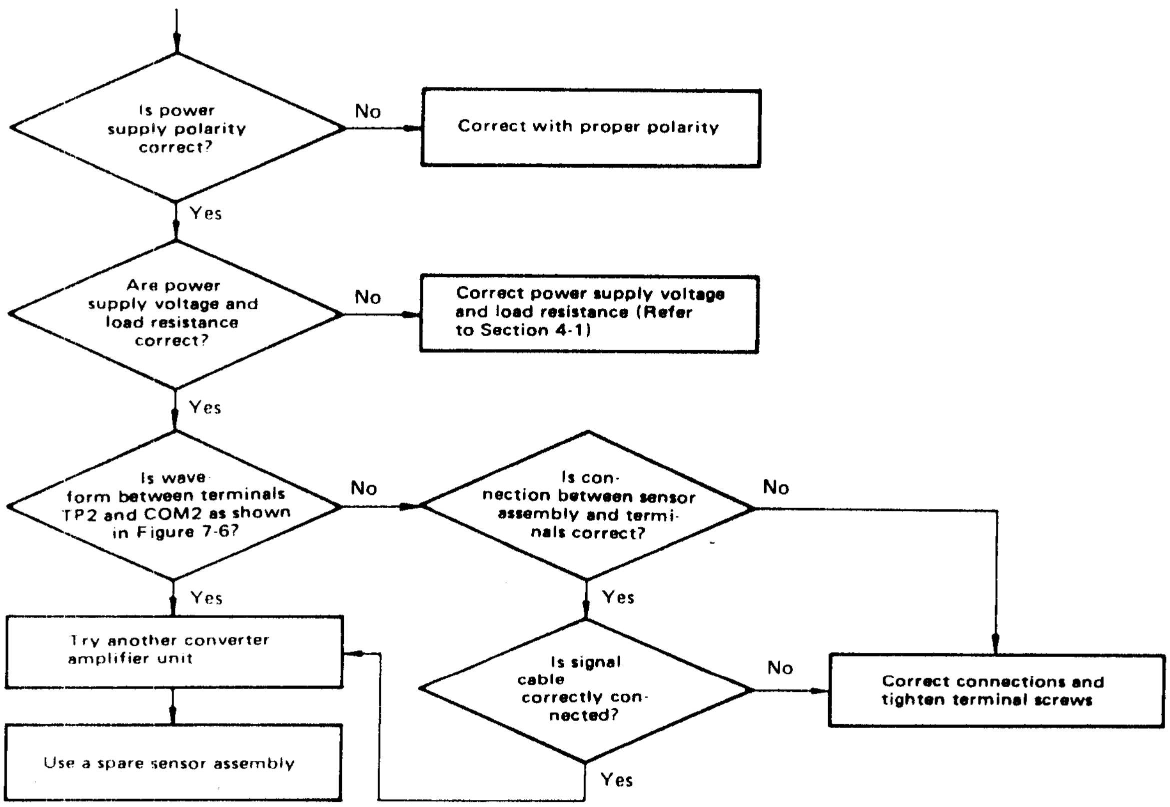
(6) V/I converter
Converts an analog output voltage from F/V converter to a 4 to 20 mA DC transmission signal.

(7) Pulse output amplifier
This amplifier amplifies pulse output signal from the Schmitt trigger and converts it to a pulse signal which meets the input level of the instrument to be connected.

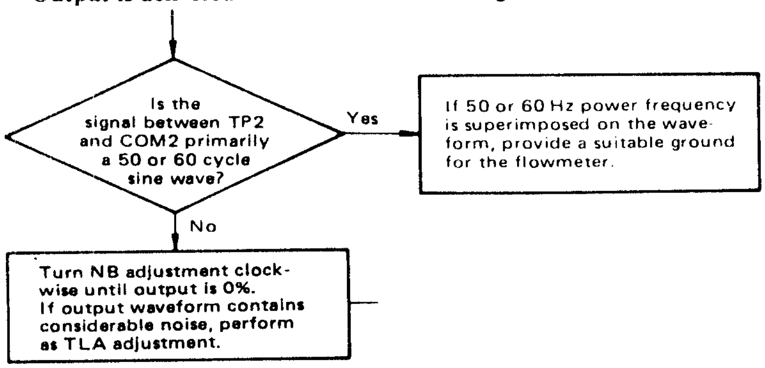
7-2. Troubleshooting Flowcharts.

The vortex flowmeter seldom fails under normal operating conditions. Improper installation of the instrument or pipeline may cause troubles. If it does not operate properly, carefully check, isolate and remedy troubles as per the following troubleshooting flowcharts.

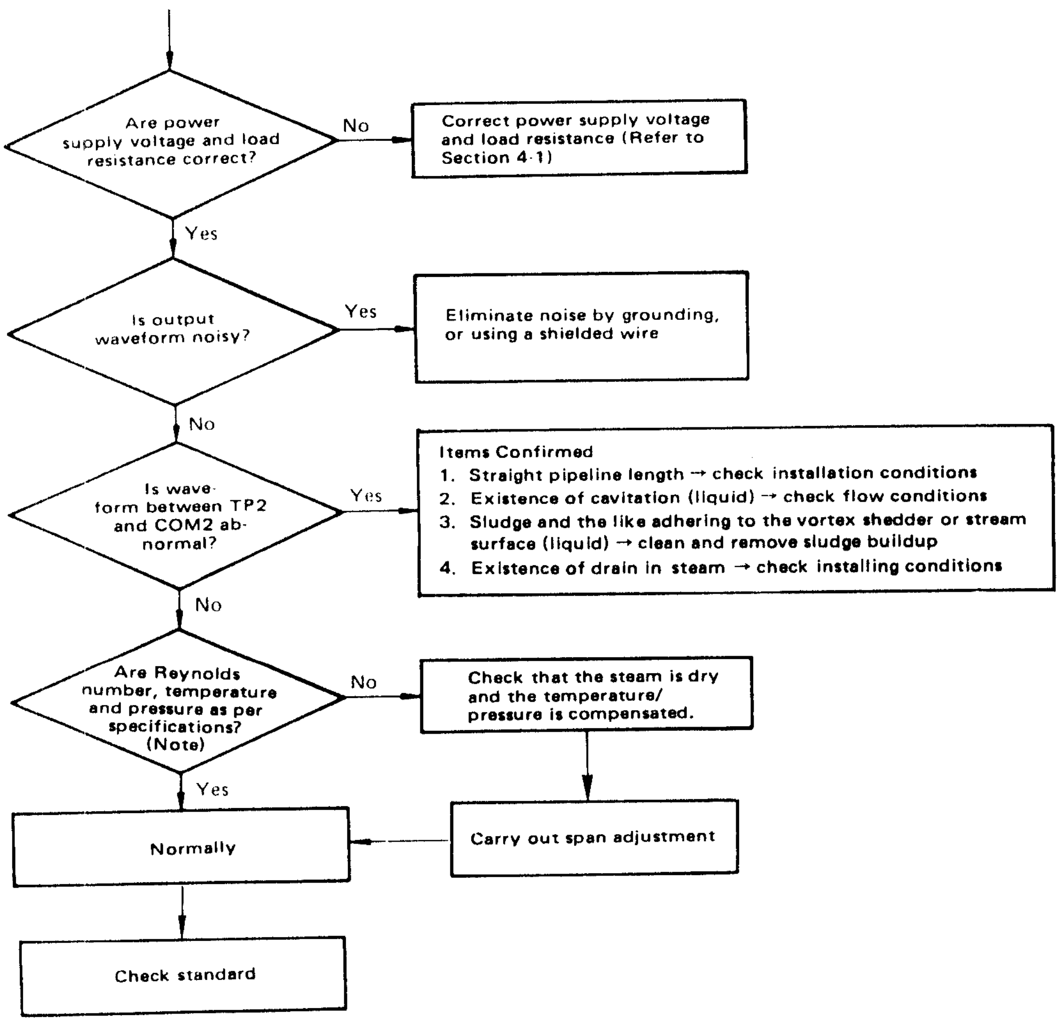
- **Vortex flowmeter does not operate at all. (no flowmeter output even when fluid is flowing)**



- Output is delivered when fluid is not flowing.

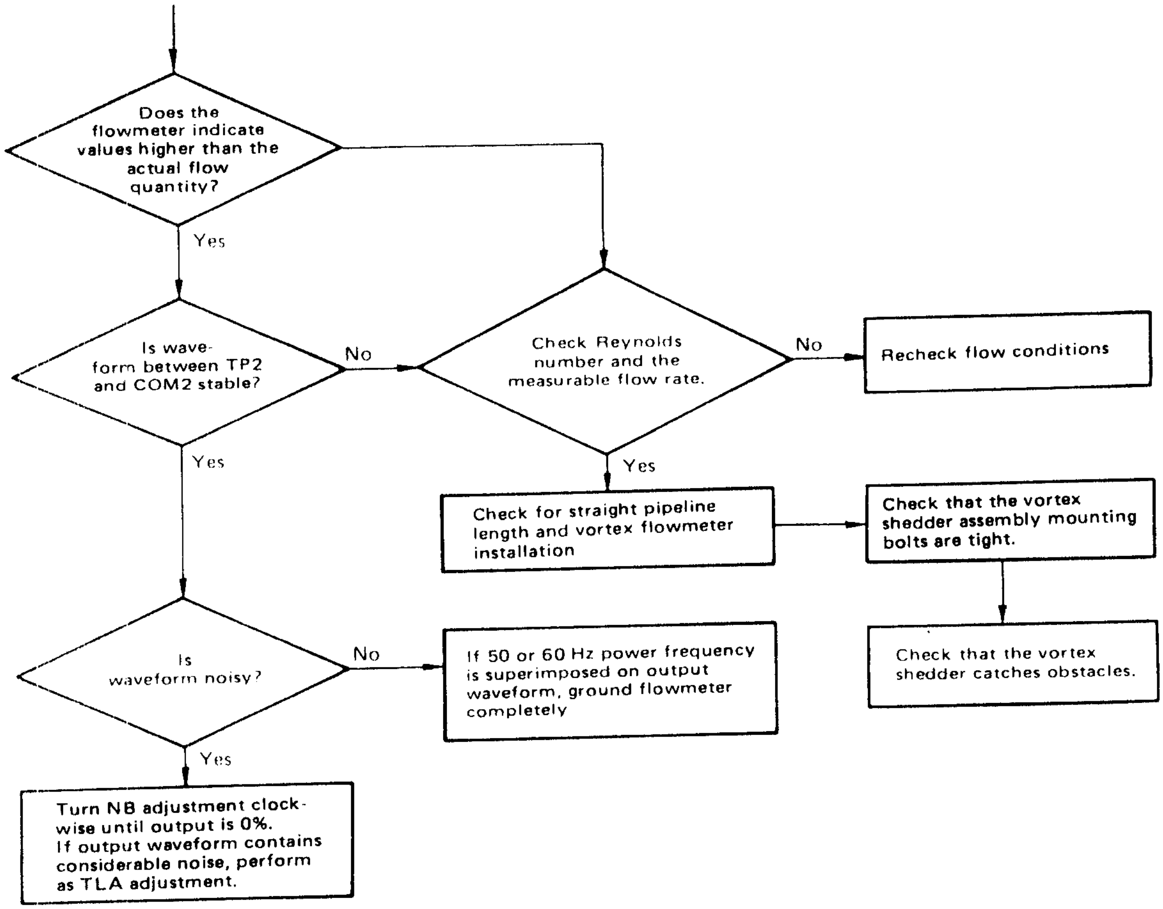


- Large flowmeter errors.



Note: Temperature and pressure at mounted place.

- Output is unstable when flow rate is small.



7-3. Amplifier Unit Check Terminals.

This section describes amplifier unit checkout procedures using test equipment. Connect test equipment (a digital multimeter, oscilloscope, and sine wave generator) between PLS and COM1 or TP2 or COM2 terminals. Input/output and power circuits of these instruments must be isolated.

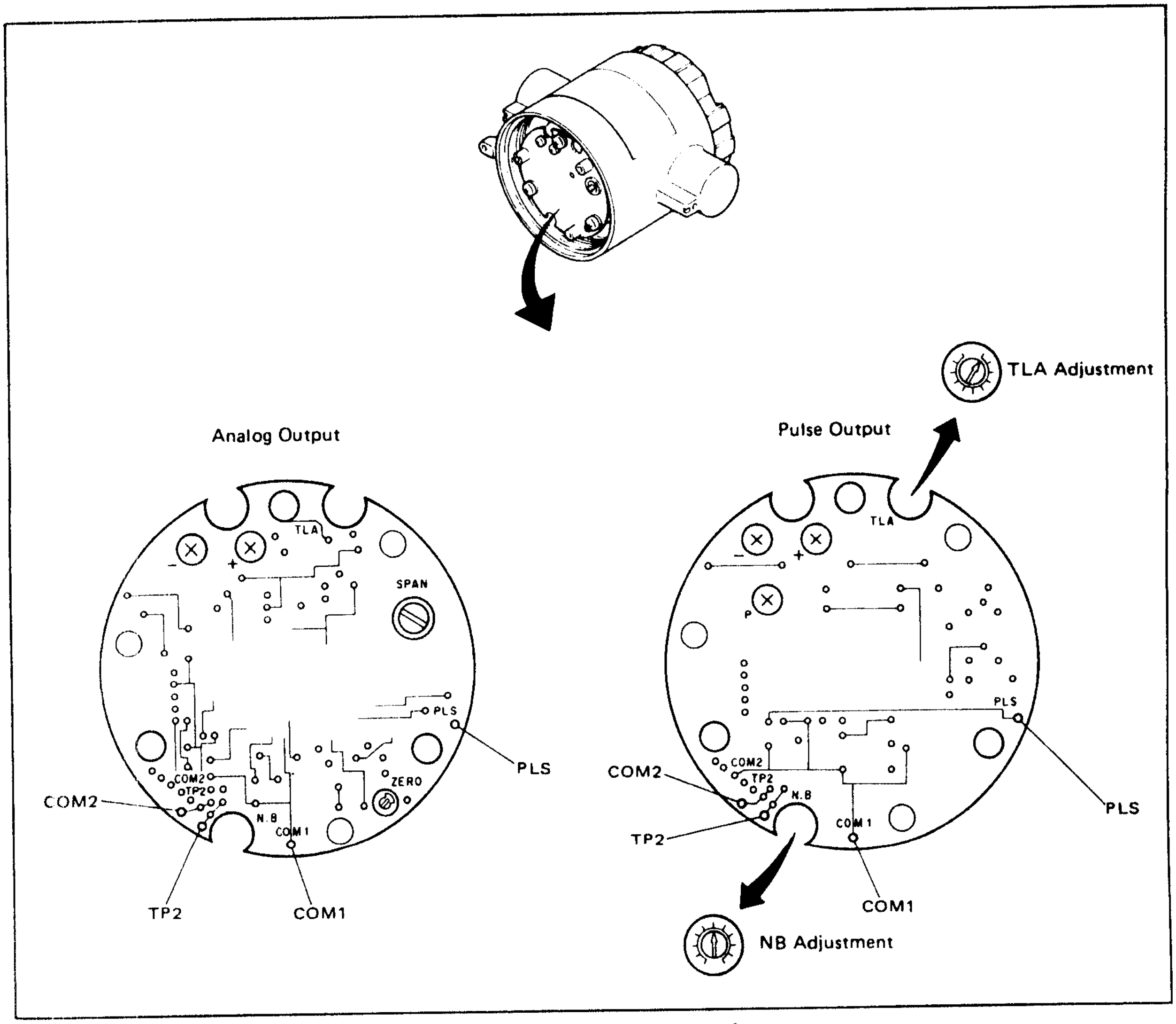


Figure 7-5. Check Terminals.

7-3-1. TP2 Check Terminal.

(1) Span adjustment
Refer to paragraph 6-2-2.

(2) NB adjustment
Refer to paragraph 6-2-3.

(3) Connect an oscilloscope between terminals TP2 and COM2. Check that the sine waveform is normal and also check that the signal conditioner assembly operates properly.

a. The vortex frequency must be normal as shown in Figure 7-6 and should not be the same level as power frequency or pipeline vibration frequency.

b. When fluid is not flowing, the signal should be less than 0.5 Vp-p noise level.

c. Figure 7-7 shows an unstable waveform due to incorrect piping. Insufficient straight pipeline length, eccentric piping, gasket interferes with fluid flow.

7-3-2. PLS Check Terminal.

(1) TLA adjustment
Refer to paragraph 6-2-4.

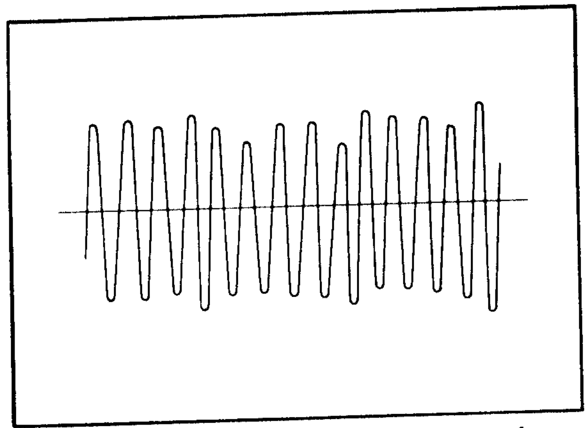


Figure 7-6. Normal Vortex Frequency Waveform.

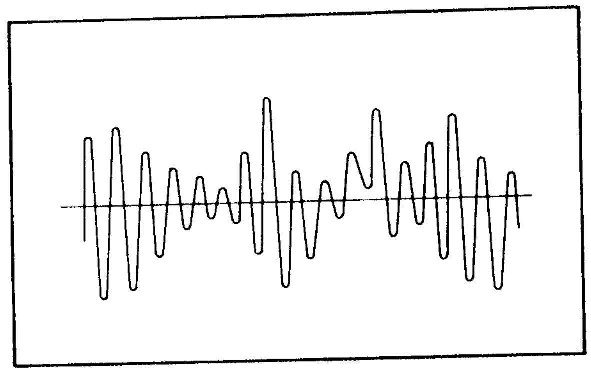
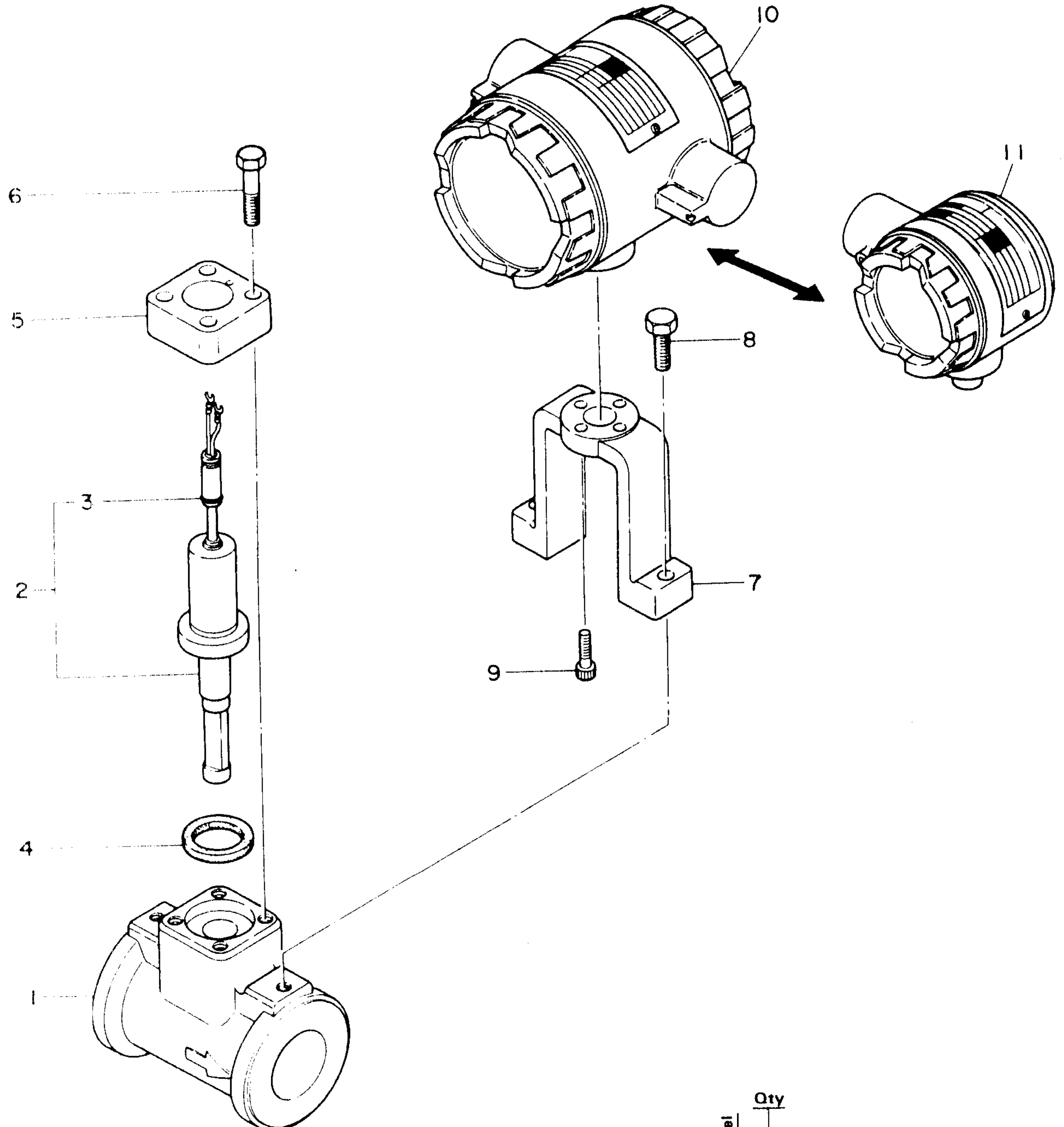


Figure 7-7. Unstable Waveform Due to Incorrect Piping.

Parts List

BODY ASSEMBLY
For Models FV-510, FV-515
VORTEX FLOWMETERS

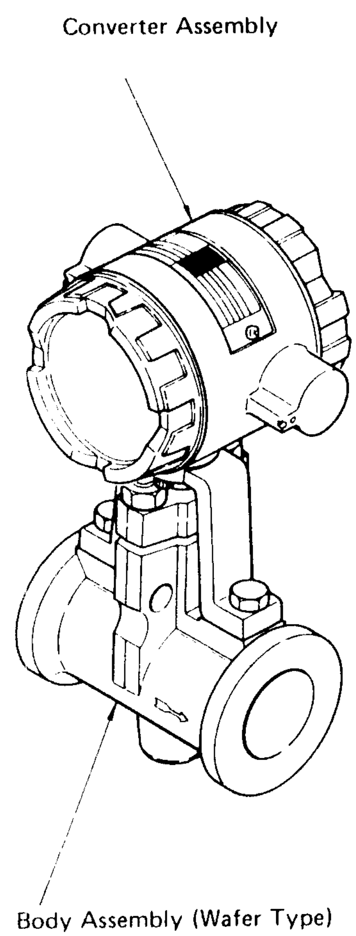


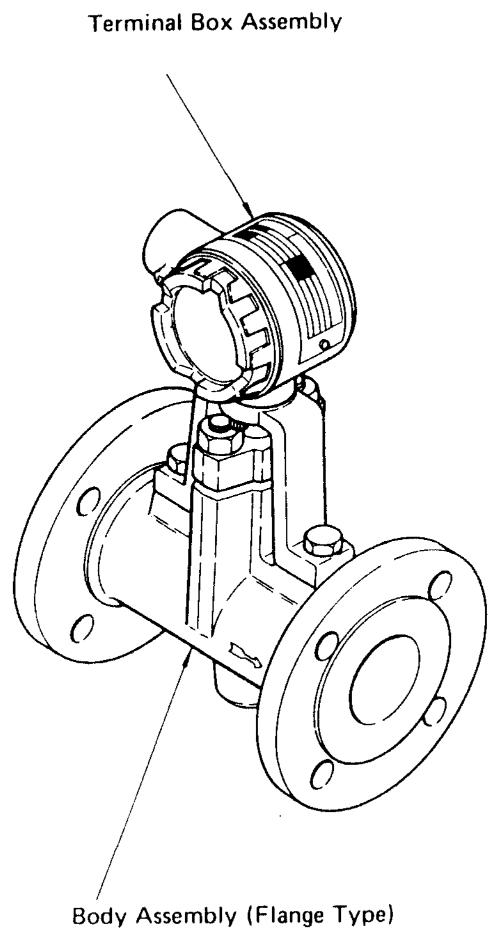
Item	Part No.	Model Qty FV-510	Model Qty FV-515	Description
1	Below	1	1	Body Assembly
	F9284AA			For JIS Wafer (1inch)
	F9284AB			For JIS Wafer (1-1/2 inch)
	F9284AC			For ANSI Wafer (1 inch)
	F9284AD			For ANSI Wafer (1-1/2 inch)
	F9284AA			For DIN Wafer (1 inch)
	F9284AB			For DIN Wafer (1-1/2 inch)
2	F9285QD	1		Vortex Shedder Assembly
	F9285QE		1	Vortex Shedder Assembly
3	G9303WH	1	1	O-Ring

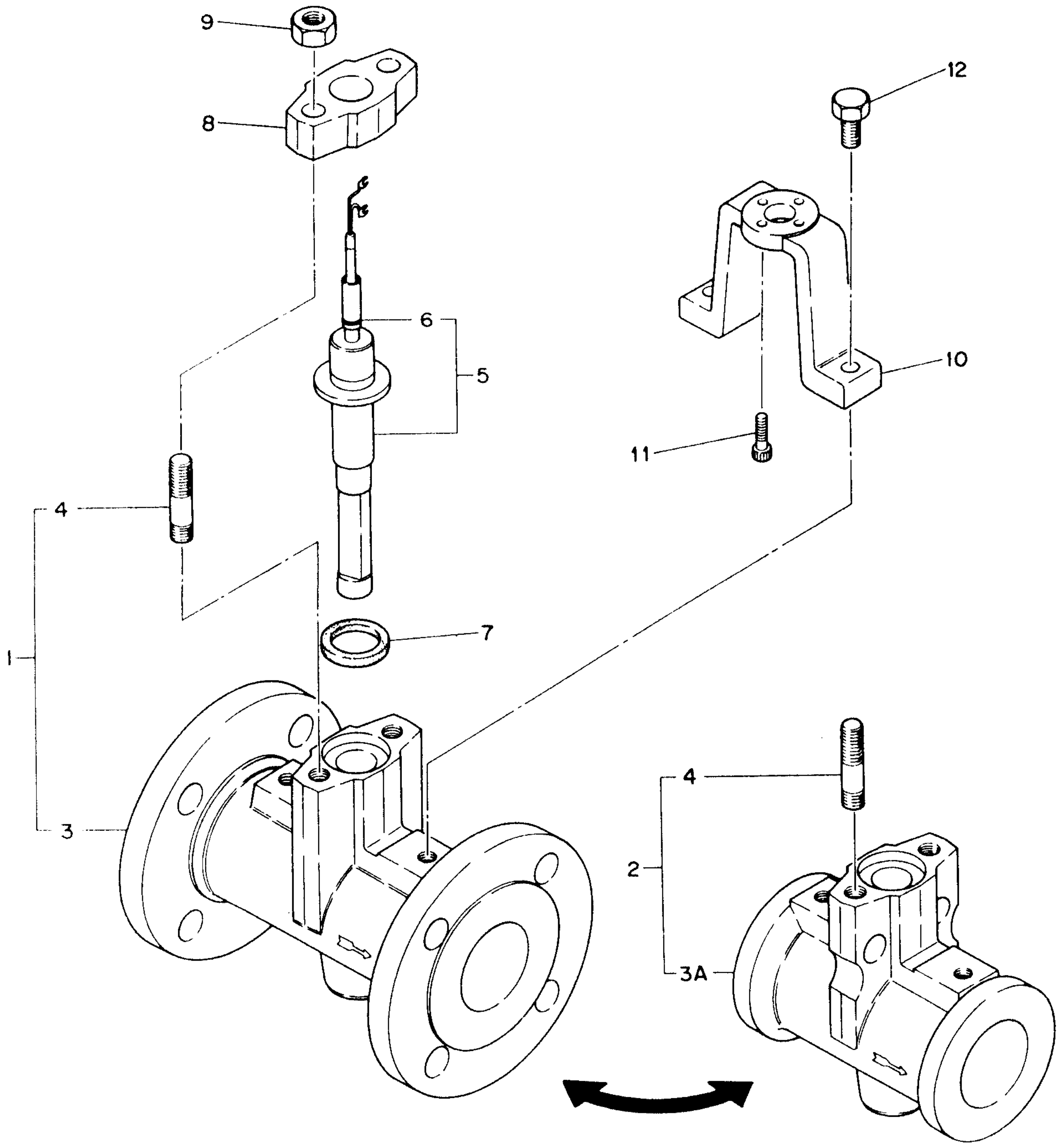
Item	Part No.	Model Qty FV	Model Qty FV-	Description
4	F9283RJ	1		Gasket
	F9283RK		1	Gasket
5	F9284FC	1	1	Plate Assembly
6	F9284FR	4	4	Bolt
7	F9284FA	1	1	Bracket
8	Y9825NU	2	2	Bolt
9	Y9520ZU	4	4	Hex Soc. H. Screw
10	–	1	1	Converter Assembly
11	–	1	1	Terminal Box Assembly

Parts List

BODY ASSEMBLY
For Models FV-520, 530, 540
VORTEX FLOWMETERS



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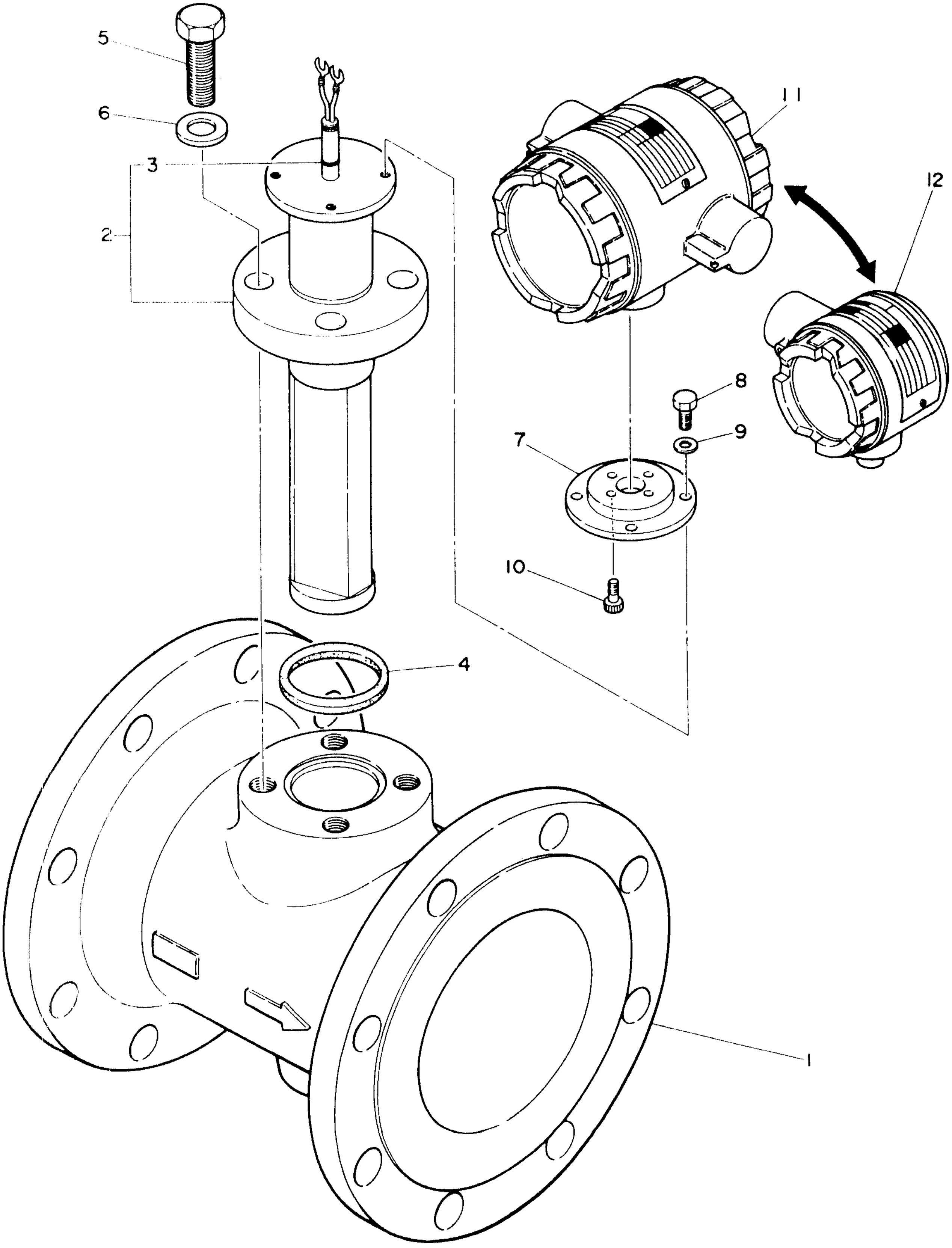
3A

Item	Part No.	Model / Q'ty FV-520	FV-530	FV-540	Description
1	–	1	1	1	Body Assembly (flange type)
2	–	1	1	1	Body Assembly (wafer type)
3	–	1	1	1	Body Assembly (flange type)
3A	–	1	1	1	Body Assembly (wafer type)
4	F9282XA	2			Bolt
	F9282XB		2		Bolt
	F9282XC			2	Bolt
5	F9285QF	1			Vortex Shedder Assembly
	F9285QG		1		Vortex Shedder Assembly
	F9285QH			1	Vortex Shedder Assembly
6	G9303WH	1	1	1	O-Ring
7	F9283NC	1			Gasket
	F9283ND		1		Gasket
	F9283NE			1	Gasket
8	F9283NJ	1			Plate
	F9283NK		1		Plate
	F9283NL			1	Plate
9	F9282XD	2			Nut
	F9282XE		2		Nut
	F9282XF			2	Nut
10	F9283NA	1	1	1	Bracket
11	E9135QM	4	4	4	Hex soc. H. Screw
12	Y9825NU	2	2	2	Hex H. Screw, M8 x 25

Parts List

BODY ASSEMBLY

For Models FV-560, FV-580
VORTEX FLOWMETER



Item	Part No.	Qty FV-560	Qty FV-580	Description
1	–	1	1	Body Assembly
2	F9285LG	1		Vortex Shedder Assembly
	F9285KA		1	Vortex Shedder Assembly
3	G9303WH	1	1	0-Ring
4	F9285KQ	1		Gasket
	F9285KR		1	Gasket
5	F9285LE	4	4	Bolt
6	Y9160WU	4	4	Washer
7	F9285LX	1		Plate
	F9285LD		1	Plate
8	Y9612NU	4	4	Bolt
9	Y9601WU	4	4	Washer
10	Y9514ZU	4	4	Bolt
11	–	1	1	Converter Assembly
12	–	1	1	Terminal Box Assembly

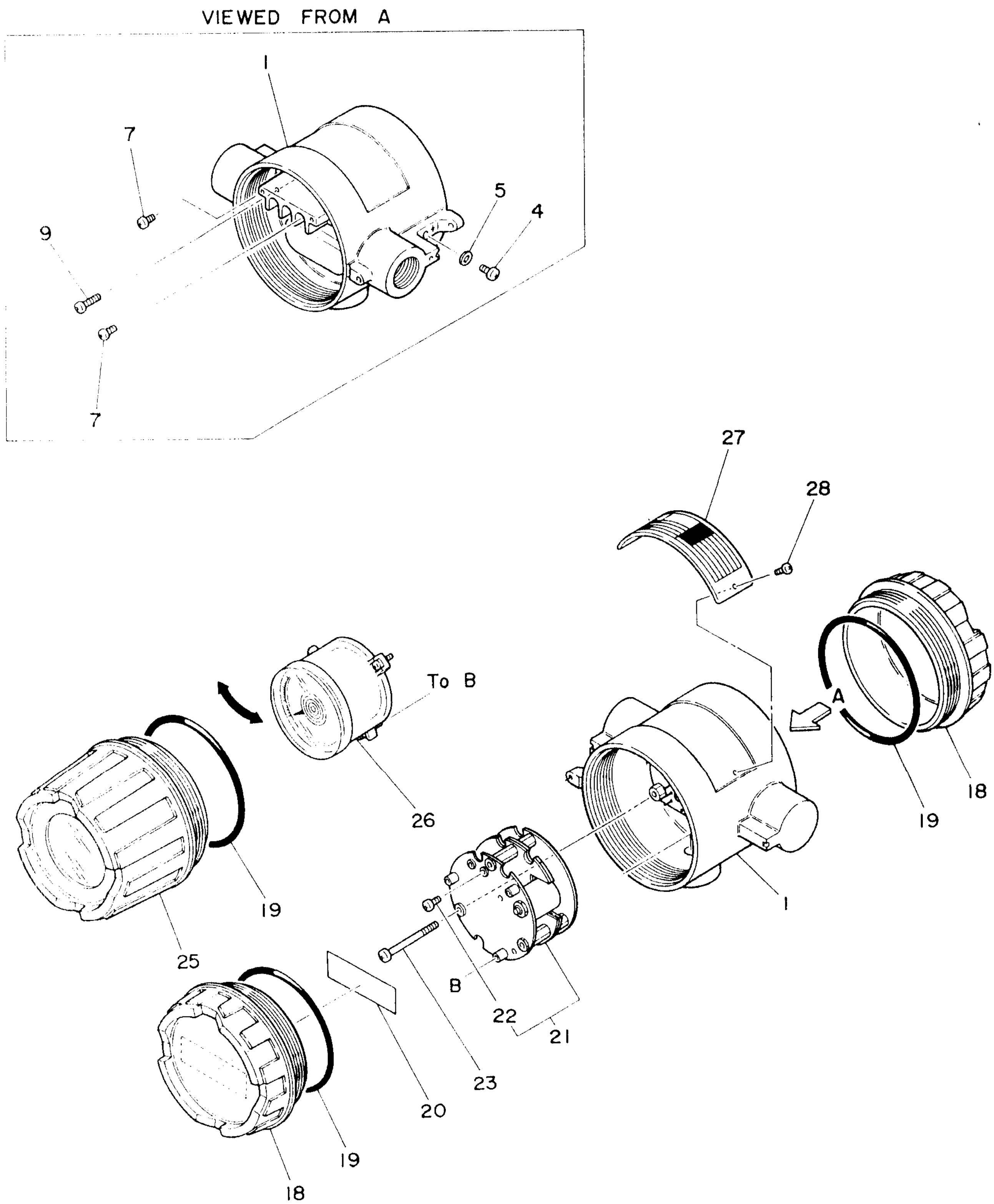
Body Assembly Part Number (item 1).

Model	Flange Rating	Body Assembly Material	
		Stainless Steel	Carbon Steel
FV-560	JIS 10 kg/cm²	F9284CD	F9284CK
	JIS 20 kg/cm²	F9284CE	F9284CL
	JIS 40 kg/cm²	F9284CF	F9284CM
	ANSI Class 150	F9284CA	F9284CG
	ANSI Class 300	F9284CB	F9284CH
	ANSI Class 600	F9284CC	F9284CJ
	DIN PN10/16	F9284LA	F9284LB
	DIN PN25/40	F9284LC	F9284LD
FV-580	JIS 10 kg/cm²	F9285XC	F9285XG
	JIS 20 kg/cm²	F9285XD	F9285XH
	ANSI Class 150	F9285XA	F9285XE
	ANSI Class 300	F9285XB	F9285XF

Parts List

CONVERTER ASSEMBLY

INTEGRAL CONVERTER TYPE
VORTEX FLOWMETERS



Item	Part No.	Qty	Description
–	Below	1	Case Assembly (item 1 through 10)
	F9284RA		For JIS Connection (General use type) } (for 4 to 20 mA DC output type)
	F9284RC		For ANSI Connection } (for 4 to 20 mA DC output type)
	F9284RQ		For DIN Connection } (for 4 to 20 mA DC output type)
	F9284RB		For JIS Connection (General use type) } (for pulse output type)
	F9284RD		For ANSI Connection } (for pulse output type)
	F9284RR		For DIN Connection } (for pulse output type)
1	–	1	Case Assembly
4	Y9506LU	1	B.H. Screw, M5 x 6
5	Y9501WL	1	Toothed Lockwasher
7	Y9405LB	4	B.H. Screw, M4 x 5
8	Y9400SP	3	Spring Washer
9	Y9314JB	2	Pan H. Screw, M3 x 14
10	Y9401WL	1	Toothed Lockwasher
18	F9283AK	2	Cover
19	G9303AP	2	O-Ring
20	F9283XB	1	Label (for ANSI and DIN connection)
21	See Table	1	Amplifier Assembly
22	Y9304JB	3	Pan H. Screw, M3 x 4
23	F9284NX	3	Pan H. Screw, M4 x 45
25	F9283BG	1	Cover Assembly } (option, for analog output type)
26	B9098AA	1	Meter Assembly } (option, for analog output type)
27	–	1	Nameplate (data plate)
28	F9270SA	2	Self-tapping Screw

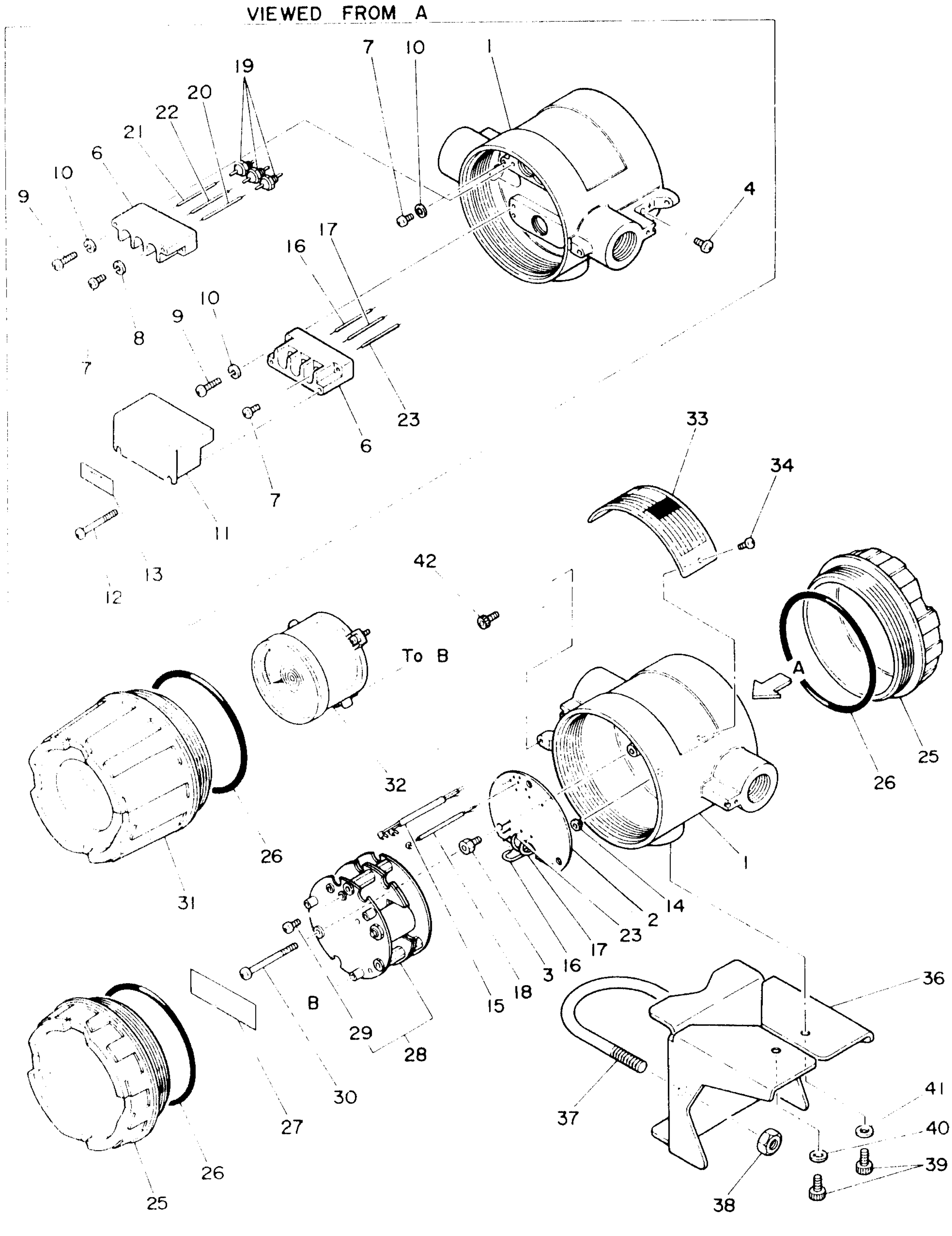
Amplifier Assembly Part Number. *

Fluid	Analog Output	Pulse Output
Liquid	F9286AJ	F9286AX
Gas or Steam	F9286BJ	F9286BX

*Install shorting link to selector pins and set gain adjustment.

Parts List

REMOTE FLOW CONVERTER



Item	Part No.	Qty	Description
	Below	1	Case Assembly (items 1 thru 24)
	F9284RG		For JIS Connection (General use type) (for 4 to 20 mA output type)
	F9284RJ		For ANSI Connection (for 4 to 20 mA output type)
	F9284RH		For JIS Connection (General use type) (for pulse output type)
			For JIS Connection (for pulse output type)
	F9284RK		For ANSI Connection (for pulse output type)
1	Below	1	Case Assembly
	F9283AC		For JIS Connection
	F9283AF		For ANSI Connection
2	F9283EX	1	Shield Plate Assembly
3	F9282PF	3	Screw
4	Y9506LU	1	B.H. Screw, M5 x 6
5	Y9501WL	1	Toothed Lockwasher
6	F9283FC	2	Terminal Assembly
7	Y9405LB	7	Pan H. Screw, M4 x 5
8	Y9400SP	6	Spring Washer
9	Y9314JB	4	Pan H. Screw, M3 x 14
10	Y9401WL	1	Toothed Lockwasher) (for JIS connection)
11	F9283FK	1	Cover
12	Y9335JB	2	Pan H. Screw, M3 x 35
13	F9283FN	1	Label (for ANSI connection)
	F9282ES	1	Label (for JIS connection)
14	F9283BW	1	Bushing

Item	Part No.	Qty	Description
15	F9283SS	1	Cable Assembly
16	G9076UA	–	Wire (red, specify length)
17	G9078UA	–	Wire (white, specify length)
18	F9283SR	1	Cable Assembly (for pulse output type)
19	G9018CC	3	Capacitor
20	G9076UA	–	Wire (red, specify length)
21	G9075UA	–	Wire (black, specify length)
22	G9078UA	–	Wire (white, specify length)
23	G9075UA	–	Wire (black, specify length)
25	F9283AK	2	Cover
26	G9303LJ	2	O-Ring
27	F9283XB	1	Label (for ANSI connection)
	F9283XC	1	Label (for JIS connection)
28		1	Amplifier Assembly
29	Y9304JB	3	Pan H. Screw, M3 x 4
30	Y9445JB	3	Pan H. Screw, M4 x 45
31	F9283BG	1	Cover Assembly (option, for analog output type)
32	B9098AA	1	Meter Assembly (option, for analog output type)
33	–	1	Nameplate (data plate)
34	F9270SA	2	Self-tapping Screw
36	F9281AY	1	Bracket
37	E9144CT	1	U-Bolt
38	Y9801BU	2	Nut
39	F9512ZU	2	Hex soc. H. Screw, M5 x 12
40	Y9501WL	1	Toothed Lockwasher
41	Y9500WB	1	Washer
42	Y9410ZX	2	Screw

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