New Style Insert Differential Pressure Type Flowmeter

# wellbar® FLOWMETER

# OPERATING MANUAL

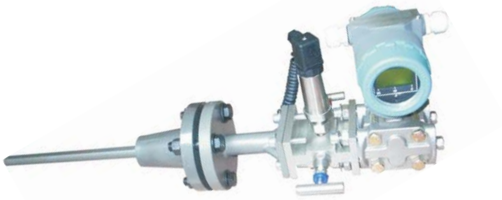

wellbar

## TABLE OF CONTENTS

## Overview

As a new style of insert instrument for flow measurement designed and produced by applying the operating principle of differential pressure, Wellbar Flow meter is a flow metering system consisting of an integrated Wellbar sensor, a differential pressure transmitter and an integrating instrument etc. and it can be connected to a control system or a computer to form a network so as to conduct fluid flow measurement and control. The intelligent integrated fluid measuring instrument can measure simultaneously the multiple variable signals as the pressure differential, pressure and temperature of the fluid in the pipe, thus to realize the on-site display and formation functions. Meanwhile, it can display the transient accumulative flow, pressure differential, temperature, flow rate and other parameters. Wellbar sensor has intently represented the latest research findings in velocity averaging flow sensors. The sensor is bullet-shaped in compliance with the theory of fluid dynamics. It can offer precise and stable differential pressure signals, strong strength, seepage resistance and clogging resistance. The sensor can ensure features, such as high measurement precision and perfect reliability and stability. The flowmeter can be used to measure multiple fluids, including gas, liquid, steam and corrosive media. It is suitable for pipes of various dimensions and can be applied in locations under high temperature and high pressure.

## Main Feature



**Integrative Wellbar Flowmeter**

Measurement Precision: ±1.0 %
Repeatability Precision: ±0.1 %
Application Pressure Range: 0~25MPa, in special application it can be up to 40MPa.
Application Temperature Range: -100℃~500℃, in special application it can be up to 800℃.
Measurement Upper Limitation: It depends on the requirements of craft and the strength of detector.
Measurement Lower Limitation: It depends on the requirement of the lowest measurement differential pressure (shown in the following table). When it is less than the lowest measurement differential pressure, it can meet the requirement by special design.

| Fliud | Lowest differential pressure | Flow rate |
|---|---|---|
| Gas | 0.026KPa | 4.5 m/s |
| Liquid | 0.260 KPa | 0.6 m/s |
| Steam | 0.400 Kpa | 9.7 m/s |

Measurement Range Ratio: When the measurement precision is ±1.0 %, the Measurement Range Ratio is 10:1. In special application, it can be 20:1.
Application Tube Diameter Range: 12mm~15000mm.
Applicable Medium: full package, unidirectional gas, steam, and liquid with viscosity not more than 10 centipoise. Requirement of Straight Tube Section: Usually the measurement precision of the first 7D, last 3D should be±2.0 %.

## Measurement Principle and Characteristic Analysis

### Operating Principle

Wellbar Flow Sensor forms the fluid measurement control system with the secondary instruments (or other remote monitoring instruments) such as the pressure differential transducer and flow totalizer. Wellbar Flowmeter is a style of insert-type instrument for flow measurement. While a Wellbar sensor is inserted into a pipe, with fluid flowing through the sensor, a high-pressure distribution area and a low-pressure distribution area will be formed respectively in the front end (the direction of incident flow) and in the rear end. The sensor has many pairs (generally three pairs) of pressure ports in both high and low pressure areas, which are arranged based on a certain rule. These pressure ports are used to measure the total pressure (including the static pressure and average velocity pressure) $P_1$ and the static pressure $P_2$ of the fluid. The $P_2$ is measured by the low pressure ports on the sides of detector (the direction of downstream). Introduce $P_1$ and $P_2$ separately into the differential pressure transmitter to measure the pressure difference $\triangle P=P_1-P_2$ . $\triangle P$ represents the magnitude of the average velocity of the fluid, based on which the fluid flow can be concluded. The formulas for flow calculation are as follows:

*Formula of volume flow*

$$Q=0.12645KY_1D^2\sqrt{\frac{\triangle P}{\rho}}$$

*Formula of mass flow*

$$M=0.12645KY_1D^2\sqrt{\triangle P\bullet\rho}$$

*Formula of standard volume flow of gas*

$$Q_{20}=0.36584KY_1D^2\sqrt{\frac{\triangle P}{\rho}}\bullet\left[\frac{P_a}{T_a}\right]$$

Where Q - Volume flow in m3/h under operating conditions.
M - Mass flow in Kg/h.
$Q_{20}$ - Volume flow in Nm3/h under the standard conditions of gas (standard conditions with 20℃ and 101.325 Kpa atmospheric pressure).
△P - Differential pressure, KPa.
$\rho$ - Density in Kg/m3 of the fluid being measured under operating conditions.
K - Flow coefficient, the magnitude of which is related to the structure of the sensor, fluid flow conditions and caliber sizes etc.And it shall be calculated through experiments.
$Y_1$ - Gas expansion factor, the magnitude of which is related to the gas pressure, the flow rate, the area ratio and the magnitude of pressure difference and shall be calculated through experiments.
D - Equivalent diameter of the measured pipe, mm
$P_a$ - Operating pressure of Gas (absolute pressure), KPa.
$T_a$ - Operating Temperature (absolute temperature), K.
Above formulas can be simplified to represent the proportionate relation between the flow and the square root of the pressure difference:

$$Q=C_1\sqrt{\triangle P}$$

$$M=C_2\sqrt{\triangle P}$$

$$Q_{20}=C_3\sqrt{\triangle P}$$

Where $C_1$- Comprehensive flow coefficient (corresponding to the volume flow under operating conditions)

$$C_1=0.12645KY_1D^2/\sqrt{\rho}$$

$C_2$ - Comprehensive flow coefficient (corresponding to the mass flow)

$$C_2=0.12645KY_1D^2\bullet\sqrt{\rho}$$

$C_3$ - Comprehensive flow coefficient (corresponding to the standard volume flow of gas)

$$C_3=0.36584KY_1D^2\bullet\left[\frac{P_a}{T_a}\right]/\sqrt{\rho}$$

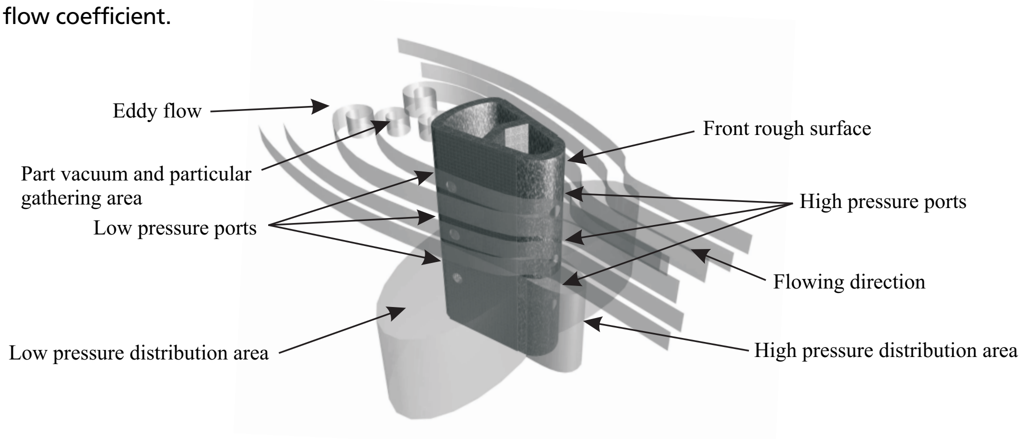
It can be seen from above formulas that if D, $\rho$ , K, $Y_1$,$F_1$ and $\rho_{20}$ have already been calculated or given, the flow of the fluid being measured can be calculated from the measured pressure difference △P.

## Qualitative

### Design

● Bullet Head figure with special craft

The applied special craft of Wellbar flow sensor are: detector with bullet head figure cross section, integrated double cavity stainless steel wearable and anticorrosive metal structure. It's shown in figure 2. The high pressure area is formed at the front end of detector by high pressure ports. It can prevent the particulates entering into the pressure ports. The low pressure ports are on the two side faces of detector and before the separating points of the hydro and detector. By this way, it can reduce the possibility of jamming the low pressure ports. On the front end metal surface of detector, it applies the rough treatment. According the aerodynamics theory, when the hydro flows passing the rough surface, a stable turbulent flow boundary layer is formed. It is useful to increase the measurement precision. By this way, even when the flow rate is slow, the detector can still get a stable differential pressure signal. Then it extends the measurement range lower limitation of the sensor and keeps the stability of flow coefficient.



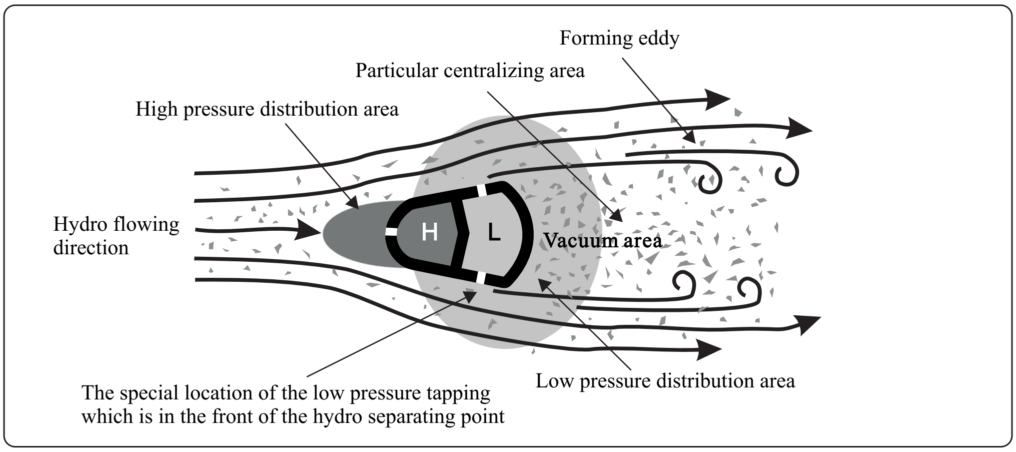

**Principle analysis drawing of Wellbar flow sensor**

**Wellbar detector entity drawing**

● Obvious Anti-jamming effect

With its obvious anti-jamming effect, Wellbar flow sensor solves the jam problem troubling other mean velocity tube flow transducer. It advances the anti-jamming capability of mean velocity tube flow transducer to a new high level.

At first the high pressure ports on the incident flow surface of the Wellbar sensor (detector) will not be jammed. At the first operation of the flow sensor, hydro enters into the high pressure ports inner cavity of the detector under the static pressure of the tube. It's same as a bottle with neck is filled with water in a pool. The pressure static balance is formed soon. After the pressure balance is set up, hydro won't enter the ports any more and bypass because of the high pressure at the ports. By split-flowing to the both sides of the sensor in involute mode, it forms an eddy flow at the rear end of the detector. Usually by the draft load of eddy flow, granule particular centralize at the rear end of the detector just as swept by the wind, the falling always centralize at the lee. The low pressure ports are located at the both sides of the sensor and in the front of the separating point and wake of the hydro, so the low pressure area can be out of the particular centralizing area. By this way, the Wellbar flow sensor realizes anti-jamming radically and generates stable differential pressure signal.




**The hydro track distribution sketch map**

## Low permanent pressure loss of the tube, low installation cost, maintenance free

The pressure loss produced by the pore plate is 60% of the measured differential pressure. And the permanent pressure loss of Wellbar flow sensor is only 3%.

● Pressure loss comparison:

The equation of the power loss caused by the throttle component:

$W=ä\times Q$

Here: W=power loss

$ä$ The pressure loss of throttle component

$Q$ Volume flow of the hydro flowing by the throttle component

The experiment equation of pressure loss basing on pore plate:

When $â= 0.6$, $ä =0.6\times\triangle P$

Here: $â$ The hole diameter ratio of the pore plate

$\triangle P$ Produced differential pressure

$ä$ Produced pressure loss

The pressure loss of Wellbar sensor:

$ä\leqslant 0.03\times\triangle P$

It can be seen from above equations that the differential pressure produced by pore plate is bigger than that produced by Wellbar flow sensor. And to the pore plate the permanent pressure loss will be inevitably 60% of the measured differential pressure, but to Wellbar flow sensor it is only 3% because of the pressure loss reduced by several times caused by the reduction of choked flow area.

● Installation Cost
To the installation of Wellbar flow sensor, only simple welding work is need. The size of the sensor is ranged from 4 cm to 20 cm. It has nothing to do with the tube diameter. Relative to needed welding work of twice the tube circle for pore plate, the installation cost of Wellbar sensor is reduced much more. For example, for the installation of Wellbar sensor on tubes from DN100 to DN1000, the needed welding line is only about 10cm, but to pore plate it's about 600cm. Especially during the installation of big tube, because of the weight of pore plate, some assistant equipments are needed, for example crane. But to Wellbar flow sensor, only 1 to 3 builders are needed. So comparatively Wellbar flow sensor can save at least 80% installation cost. Basing on experience, to the installation of Wellbar flow sensor, for the drilling 15 minutes are needed, welding installation base 30 minutes, fixing sensor 15 minutes. So the total time is less than 1 hour. Even during the installation, the production line is running, the total time is only about one and a half hour.
● Supporting on-line installation and maintenance For those measure points that is impossible to stop production line for the installation or those medium that are abundant of particular, the on-line installation is permit. Under the permit condition of flow, temperature, pressure, the Wellbar flow sensor can be installed when the production line is running. And it can also be checked and maintained when the production line is running.
● Wide Measurement range and Application Wellbar flow sensor can be used for the measurement of full tube and unidirectional hydro of medium such as diversified gas (air, coal gas, natural gas, etc), steam, liquid (water solution and some other medical solution). It can also be used for round tube or rectangular tube with different size. The design of sensor is original. It applies special craft made double cavity bullet head structure by integration 316L metal. It is suitable for the application in high temperature, high pressure, corrosive, explosive and some other danger condition.
● High precision, wide measurement range Usually the Wellbar flow sensor has following characteristic: ±1% measure precision, ±0.1% repeatability, 10:1 measurement range ratio. After the tube connection type (VRB60 type) is processed by special craft, the measurement range ratio can be 20:1 without requirement on straight tube.

## Quantitative Analysis

To illustrate the energy saving effect of Wellbar flow sensor in detail, the comparison of the heat energy loss between the standard pore plate and Wellbar flow sensor by common steam flow 40t/h is shown in the following:
The known condition of measurement of steam flow
Max flow $Q_{max}$ = 50 t/h  Common flow $Q_{com}$ = 40 t/h
Work pressure: 0.6MPa  Work Temperature: 270℃  Tube Size: 529×7mm
The design calculation parameters of standard pore plate
Hole diameter of pore plate (20℃) $d_{20}$:210.1814mmDiameter ratio β = 0.38913
Max differential pressure $\triangle P_{max}$ = 100KPa
Common differential pressure $\triangle P_{com}$ = 64KPa
Density of Steam ( 0.7 Mpa absolute pressure, 270℃ work temperature) $\rho$ = 2.85307kg/m$^3$
The calculation of heat energy loss of standard pore plate
a. The pressure loss of pore plate under operation condition
Calculation equation: $\ddot{a} = (1-\beta^{1.9})\,\Delta P$
Pressure loss with common flow: $\ddot{a}_{com}=(1-0.38913^{1.9})\times 64=53.3497\ KPa$
Pressure loss with max flow: $\ddot{a}_{max}=(1-0.38913^{1.9})\times 100=83.3589\ KPa$
b. The heat energy loss converted from pressure loss of pore plate:
Calculation equation: $P=\dfrac{Q}{\rho\times 3600}$
Here: P-Power KW
$\tilde{n}$-Steam density kg/m$^3$
$\ddot{a}$-Pressure loss of pore plate KPa
$Q$-Steam flow kg/h
Power loss with common flow:

$$P_{com}=\frac{40000\times 53.3497}{2.87307\times 3600}=207.767KW$$

Power loss with max flow:

$$P_{max}=\frac{50000\times 83.3589}{2.85307\times 3600}=405.795KW$$

c. The coal consumption of power loss

Know parameters: *1KW/hour = 859.845 KC1kg standard coal = 7000 KC*

Now only the coal consumption converted from power loss with common flow. The daily coal consumption:

$$Coal\ consumption/day = 24 \times P_{com} \times 859.845/7000 = 24 \times 207.767 \times 859.845/7000 = 612.50542kg$$

Considering the heat effect of boiler is 0.9, so the actual daily coal consumption:

$$612.52542/0.9 = 680.56kg/day\ (Standard\ coal)$$

Taking into account the operation days per year is 300 days, the coal consumption caused by pore plate per year is:

$$680.56 \times 300 = 204.168\ ton\ (Standard\ coal)$$

If the price of standard coal is 400AUD per ton, the economy loss from pore plate every year is:

$$680.56 \times 400 = AUD81，667.20 \approx AUD81,660.00$$

## The heat loss calculation of Wellbar flow sensor

a. Calculate the pressure loss under work condition of Wellbar flow sensor

The differential pressure △P is produced when the steam flows pass the Wellbar flow sensor. It can be calculated by software.

Differential pressure under max flow:

$$\triangle P = 0.848KPa$$

Differential pressure under common flow:

$$\triangle P_{com} = (40/50)^2 \times 0.848 = 0.543\ KPa$$

Because the differential pressure from Wellbar flow sensor is little, about one tenth of that from pore plate, the pressure loss is much less (to tube whose diameter is bigger than 500mm, the pressure loss of Wellbar flow sensor is about 3%). To illustrate the obvious energy saving effect of Wellbar flow sensor, it takes into account the 100% pressure loss.

Pressure loss under max flow:

$$\ddot{a}_{max} = \triangle P_{max} = 0.848\ KPa$$

Pressure loss under common flow:

$$\ddot{a}_{com} = \triangle P_{com} = 0.543\ KPa$$

b. Heat loss converted from pressure loss of Wellbar flow sensor. It's same as the calculation of pore plate.

Power loss under common flow:

$$P_{com} = \frac{40000 \times 0.543}{2.85307 \times 3600} = 2.1147KW$$

c. Calculate the coal consumption from the power loss

Under common flow, the daily coal consumption is:

$$Coal\ consumption/day = 24 \times 2.1147 \times 859.845/7000 = 6.234kg/day\ (Standard\ coal)$$

Considering the heat effect of boiler is 0.9, so the actual daily coal consumption:

$$6.234/0.9 = 6.927\ kg/day\ (standard\ coal)$$

Considering 300 days per year, the coal consumption of Wellbar flow sensor is:

$$6.927/300 = 2078.1\ kg = 2.078\ ton\ (standard\ coal)$$

If the price of standard coal is 400 RMB per ton, the economy loss from pore plate every year is:

$$2.078/400 = 831.2AUD$$

## Comparison and Analysis

From above comparison results, it can be seen that the economy loss because of pressure loss of Wellbar flow sensor is only about 1%(831.2/81667.2 = 1%) of that of pore plate. So energy saving and economy profit caused by Wellbar flow sensor is obvious.

## Model selection schedule and Description

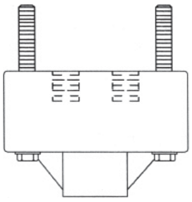
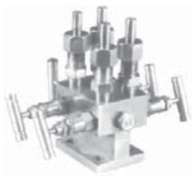
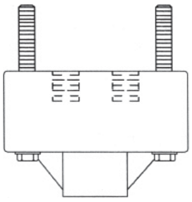
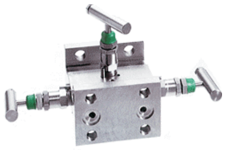
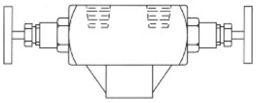
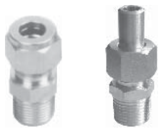
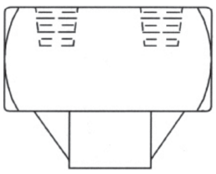
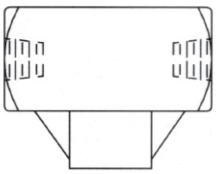
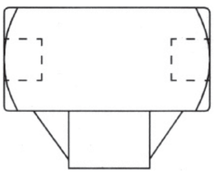
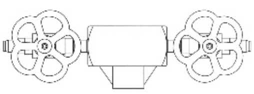
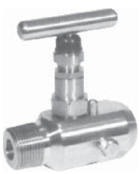
| Item | Specification & Code | Description |
|---|---|---|
| Model of Sensor | VRB66········· | Wellbar sensor (Multi point cross section) |
| | VRB65········· | Wellbar sensor (wholly welded) |
| | VRB64········· | Wellbar sensor (on-line installation) |
| | VRB63········· | Wellbar sensor (Clamp connection) |
| | VRB62········· | Wellbar sensor (flanged connection) |
| | VRB61········· | Wellbar sensor (threaded connection) |
| | VRB60········· | Wellbar sensor (small pipes connection) |
| Support Configuration | 0········· | Single support (below 800mm) |
| | 1········· | Double support (above 800mm , Does not apply to model 64) |
| Probe Specification | B········· | Large (800mm~8000mm，>8000mm particularly customize) |
| | M········· | Medium (100mm~800mm) |
| | S········· | Small (<100mm) |
| Measurement Medium Working Pressure/ Temperature | —A □/□········· | Air，□℃ temperature / □ MPa pressure |
| | —L □/□········· | Liquid，□℃temperature / □ MPa pressure |
| | —S □/□········· | Steam，□℃temperature/ □ MPa pressure |
| | —G □/□········· | Coal gas,flue gas,nitrogen gas,other gases,□℃temperature/□MPa pressure |
| | —E □/□········· | Strong- corrosive medium, □℃temperature / □ MPa pressure |
| Method of Connection with Transmitter | —F········· | Five-valve manifold connection |
| | —Z········· | Three-valve manifold connection |
| | —T········· | Two-valve manifold connection |
| | —P········· | Upward welding with pipe fitting connection |
| | —R········· | Both-side transform valve sleeve pipe fitting connection |
| | —S········· | Horizontal inserted-welding connection at both side. |
| | —V········· | High-pressure valve direct-welding connection. |
| Intergrated Differential Pressure Flow Measurement | N········· | Not equipped Differential Pressure Flow Transmitter |
| | D········· | Equipped Differential Pressure Transmitter |
| | Q········· | Equipped Flow Transmitter |
| Intergated Pressure Measurement (pressure compensation) | N········· | Not equipped Pressure Transmitter |
| | Y········· | Equipped Pressure Transmitter |
| Intergated Temperature Measurement (temperature compensation) | N········· | Not equipped Temperature Measurement Component |
| | K········· | Equipped K Type Thermocouple |
| | P········· | Equipped Pt100 Thermal Resistance |
| Pipe Dimension | H········· | Horizontal Installation |
| | U········· | Vertical Installation |
| Pipe material | —Round pipe：Diameter/thickness | |
| | —Square pipe：Length/width/thickness | |
| Pipe Direction | —CS ······ | Carbon Steel (Indicate the model of material) |
| | —SS ······ | Stainless Steel (Indicate the model of material) |
| | —CM······ | Alloy Steel (Indicate the model of material) |
| | —NM······ | Non-metallic (Indicate the model of material) |
| *Code of model selection* | Usually combined by five random numbers or English letters | |
| *(Particular explanation)* | Remark: Generally, the body of the sensor and all the parts are made by 316L stainless steel. | |

## Technical Parameter and Application

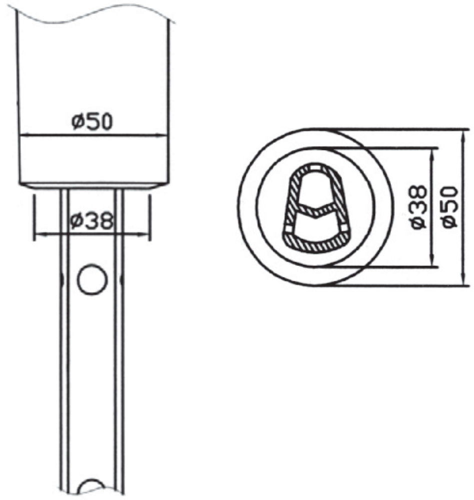
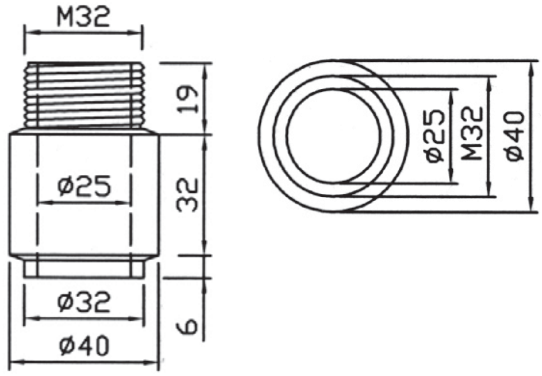
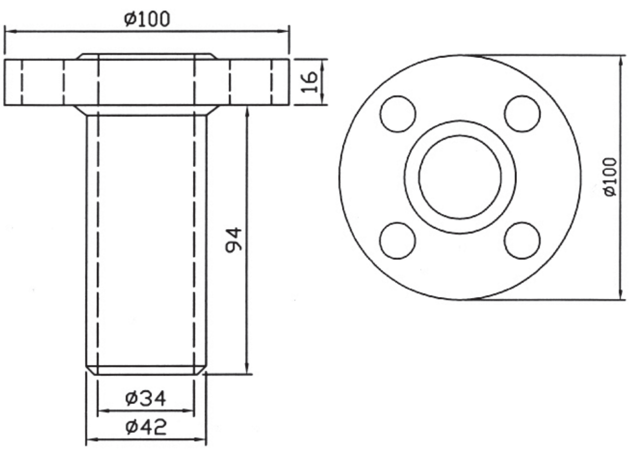
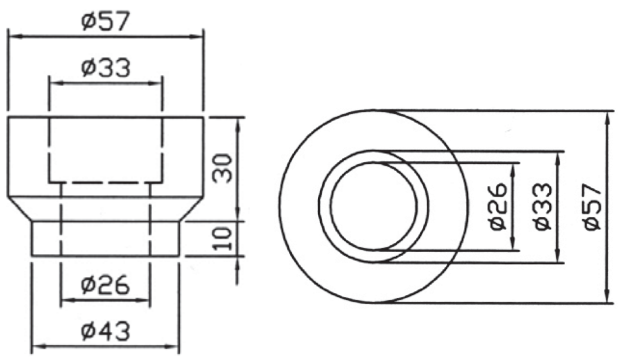
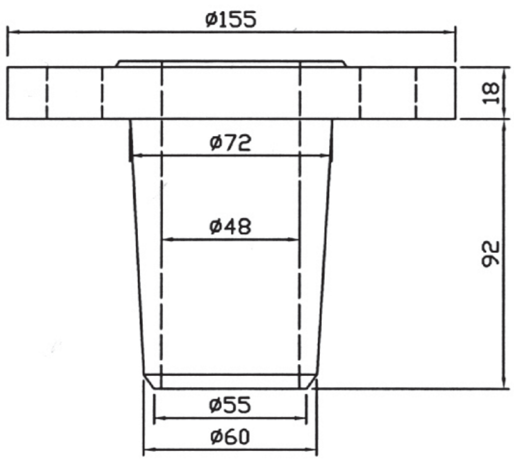
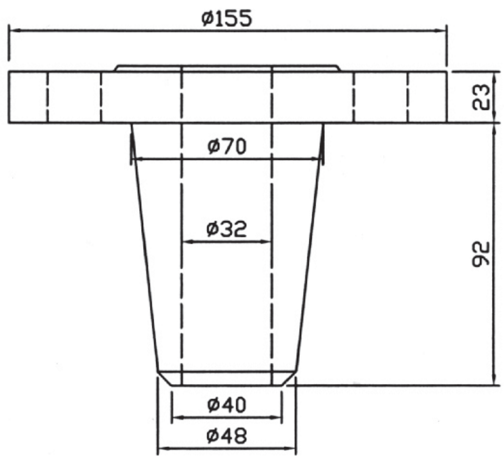
| Model | VRB66 | VRB65 | VRB64 | VRB63 |
|---|---|---|---|---|
| External View |  | <br>(Double support) |  |  |
| Range of Diameter | 100～15000mm | 80～3000mm | 50～5000mm | 50～2000mm |
| Suitable Medium | Air<br>Applied to boiler air quantity measurement | High-pressure gas<br>High-pressure liquid<br>High-pressure steam | Low-pressure gas<br>Low-pressure liquid<br>Low-pressure steam | Apply to non-metallic pipe, gas, liquid, and non-dangerous situations |
| Range of Pressure | 0～1.6MPa | Generally 0～40.0MPa | Generally 0～2.5MPa | Generally 0～2.5MPa |
| Range of Temperature | Generally -80～550℃ | Generally -80～550℃<br>Particularly 700℃ | Generally -80～250℃ | Generally -80～250℃ |
| Range Ratio | Better than 10:1 | Better than 10:1 | Better than 10:1 | Better than 10:1 |
| Min. Flow Rate | Gas⩾4.5m/s | Gas⩾4.5m/s<br>Liquid⩾0.6m/s<br>Steam⩾9.7m/s | Gas⩾4.5m/s<br>Liquid⩾0.6m/s<br>Steam⩾9.7m/s | Gas⩾4.5m/s<br>Liquid⩾0.6m/s<br>Steam⩾9.7m/s |
| Measurement Precision | ±1% | ±1% | ±1% | ±1% |
| Repeatability | ±0.1% | ±0.1% | ±0.1% | ±0.1% |
| Method of Installation & Connection | Multi point cross section | Wholly welded | On-line installation and regulation | Clamp connection |
| Supporting Instrument | Differential pressure transmitter and flow integrating instrument etc | | | |

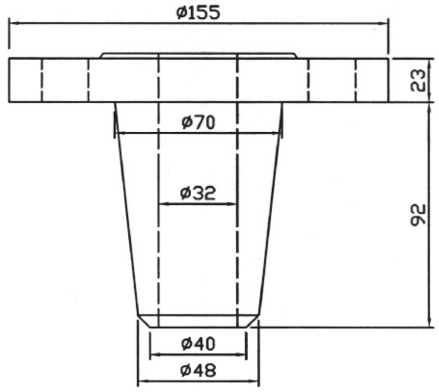
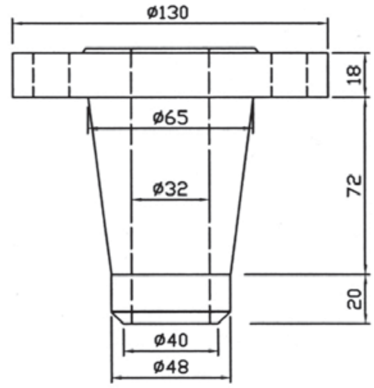
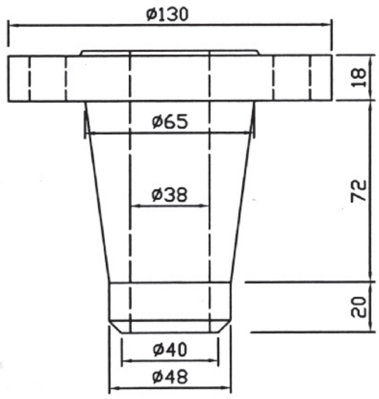
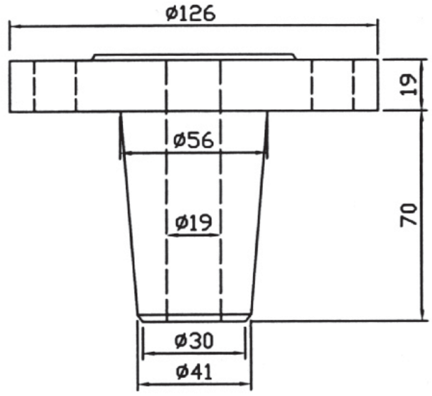
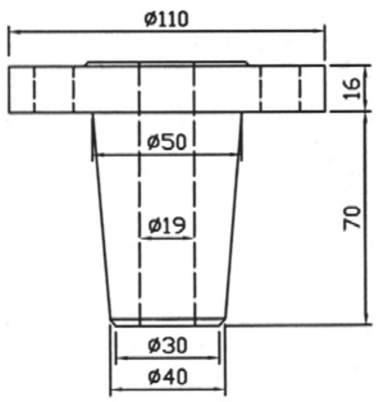
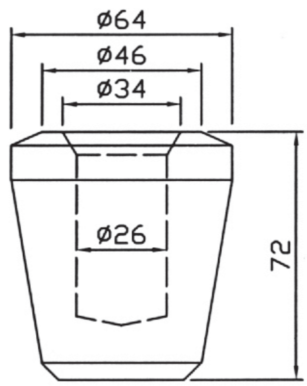
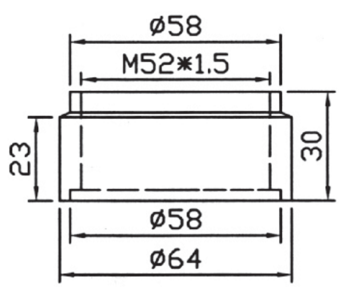
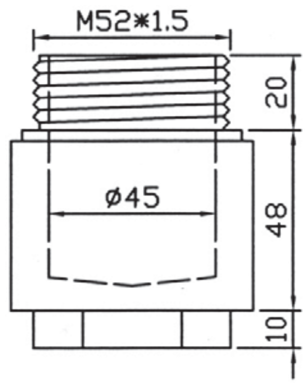
| Model | VRB62 | VRB61 | VRB60 |
|---|---|---|---|
| External View |  *(Double support)* |  |  |
| Range of Diameter | *50～15000mm* | *50～15000mm* | *12～80mm* |
| Suitable Medium | *High and low pressure steam, liquid, gas, suitable for pipeline gas measurement and dangerous situations* | *Suitable for use at normal temperature and pressure of liquids, gases and non-hazardous situations* | *Suitable for small pipe high, the low pressure steam, gas, liquid flow measurement* |
| Range of Pressure | *Generally0～4.0MPa* | *Generally 0～2.5MPa* | *Generally 0～10.0MPa* |
| Range of Temperature | *Generally -80～550℃*<br>*Particularly 700℃* | *Generally -80～550℃* | *-80～300℃* |
| Range Ratio | *Better than 10:1* | *Better than 10:1* | *Better than 10:1, Particularly 20:1* |
| Min. Flow Rate | *Gas≥4.5m/s*<br>*Liquid≥0.6m/s*<br>*Steam≥9.7m/s* | *Gas≥4.5m/s*<br>*Liquid≥0.6m/s*<br>*Steam≥9.7m/s* | *Gas≥4.5m/s*<br>*Liquid≥0.6m/s*<br>*Steam≥9.7m/s* |
| Measurement Precision | ±1% | ±1% | ±1% |
| Repeatability | ±0.1% | ±0.1% | ±0.1% |
| Method of Installation & Connection | *Flanged connection* | *Threaded connection* | *Pipes connection* |
| Supporting Instrument | *Differential pressure transmitter and flow integrating instrument etc* | | |

## Introduction of Pressure pipe joint

| Model | Joint Sketch Map | Connection method of pressure pipe | Connection component Picture | Characteristic | Standing rating temperature/pressure |
|---|---|---|---|---|---|
| F |  | Directly connect with standard H type five-valve manifold by 4 bolts.<br>For short: five-valve manifold |  | **F** connector can connect with H type 5-valve manifold directly. It's used for two group differential pressure output. It's suitable for middle, low pressure medium connected by diversified pressure pipe. | 400℃/6MPa |
| Z |  | Directly connect with standard H type three-valve manifold by 4 bolts.<br>For short: three-valve manifold |  | **Z** connector can connect with H type 3-valve manifold directly without pressure pipe transducer. It's suitable for low pressure pollution-free medium with temperature below 80℃. | 400℃/6MPa |
| T |  | 1/2"NPT threaded cutting sleeve connects with the pressure pipe of instrument. The open is upward.<br>For short: two-valve manifold |  | **T** with inner instrument cut-off valve, T type connector makes the installation more convenient. It is suitable for middle, low pressure medium in horizontal tube flowing. | 400℃/6MPa |
| P |  | 1/2"NPT threaded active welding tube connects with pressure pipe of instrument. The open is upward.<br>For short: upward open mode |  | **P** type connector structure is simple. It's easy to maintain. It's suitable for middle, low pressure medium in horizontal tube flowing. | 400℃/6MPa |
| R |  | The cutting sleeve of 1/2"NPT screw thread connection valve connects with pressure pipe. The open is on both sides.<br>For short: side open |  | **R** type valve tube connector is suitable for the middle, low pressure medium in horizontal, vertical tube. | 400℃/6MPa |
| S |  | Directly welding the inserted-welding short pipe with the valve or pressure pipe of instrument. No thread connection.<br>For short: Inserted-welding mode |  | **S** type connector is structure simple, strong. It has common application. It's suitable for the application in high temperature, high pressure medium. | 550℃/25.4MPa |
| V |  | Directly welding the high pressure welding stop valve with the pressure pipe of instrument.<br>For short: Welding valve mode |  | **V** *type connector is strong and has common application. It is suitable for the application in high temperature, high pressure medium.* | 550℃/25.4MPa |

## Installation flange support seat dimension drawing

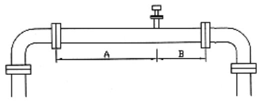
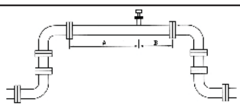
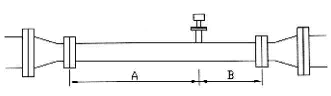
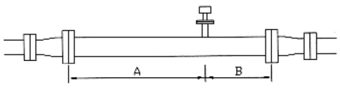
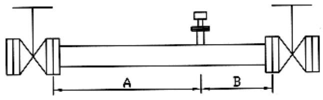
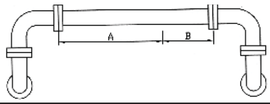
| | |
|---|---|
|  |  |
| VRB65 installation base dimension drawing | VRB64 installation base dimension drawing |
|  |  |
| VRB63 installation flange dimension drawing | VRB61 installation base dimension drawing |
|  |  |
| VRB62 large size dust-cleaning probe installation flange dimension drawing | VRB62 large size probe installation flange dimension drawing |

| | |
|---|---|
|   |   |
| VRB62 medium size probe high pressure installation flange dimension drawing | VRB62 medium size probe middle pressure installation flange dimension drawing |
|   |   |
| VRB62 medium size probe low pressure installation flange dimension drawing | VRB62 small size probe high pressure installation flange dimension drawing |
|   |   |
| VRB62 small size probe low pressure installation flange dimension drawing | Simple double faced support installation base dimension drawing |
|   |   |
| Dust-cleaning probe double support installation base dimension drawing | Dust-cleaning probe double faced support installation base back cover dimension drawing |

# Introduction of the installation of Wellbar flow sensor

## Requirement of Straight Tube Section

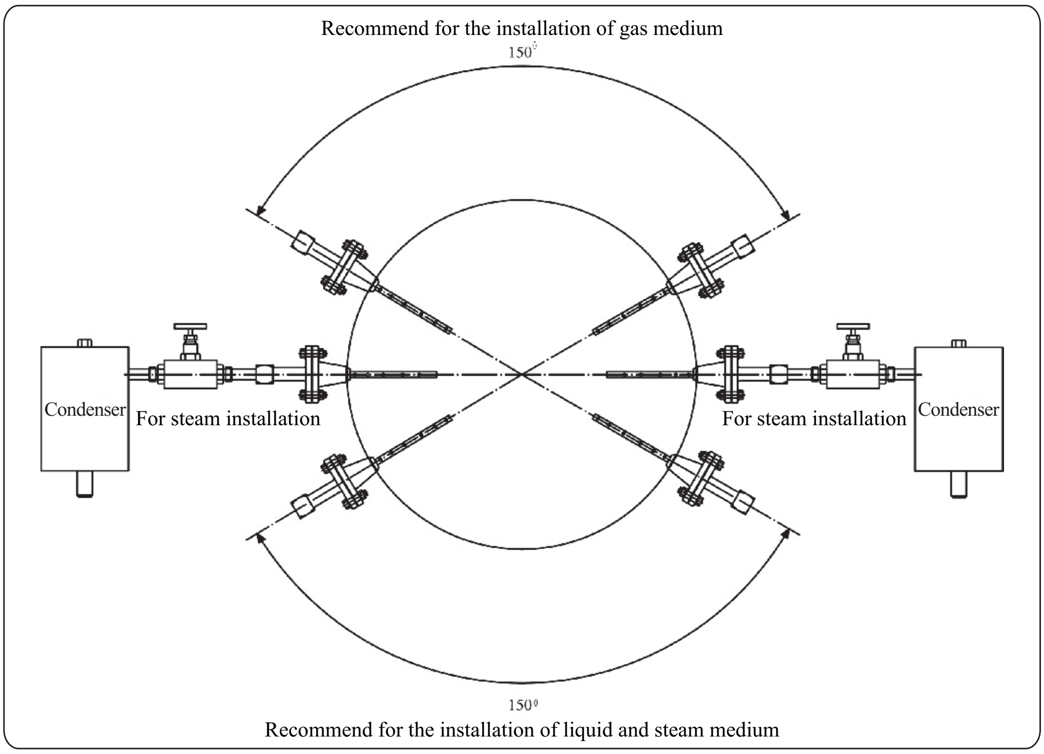
Note: Rectangular pipe: " D " represents the inside diameter of pipelines.
Round pipe: " D " represents the equivalent diameter.

| Pipeline Definition | Installation Location | Precision | Upstream Straight Run A | Downstream Straight Run B |
|---|---|---|---|---|
| *With upstream and down-stream singleelbow pipe* |  | 1.0% | 7D | 3D |
| | | 2.0% | 4D | 2D |
| *With upstream and down-stream twinelbow pipe* |  | 1.0% | 9D | 2D |
| | | 2.0% | 5D | 2D |
| *With upstream and down-stream increaseand reduction in pipe size* |  | 1.0% | 7D | 3D |
| | | 2.0% | 4D | 2D |
| *With upstream and down-stream increase and reduction in pipe size* |  | 1.0% | 7D | 3D |
| | | 2.0% | 4D | 2D |
| *With upstream regulating valve* |  | 1.0% | 24D | 4D |
| | | 2.0% | 12D | 3D |
| *With upstream and down-stream twinelbow pipe not located on a same plane* |  | 1.0% | 17D | 4D |
| | | 2.0% | 9D | 3D |

## Installation Location and Direction

According to the actual condition of the site, the installation location of Wellbar flow meter is selected referring to the requirement of the min straight tube section.

It is recommended that when the measurement medium is gas, the location is at the top of tube; for liquid and steam,at the bottom of tube; for Wellbar sensor equipped with condenser, at the side of tube.




**The sketch map of installation direction**

## Explanation of Installation

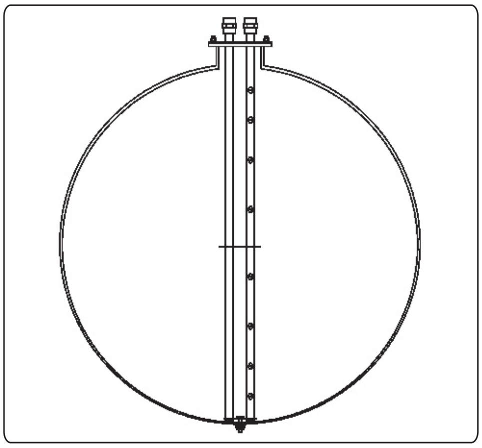
### Explanation of installation of integration welding type VRB66 Wellbar flowmeter

### Installation instructions for round pipe of air flow specific model VRB66:

Select the installation position on the process pipeline and determine the installation direction of Wellbar flow sensor according to the requirements of straight pipe section (see the above table) and the quantities of air flow sensors as well as the insertion length at each measurement point.

Open holes on the pipeline after determining the installation position and direction of Wellbar flow sensor.

Single side support: Put the Wellbar probe against the flow surface and face to the fluid direction. Firstly weld two points on the mounting base of lower flange by point welding method. The bottom of lower flange cannot protrude beyond the internal diameter of the pipeline and the upside of it is parallel to the pipeline. Calibrate the position of the mounting base of lower flange, which requires the axial lead of lower flange to pass through the circle center of the pipeline. After the calibration, complete all the welding of the mounting base of lower flange.



Place the sealed gasket on the lower flange, and then insert the whole Wellbar sensor into the bottom, rotate the screw, reach the probe top to the inner wall of the pipeline, and adjust the measurement direction of Wellbar probe to be in line with the fluid direction, and then fasten the nut.

Double side support: According to the double holes that have been opened, firstly tighten the lower and upper flanges of the Wellbar probe by bolts, insert them into the holes, and the flow direction should be consistent. Weld two points on the mounting base of lower flange by point welding method. Calibrate the probe and ensure that the probe protrudes beyond the outsidepart of the pipeline and should be in the central position of the lower hole. Remove the bolts on the Wellbar probe and test the flexibility of the insertion and withdrawal. After proper calibration, complete all the welding of the mounting base of lower flange.

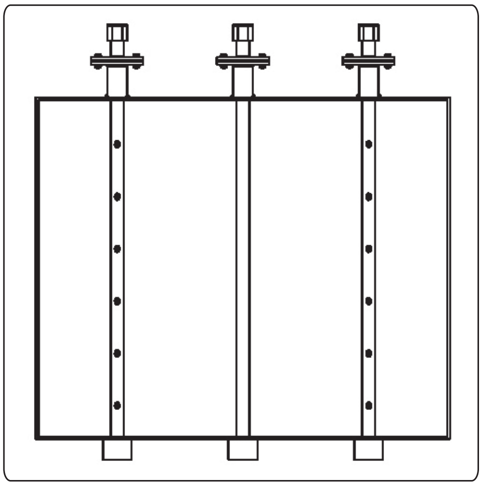
Place the sealed gasket on the lower flange, and then insert the whole Wellbar sensor into the mounting base. Let the supported bolt pass through the supported hole, and then rotate the screw, and adjust the measurement direction of Wellbar probe to be in line with the fluid direction and fasten the nut on the flange. Cover the double side supported bolt with sealed gasket and nut, and then fasten the nut.

### Installation instructions for square pipe of air flow specific model VRB66：

Select the installation position where the length of square pipe is in line with the insertion length of the sensor and determine the installation direction of Wellbar flow sensor according to the requirements of straight pipe section (see the above table) and the quantities of air flow sensors as well as the insertion length at each measurement point.

After determining the installation position and direction of Wellbar flow sensor, reasonably distribute the installation position of the sensor and drill holes on the square pipe by equal area installation method according to the sensor quantities.

Single side support：Put the Wellbar probe against the flow surface and face to the fluid direction. Firstly weld two points on the mounting base of lower flange by point welding method. The bottom of lower flange cannot protrude beyond the internal diameter of the pipeline and the upside of it is parallel to the pipeline. Calibrate the position of the mounting base of lower flange, which requires the axial lead of lower flange to perpendicular to the pipeline wall. After the calibration, complete all the welding of the mounting base of lower flange.



Place the sealed gasket on the lower flange, and then insert the positive pressure sensor and negative pressure sensor into the lower flange respectively, rotate the screw, and adjust the measurement direction of the probe to be in line with the fluid direction, and then fasten the nut.

Double side support: According to the double holes that have been opened, firstly tighten the lower and upper flanges of the Wellbar probe by bolts, insert them into the holes, and the flow direction should be consistent. Weld two points on the mounting base of lower flange by point welding method. Calibrate the probe and ensure that the probe protrudes beyond the outside part of the pipeline and should be in the central position of the lower hole, and then cover with supported base and carry out point welding. Remove the bolts on the Wellbar probe and test the flexibility of the insertion and withdrawal. After proper calibration, complete all the welding of the mounting base and supported base of lower flange.

Place the sealed gasket on the lower flange, and then insert the positive pressure sensor and negative press sensor into the lower flange respectively. Rotate the screw, and adjust the measurement direction of the probe to be in line with the fluid direction, and then fasten the nut.

## Explanation of installation of integration welding type VRB65 Wellbar flowmeter

The selection of the installation location on tube and the installation direction of Wellbar flow meter (shown in the installation direction sketch map) are decided basing on the requirement of straight tube section (shown in previous table) and the measurement medium.

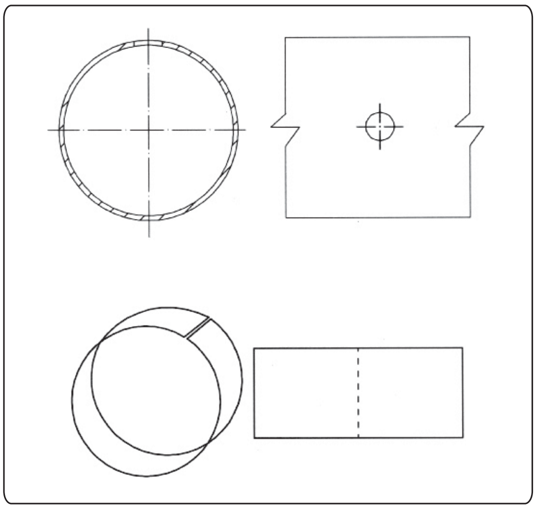
After the installation location and direction are decided, drilling hole on the tube.

- Single support:

Basing on the decided installation location, direction, and the actual size of Wellbar detector, a hole is drilled on the tube.

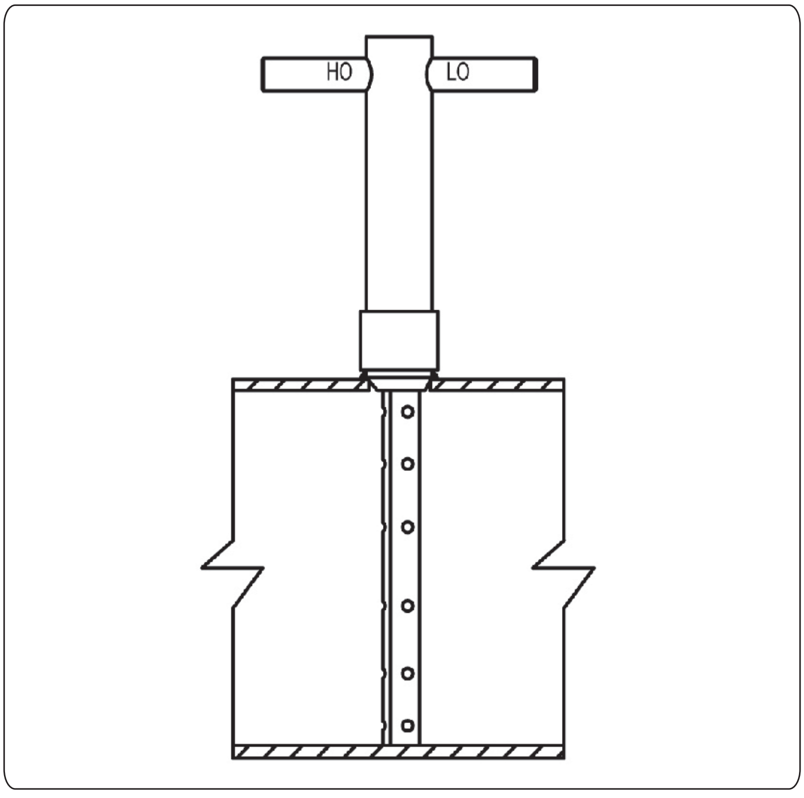
- Double support:

Folioing a thick paper whose length is same as the circle of tube, then enclosing the paper around the tube. Mark at the superposition and the folio position to decide the up, down hole position. According to the Wellbar detector and the actual size of the supporting base, decide the two holes on the tube.



Plug the Wellbar detector into the tube. Fix the Wellbar sensor to right place by dot welding. It's required that the detector is in the tube inner diameter and on the same line of the center line.

Welding the connection fully and detecting the welding seam by detecting instrument. Then perform the rust protection process to the welding seam.

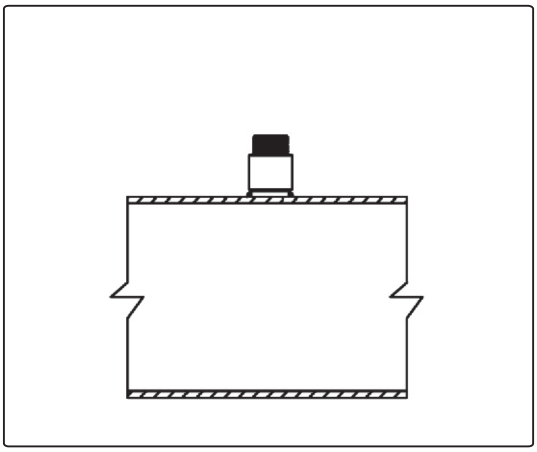



**The installation sketch map of VRB65**

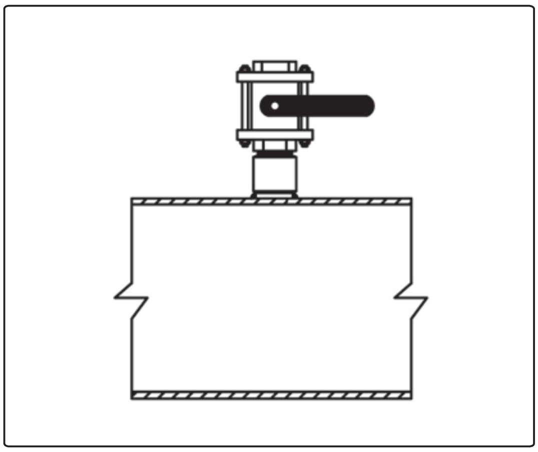
## The explanation of on-line installation type VRB64 Wellbar flowmeter

The installation location on tube and the installation direction of Wellbar flow meter (shown in the installation direction sketch map) are decided basing on the requirement of straight tube section (shown in previous table) and the measurement medium. Deciding the installation location and direction of Wellbar flow meter.

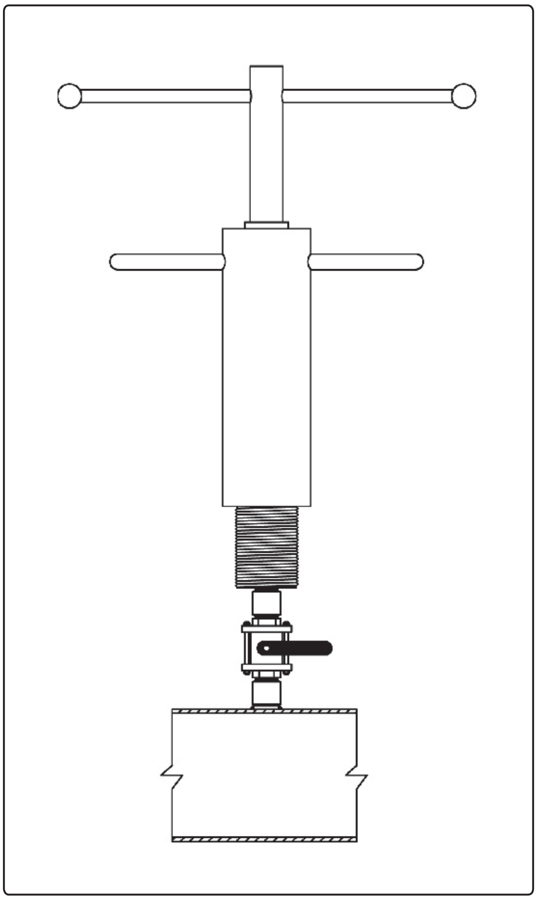
Welding the base of Wellbar flow meter to the decided installation location of the tube.



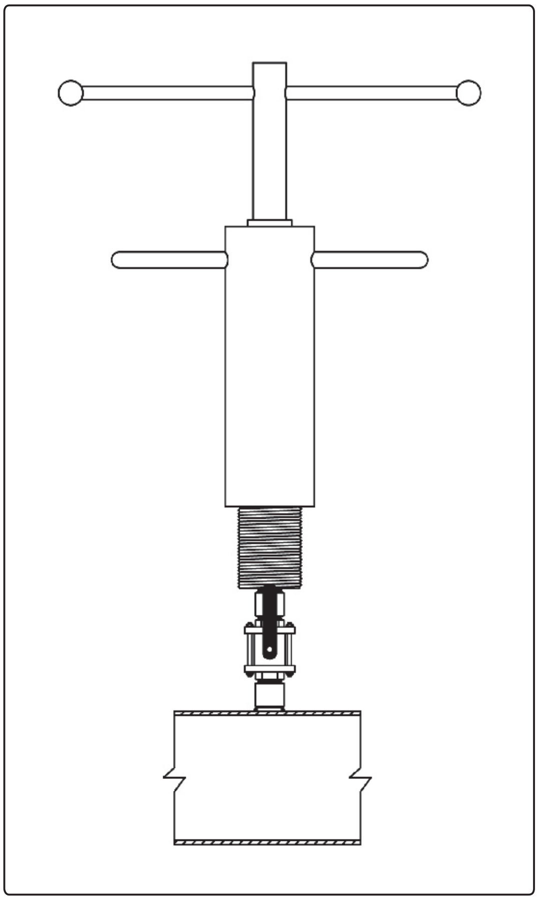
Installing the tube stop valve on the welded welding base.



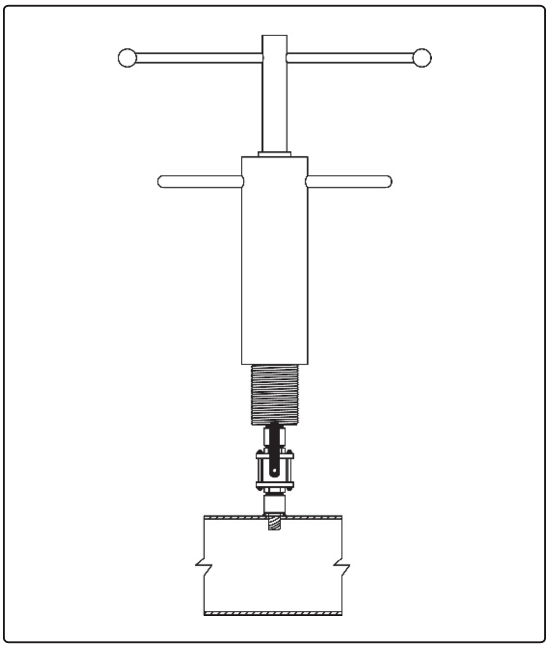
Install the on-line drilling tool tube stop valve



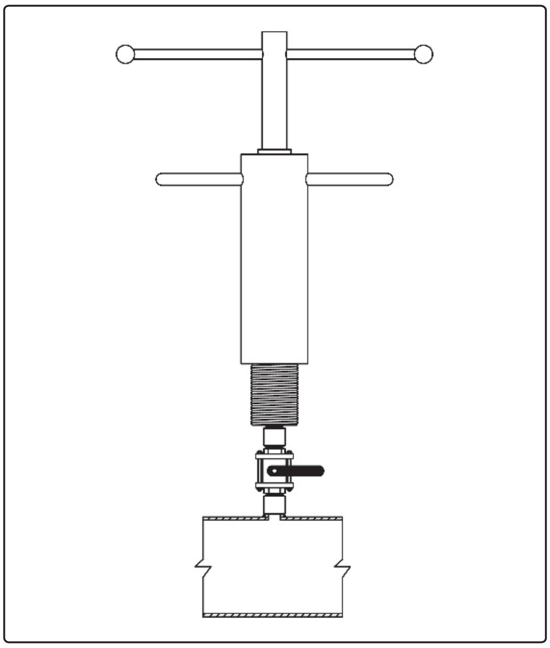
Turn on the tube stop valve, turn around the handle to drill into the tube.



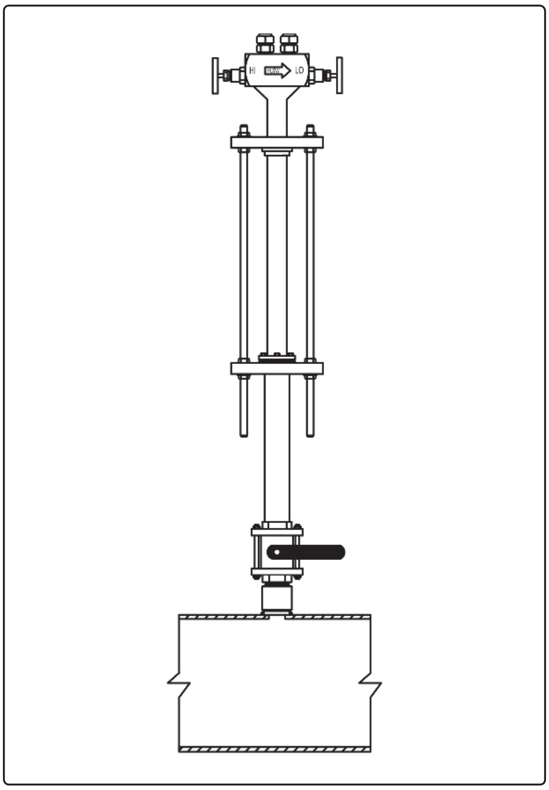
Drill through the tube wall.



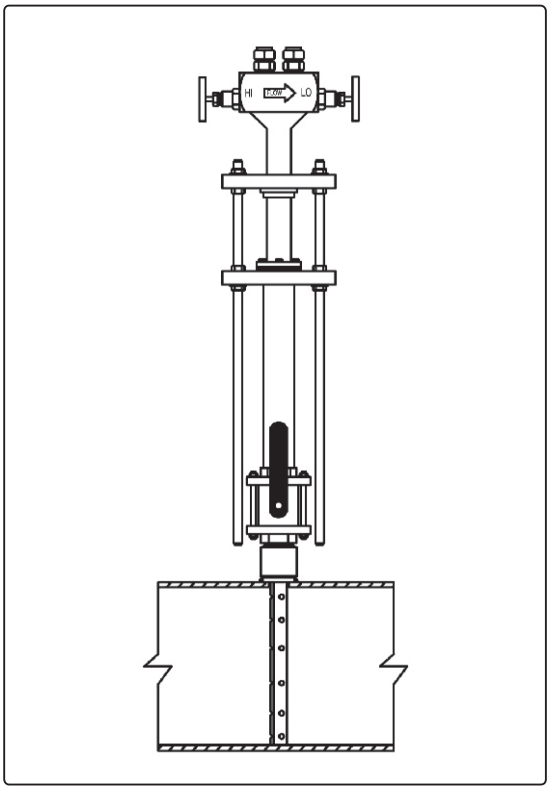
Inversely turn around the handle to retrieve the drill bit to the top of stop valve, then turn off the tube stop valve.



Turn off the on-line drilling tool, connect the Wellbar flow meter to the tube stop valve with the incident flow surface facing to the flowing direction.



After turning off the stop valve of the Wellbar sensor, turning on the tube stop valve. Then after plugging the Wellbar flow meter into the required location of tube by turning around the drive rod, lock the screw, nut. The on-line installation is completed.

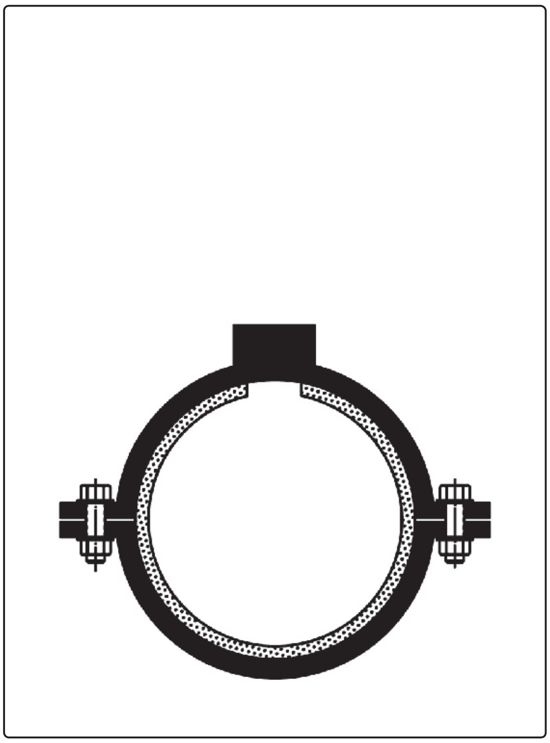


## The explanation of installation of Adjustable Flanged Type VRB63 Wellbar Flow meter

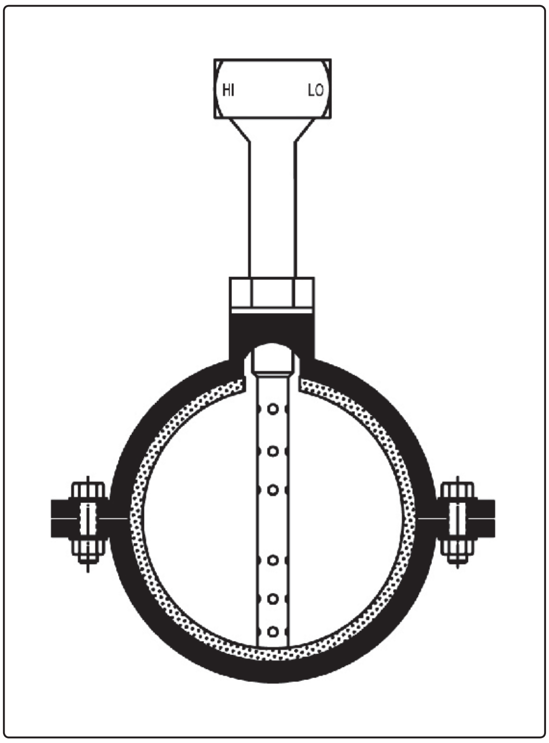
The selection of the installation location on tube and the installation direction of Wellbar flow meter (shown in the installation direction sketch map) are decided basing on the requirement of straight tube section (shown in previous table) and the measurement medium.

After the installation location and direction are decided, drilling hole on the tube.( drilling hole on the plastic-lined tube before installing the lining)

The burr with the edge of the hole should be clean, fixing the sealing gasket around the hole of pipe with the clamping band,and then tighten the screws of clamping band.



Screw the Wellbar probe into the clamping Installation base till the bottom of detector contacting with the tube surface, Adjusting the measuring direction of Wellbar probe to the flow direction,then locking the nut.



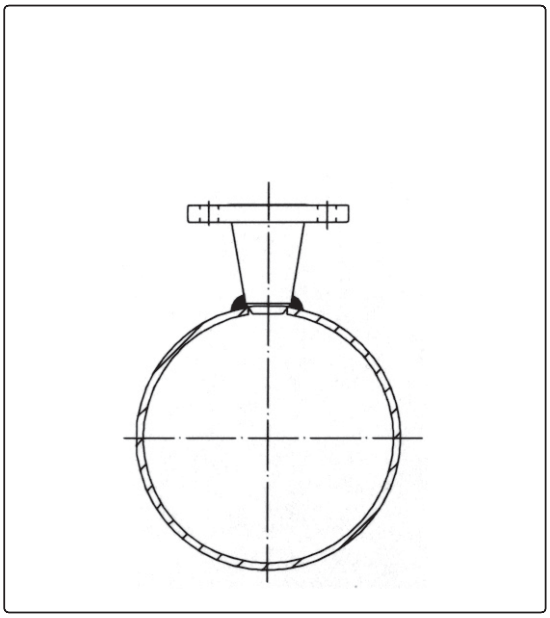

## Explanation of installation of flange connection type VRB62 Wellbar flow meter

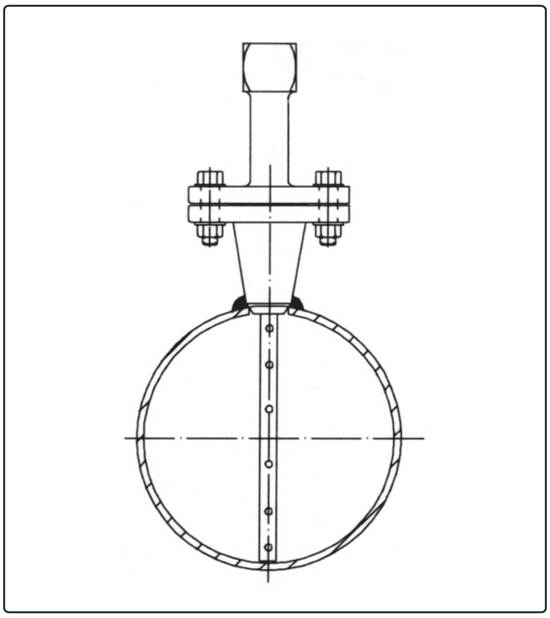
The installation location on tube and the installation direction of Wellbar flow meter (shown in the installation direction sketchmap) are decided basing on the requirement of straight tube section (shown in previous table) and the measurement medium.

Deciding the installation location and direction of Wellbar flow meter. Drilling on the tube.

Single support: Making the incident flow surface facing the flow direction, fixing the down flange base by dot welding with the bottom of the flange not exceeding the wall of the tube, and the top of the flange paralleling with the tube. Adjusting the base location of the down flange to make the axial lead passing through the circle point of tube, then welding the whole connection of the flange installation base.

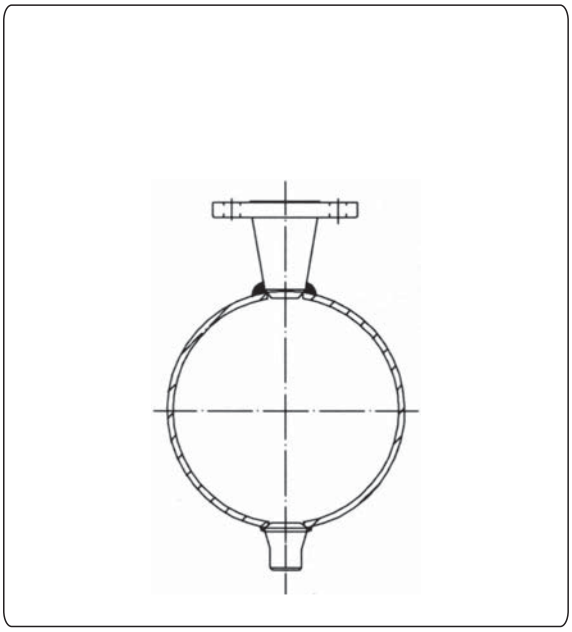
After placing the gasket seal on the flange, plugging the Wellbar flow meter body to bottom of tube, turning around the screw thread so that the top of the detector contacts with the inner wall of tube. Adjusting the measuring direction of Wellbar detector to the flow direction, then locking the nut.

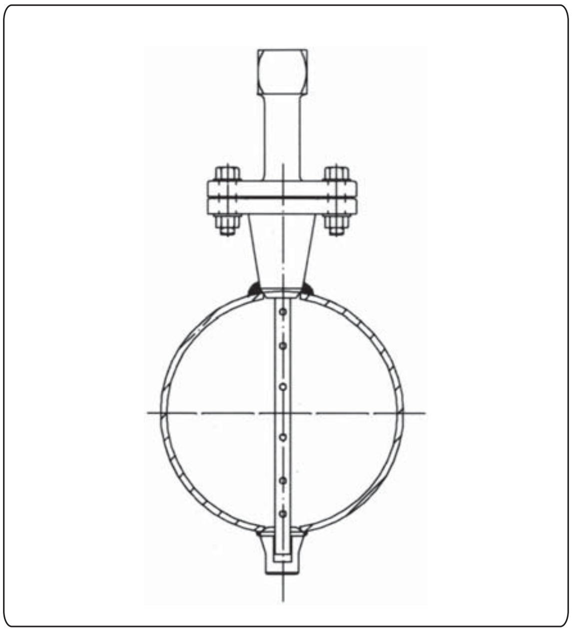




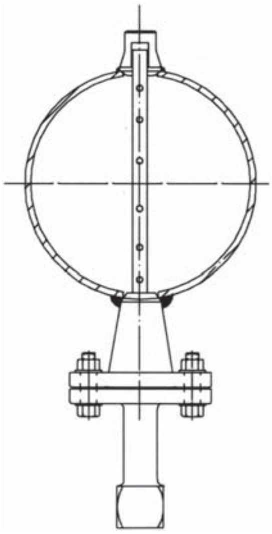
Double support: Basing on the drilled two holes, locking the up and down flanges of the Wellbar detector with bolt, then plugging into the hole. The flowing direction must be same. Fixing the down flange base by dot welding, adjusting the detector to ensure that the section of the sensor extending out of tube is in the center position of down hole, then fixing the supporting base by dot welding, disassembling the bolt on the Wellbar detector to test whether the plugging and pulling are flexible. After adequate adjusting, fix the down flange base and supporting base by welding.

After placing the gasket seal on the down flange, plugging the Wellbar flow meter body to bottom of supporting base, adjusting the measuring direction of Wellbar detector to the flow direction by turning around the screw thread, then locking the nut. The flowing direction should be same as the measurement direction of Wellbar detector.

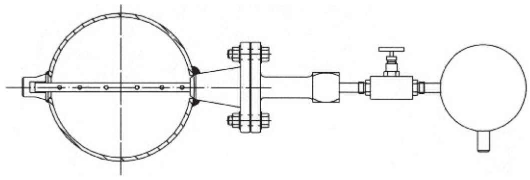




The bottom installation sketch map of double supporting Wellbar detector



The side installation sketch map of Wellbar detector with condenser both sides supporting for measurement of steam

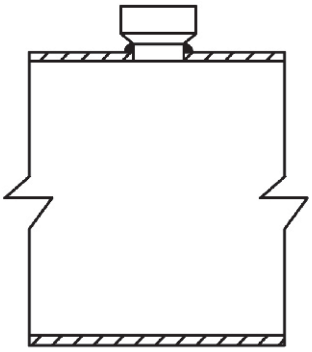


## Explanation of installation of screw rod connection type VRB61 Wellbar flow meter

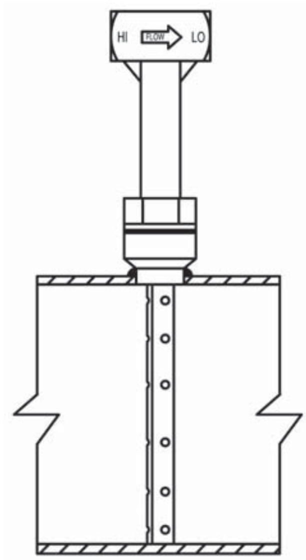
The installation location on tube and the installation direction of Wellbar flow meter (shown in the installation direction sketch map) are decided basing on the requirement of straight tube section (shown in previous table) and the measurement medium.

3.5.2 Deciding the installation location and direction of Wellbar flow meter. Drilling on the tube.

Single support: Fixing the down installation base by dot welding with the bottom of the flange not exceeding the wall of the tube, and the top of the flange paralleling with the tube. Adjusting the installation base location to make the axial lead passing through the circle point of tube, then welding the whole connection of the installation base.



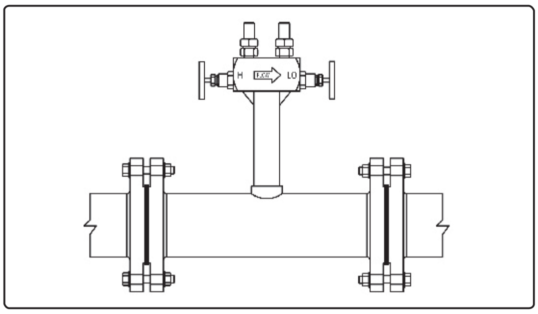
Screw the Wellbar sensor body into the installation base till the bottom of detector contacting with the tube surface. Adjusting the measuring direction of Wellbar detector to the flow direction, then locking the nut.



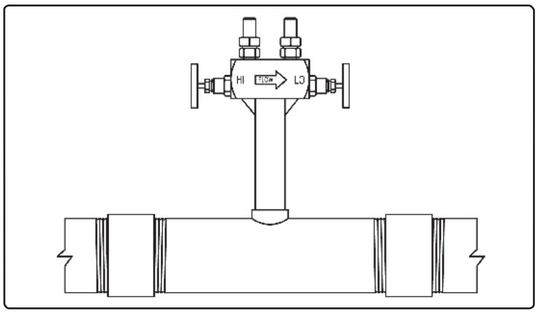

Double support: please refer to the installation method of flange connection type VRB62 Wellbar flow meter.

## Explanation of installation of tube connection type VRB60 Wellbar flow meter

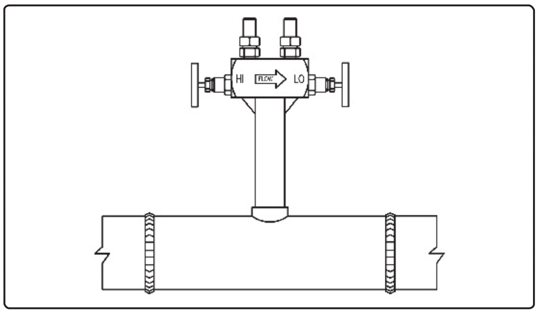
The installation location on tube and the installation direction of Wellbar flow meter (shown in the installation direction sketch map) are decided basing on the requirement of straight tube section (shown in previous table) and the measurement medium.
Cutting the length of installation flange of Wellbar sensor on the tube.
Assemble the Wellbar sensor flange with the tube flange and the gasket seal by bolts.
According to different measurement medium, select the method of sensor 3-valve manifold (refer to sketch map).
Connect the assembled sensor with the tube by welding. The sensor and tube should be on the same axial line.



**Flange connection type**



**Welding tube connection type**

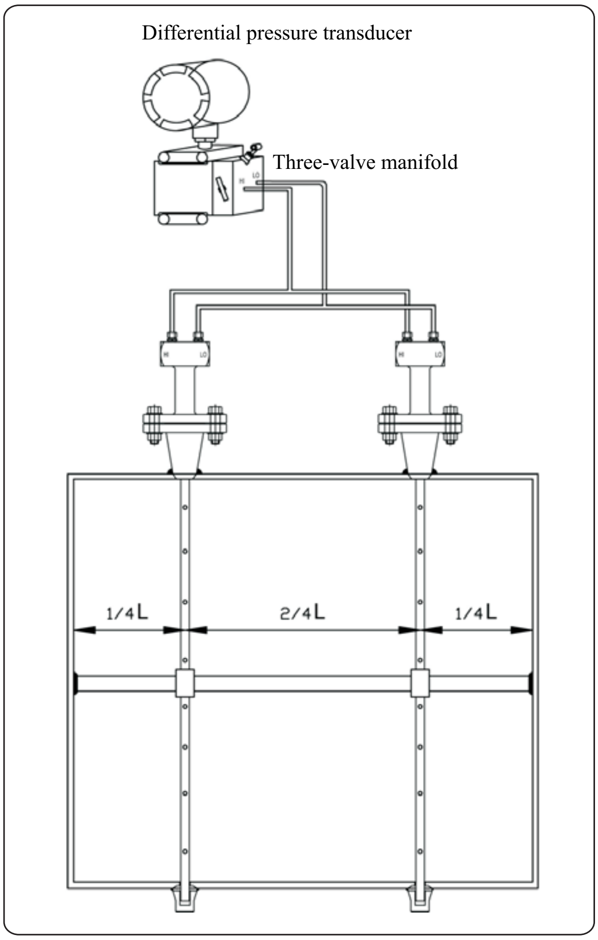


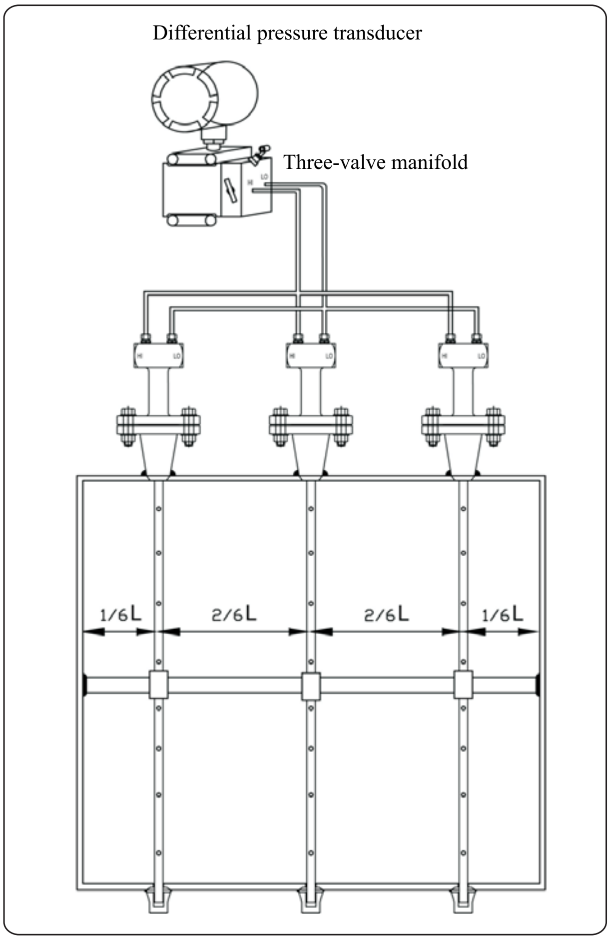
**Screw connection type**

## Explanation of installation of Wellbar flow meter for large pipe diameter measurement (Pipeline⩾3000mm)

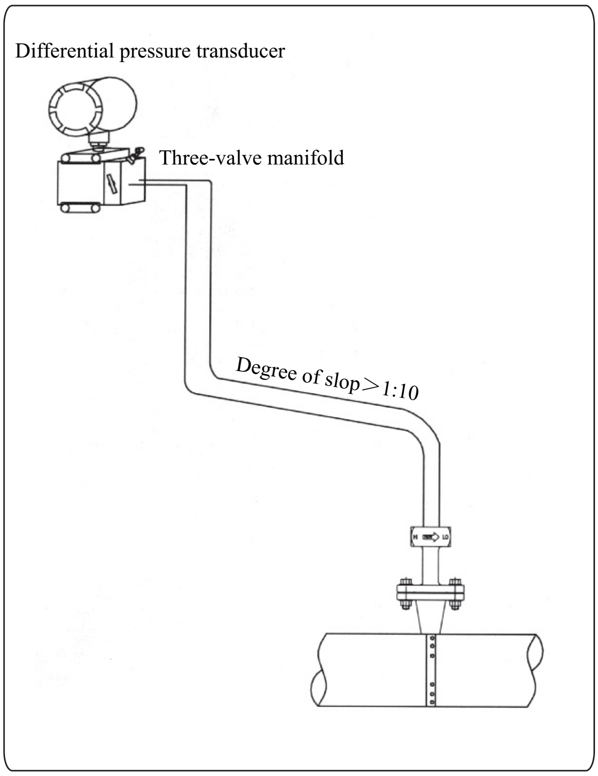
Installation method of single measurement equipment

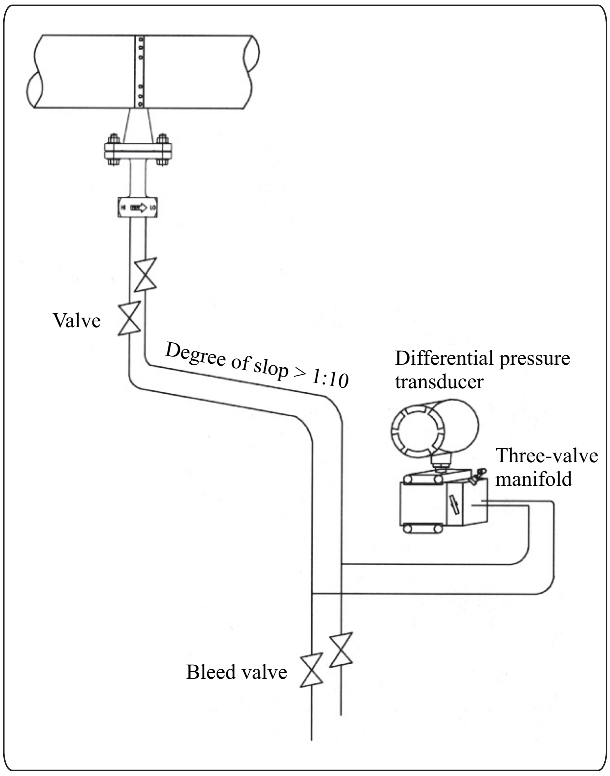
Installation method of single measurement equipment
Select the installation location basing on the direction, size of tube, and the requirement of straight tube section around the measurement equipment.
At the center of the selected location, drill up, down two holes basing on size of the installation flange, and installation supporting base provided with production.
Referring to the above shown installation method of other type Wellbar sensor, fixing the installation flange, plugging the measurement equipment into tube. The detector lies at the middle location of hatch of the supporting base. Then fixing the installation supporting base. Adjusting the angle of detector (incident flow), fixing the detector on the installation flange by bolt, then welding the installation flange and installation supporting base.
Moving the middle mounting base on the detector to the center location of measurement detector (avoiding probe measurement orifices), With 50 * 50 angle steel or channel steel welding pipe on both sides,and keeping up the same flat surface with the middle mounting base.according to the location and size of connection hole on the middle mounting base,drilling a hole on the angle steel or channel steel,and then drilling the rest of the hole according to the sensor probe count.
With bolts connecting the hole on the angle steel or channel steel with the middle mounting base and tighten the screw,then welding firmly the angle steel or channel steel with spot welding on both sides of the tube. shown in below the installation direction sketch map.
When the multi Wellbar probe is installed, all the high pressure output HI linked, the low pressure LO linked,and then through the three-way short tube welding press-leading tube which connecting with the difference transmitter high pressure and low pressure.



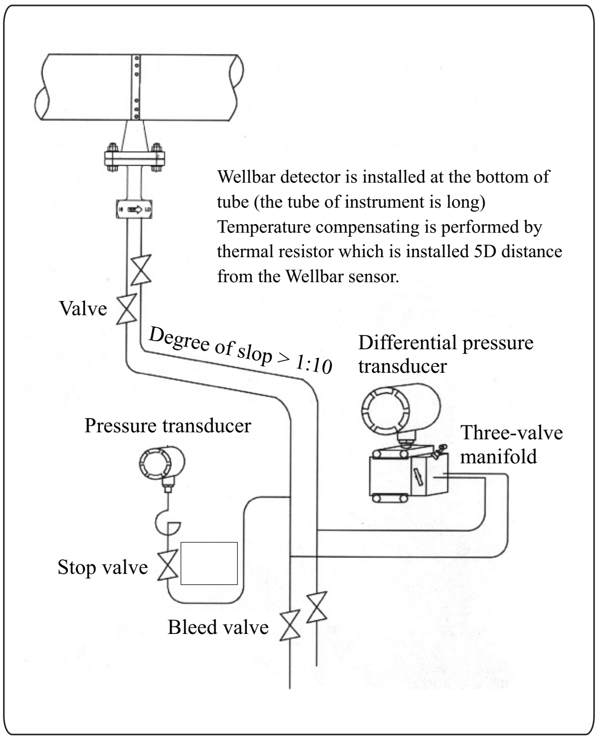

## The sketch map of pipe connection of instrument



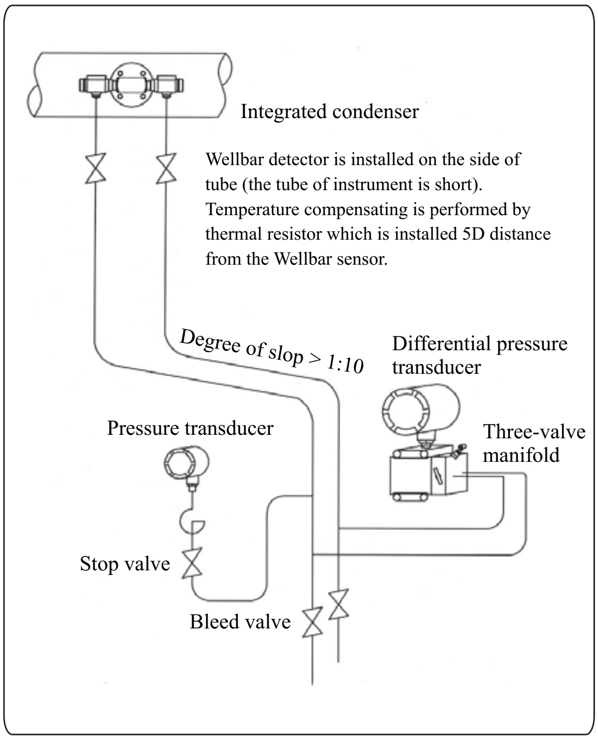




**Connection diagram of gas flow measurement(1)**

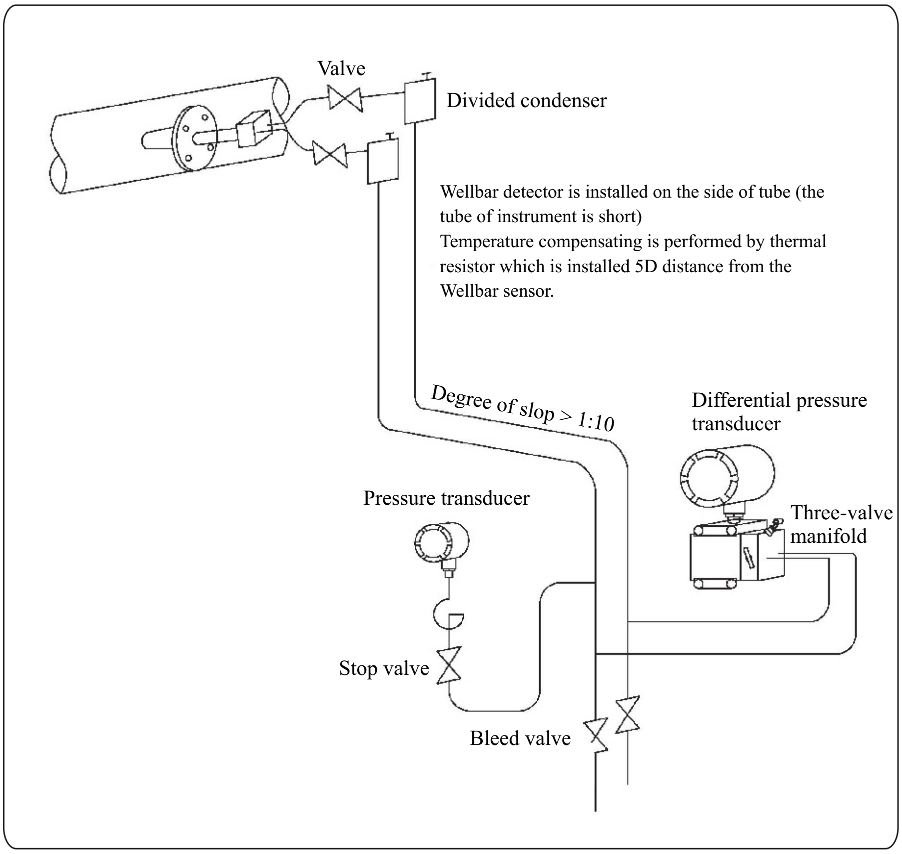
**Connection diagram of gas flow measurement(2)**




**Connection diagram of steam flow measurement (3)**

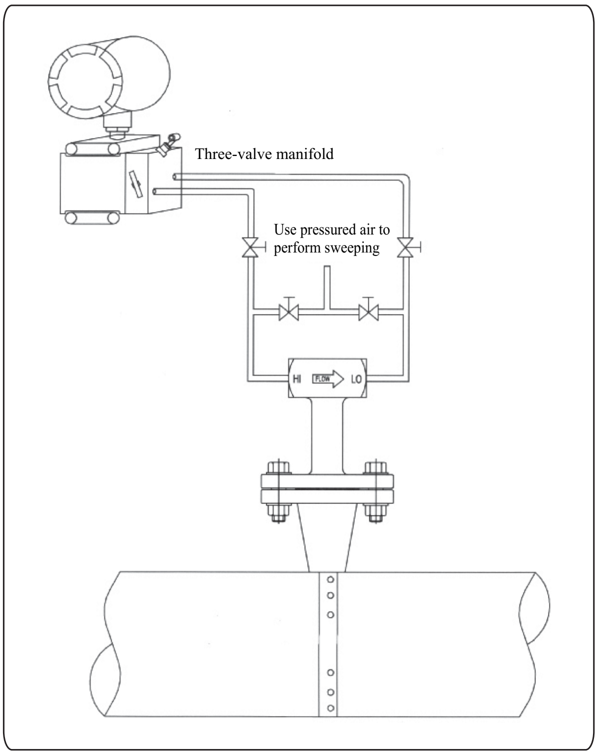



**Connection diagram of steam flow measurement (4)**

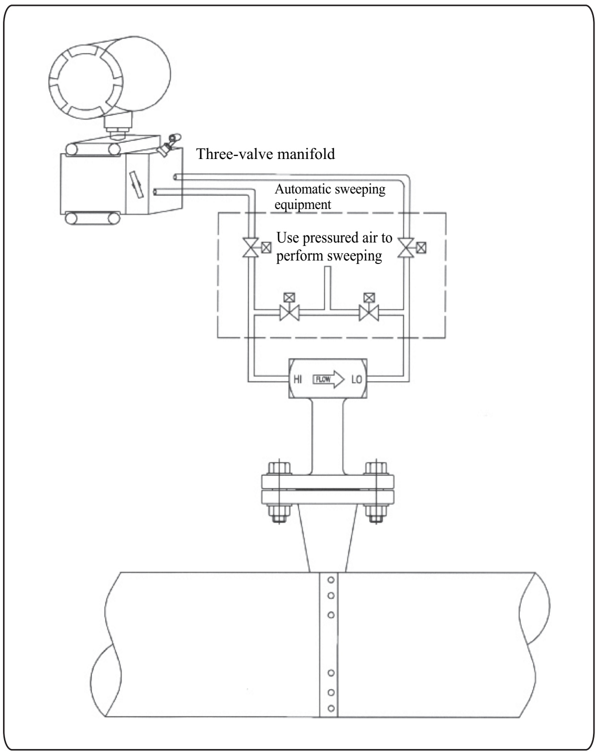



**Connection diagram of steam flow measurement (5)**

## When measurement is performed in condition abundant of dust, dirt, pressured air is used to perform anti-sweeping installation

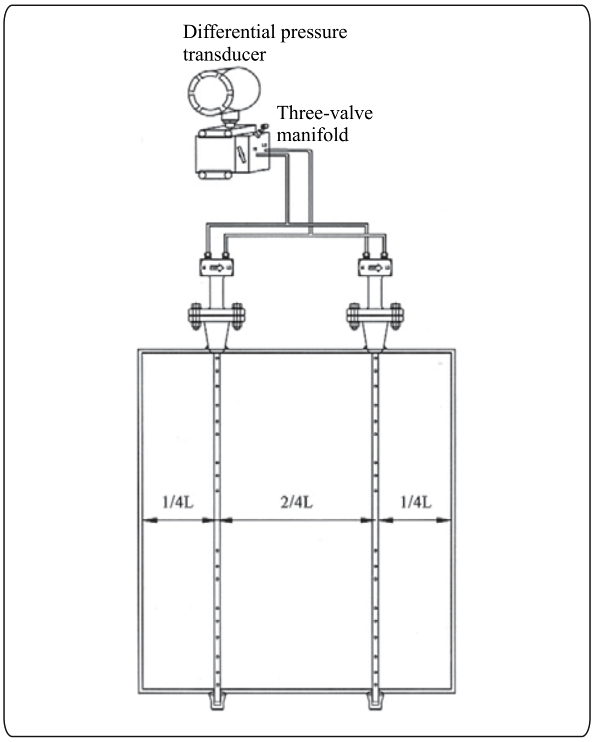



**Tube connection diagram of manual sweeping (1)**

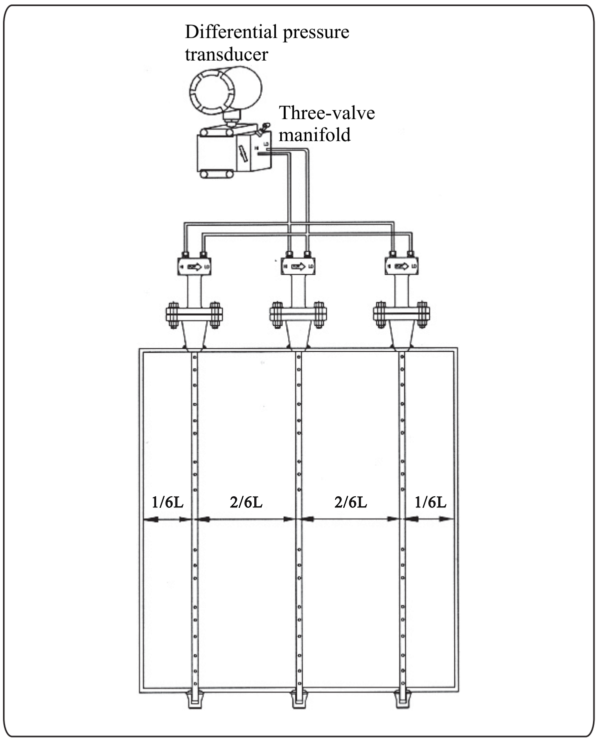



**Tube connection diagram of automatic sweeping (2)**

## Sketch map of pipe connection of multi Wellbar flow meters




**Connection diagram of two Wellbar sensors (1)**




**Connection diagram of two Wellbar sensors (2)**

Notice: The high pressure output ports HI of multi Wellbar sensors are connected together. The low pressure output are also connected together. The connections to the high, low inputs of transducer are made by welding the three-way short pipes with the pressure pipes.

## The transportation of instruments and transducer

After the instrument pipe are welded, connecting the transducer and instruments correctly, or DCS and signal wire of the transducer, setting the parameters of instrument or DCS.

Close the two valves on the three valve manifold or five valve manifold that are connected with the process. Then open the middle balance valve. The high pressure, low pressure valves are connected. No signals are produced. Referring to the manual of transducer to check whether the zero point of differential pressure transducer is right. Adjusting the potentiometer which marked 〃 zero〃 by current meter or current meter provided with transducer. If it's the intelligent transducer, modifying the zero parameter by manual holder provide together with differential pressure till zero is standard value.

Turn on the blow down valve, clean the rust, dirty in the pipe by pressure difference. Then turn off the blow down valve.

● If the medium is gas, after cleaning of the pipe, loosing the two exhausting steam bolts, turning on the high pressure, low pressure valve of three valve manifold or five valve manifold to clean the differential pressure transducer. Then turning off the middle balance valve, tighten the middle balance valve. Then it's time to deliver the flow measurement system.

● If the medium is steam, naturally cooling steam in the condenser for one to two hours. Then turning on the high pressure valve, turning off the middle balance valve, to fill chilled water in the transducer. Loosing the blow down bolt on the high valve and low valve to let out the air bubble in transducer, then tighten the blow down bolt. Then it's time to deliver the flow meter. If the cooling time is too long, turning on the two blow down bolt on the condenser, to fill water into instrument pipe directly till the water levels *in two condensers are same. Tighten bolt, turn on valve, then it's time to deliver flow measurement system.*

## The analysis of failure during measurement

● No signal changing

Possible Reason: a. Valve is not open or the middle balance valve is not closed.

b. The connection of signal wire is wrong or the parameter setting of instrument and DCS are not correct.

c. The measured different pressure value of transducer doesn't fit the design value of Wellbar sensor. It's a little more.

d. The design parameter provided by the custom to the instrument company is large. It doesn't fit the actual value.

Solution: a. Check valve of instrument.

b. Check the signal connection and instrument parameter.

c. Reset the measurement range of transducer to be same as that of the max differential pressure of Wellbar sensor.

d. Provide new parameter to the instrument company basing on the actual condition to recalculate the differential pressur evalue.

● The measured value is more than the actual value

Possible reason: a. Is the size of tube same as the design value?

b. Is the detector installed properly?

c. Does the straight tube section meet the design requirement?

d. Is the measurement range of differential pressure transducer changed?

e. Is the measurement range of differential pressure transducer changed?

f. Does the parameters provided by the custom fit the actual condition?

Solution: a. If the size of the tube doesn't fit, modify the design.

b. Change the installation direction of detector so that the high tapping is facing the flow.

c. Because the site condition can't meet the requirement of straight tube, by comparing the standard instrument measurement value $Q_{m1}$ and site measured value $Q_{m2}$, updating the flow coefficient K with the change factor, that's $N \times K$. Here $N= Q_{m1} / Q_{m2}$ .

By this way,the measurement range of transducer is ensured.

d. Recalibrating the differential pressure transducer.

e. Revise the range of the differential pressure transducer according to the max differential pressure of the probe.

F. If the parameters doesn't fit the actual value, such as working pressure,working temperature, it will cause the density of medium $\rho_1$ different from the design value. Basing on the actual pressure, temperature, getting the density $\rho_2$ in the additional chart.

Then updating the flow coefficient K with $N= \rho_1 / \rho_2$, that's to replace K by N x K, the correct measurement value is available again.

## Maintenance of Flow meter

The Wellbar Flow meter requests less maintenance while the Wellbar integrated sensor needs no maintenance. Supporting secondary instruments also request minor routine maintenance and only some normal maintenance, such as zero check and metering range inspection, is needed. However, under some circumstances, in case that a large deviation exists between the working conditions and the design conditions of the medium to be measured, some jobs including site parameter correction may be requested. There are the following conditions as examples:

If the production process is not continuous and intermittent operation exists, then it is requested to pay attention to maintain the flow meter. If the production process is paused, be sure to open the equalizing valve on the three-valve manifold and close the high pressure valve $P_1$ and the low-pressure valve $P_2$ so that the differential pressure transmitter will turn into a state without input of pressure difference. While the production process is restored, be sure to again open valve $P_1$ and valve $P_2$ and close the equalizing valve so that the differential pressure transmitter will turn into the measuring condition with input of pressure difference.

With reference to a certain medium containing much dust, for example, crude gas (not cleaned), industrial water (containing sand) and humid gas (containing dust) etc., since dust is expected to possibly block the pressure ports on the probe, it is requested to conduct blowing on fixed times. The method for blowing is to induce compressed air into the sensor and blow back to blow off the dust particles in high-pressure ports and low-pressure ports so as to prevent clogging from occurring. For every time, the duration of blowing should not exceed 30 seconds. During this period, the pressure pipe led to the differential pressure transmitter should be closed and then opened after the blowing is finished. In case that blowing in compressed air is not allowed, such as high temperature coal gas, steam can be used for blowing.

In case that the working conditions of the medium being measured are greatly deviated from the design conditions, it is requested to adjust the parameters depending on different occasions. For example:

● If the maximum flow of the medium being measured is greater than the design value, then it will occur that the current of the pressure difference output of the differential pressure transmitter will exceed 20mADC (generally called a phenomenon of "beyond the range"), which indicates that the pressure difference generated by the sensor is greater than the designed maximum pressure difference $\triangle P_{max}$. Usually, the way to solve is to increase the range of the transmitter so as to adapt to the max requirement of the maximum flow. For example, the designed maximum flow of the air being measured is $Q_{max}$ = 5000m$^3$/h; the max designed maximum pressure difference $\triangle P'_{max}$ = 0.6KPa; the range of the differential pressure transmitter is calibrated between 0 and 0.6KPa. However during the actual application, the maximum flow of the air is $Q'_{max}$ = 6000m$^3$/h. If other max conditions (air pressure, temperature, pipeline, diameter etc.) are assumed unchanged, then the corresponding maximum pressure difference $\triangle P'_{max}$ = $(6000/5000)^2 \times 0.6$ = 0.864KPa. Therefore the range of the differential pressure transmitter max should be calibrated between 0 and 0.864KPa, which is corresponding to the airflow between 0 and 6000m$^3$/h. Meanwhile, the upper limit of flow and the upper limit of pressure difference given by the flow integrating instrument should also be changed accordingly.

● If the pressure and temperature of the medium being measured are deviated from the design values, then it will occur that the flow display by the measurement is not accurate and not in compliance with the requirement of technology and production. The way to solve is to conduct temperature and pressure compensation. For example, use the method of formula calculation to conduct compensation. If the designed maximum flow of the air is $Q_{max}$ =5000m3/h; the temperature is $T_1$ = 473.15K; the pressure is $P_1$ = 103.33KPa (absolute pressure). During the application, the actual air temperature is $T_1'$ = 523.15K; the pressure is $P_1'$= 102.93KPa; other conditions (the maximum pressure difference $\triangle P_{max}$ and caliber D etc.) keep unchanged.Then what is the actual maximum flow.

Then what is the actual maximum flow $Q_{max} = Q_{max} \cdot \sqrt{\frac{P_1 T_1'}{P_1' T_1}}$

Substitute by above data, then it can be calculated that $Q'_{max}$ =5268m$^3$/h.

So the upper limitation of flow should be revised to 5268m$^3$/h, but the upper limitation of differential pressure $\triangle P_{max}$ needn't be changed. When the pressure and temperature change frequently,we should use the self compensation function of the intelligent flow totalizer to ensure the measurement result not exceed the allowable error range.

## Information for Order

In order to select the model correctly, please fill out the form below. The method of connection with transmitter can be vacant if it's not specific, and our engineer will select the model according to the client's technical requirement.

*User* ________________ *Designated position* ________ *Fluid description* ________

*Pressure under working conditions* ________ *KPa* *Temperature under working conditions* ________ ℃

*Maximum flow* ________ *Normal flow* ________ *Minimum flow* ________ *or Range of Flow* ________

*Material of process pipes* ________ *Inside diameter of round pipes (or width of rectangular pipes)* ________ *mm*

*Outside diameter of round pipes (or height of rectangular pipes)* ________ *mm* *Wall thickness* ________ *mm*

*Method of connection between sensor and transmitter* *F Joint* ☐ *Z Joint* ☐ *T Joint* ☐ *P Joint* ☐ *S Joint* ☐ *V Joint* ☐ *C Joint* ☐

*Mode of pipe installation* *Horizontal* ☐ *Vertical* ☐ *Model of pressure transmitter to be supplied* ________

*Model of DP transmitter to be supplied* ________ *Other components to be supplie* ________

*Contact* ________ *Tel.* ________ *Date* ________

## Appendix 1: Density Chart of Relative Liquid

Density of different liquid under standard condition (kg/L)

| Name of liquid | Density |
|---|---|
| Acetone | 0.791 |
| Ammonia (24%) | 0.91 |
| Ammonia (35%) | 0.882 |
| Benzene | 0.879 |
| C. Tetrachloride | 1.594 |
| Trichloromethane | 1.489 |
| Crude Oil | 0.74-0.94 |
| Diesel | 0.85-0.88 |
| Ethyl oxide | 0.714 |
| Ethyl alcoh | 0.789 |
| Gasoline (for automobile application) | 0.78 |
| Gasoline (for aviation application) | 0.72 |
| Glycerine | 1.261 |
| Glyceryl alcohol | 0.95-1.08 |
| Civil Fuel | 1.195 |
| Fliudchloric acid (40%) | Approx.0.9 |
| Maschine oil | 13.546 |
| Mercury | 0.7915 |
| Methyl Alcohol | 1.032 |
| Milk | Approx.0.85 |
| Mineral Oil (lubrication) | 0.93 |
| Mineral Oil (Drum) | 1.31 |
| Nitric Acid (50%) | 1.512 |
| Nitric Acid (100%) | 0.702 |
| Octane | 0.91 |
| Olive Oil | 0.9-1.0 |
| Paraffin Oil | 0.81 |
| Petroleum | 1.395 |
| Kalium Carbonate | 0.96 |
| Castor Oil | 0.83 |
| Alcohol Spirit | 1.4 |
| Thiosulfonic Acid (50%) | 1.834 |
| Thiosulfonic Acid (100%) | 0.76-0.97 |
| Silicone Resin | 0.855 |
| Turpentine | 0.8669 |
| Toluene | 0.87 |
| Transmission Oil | 0.9982 |
| Water | 1.105 |

Density of different gas under standard condition ($kg/m^3$)

| Name of liquid | Density |
|---|---|
| Air | 1.2929 |
| Alkaline Air | 0.7714 |
| Argon | 1.784 |
| Butane | 2.703 |
| $CO_2$ | 1.9769 |
| CO | 1.25 |
| Chlorine | 3.214 |
| Methyl ether | 2.1098 |
| Helium Gas | 0.1785 |
| $H_2$ | 0.08988 |
| Fliudgen Chloride | 1.6392 |
| Krypton | 3.744 |
| Methane | 0.7168 |
| Neon Gas | 0.9002 |
| $N_2$ | 1.2505 |
| $O_2$ | 1.42895 |
| Propane | 2.0096 |
| Civil Coal Gas | Approx.0.6 |
| Water house | 0.768 |
| Hernia | 5.897 |
| Blast Furnace | $1.33kg/Nm^3$ |
| Coke-oven Gas | $0.46kg/Nm^3$ |
| Converter-oven Gas | $1.368kg/Nm^3$ |

Nominal Diameter

| Nominal Diameter | Outer Diameter | Wall thickness | Nominal Diameter | Outer Diameter | Wall thickness |
|---|---|---|---|---|---|
| 40 | 45 | 3.5 | 300 | 325 | 8 |
| 50 | 57 | 3.5 | 350 | 377 | 9 |
| 70 | 76 | 4 | 400 | 429 | 9 |
| 80 | 89 | 4 | 450 | 478 | 9 |
| 100 | 108 | 4 | 500 | 429 | 9 |
| 125 | 133 | 4 | 600 | 630 | 9 |
| 150 | 159 | 4.5 | 700 | 720 | 9 |
| 175 | 194 | 6 | 800 | 820 | 9 |
| 200 | 219 | 6 | 900 | 920 | 9 |
| 225 | 245 | 7 | 1000 | 1020 | 9 |
| 250 | 273 | 8 | | | |

## Appendix 2: Density Chart of Air and Water

The density of Air under different temperature and Pressure

| ℃ | bar 0.96 | 0.97 | 0.98 | 0.99 | 1 | 1.01 | 1.01 | 1.02 | 1.03 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.224 | 1.237 | 1.25 | 1.263 | 1.275 | 1.288 | 1.293 | 1.301 | 1.341 |
| 2 | 1.216 | 1.228 | 1.24 | 1.253 | 1.266 | 1.279 | 1.283 | 1.291 | 1.304 |
| 4 | 1.207 | 1.219 | 1.232 | 1.244 | 1.257 | 1.27 | 1.274 | 1.282 | 1.295 |
| 6 | 1.198 | 1.211 | 1.223 | 1.236 | 1.248 | 1.26 | 1.265 | 1.273 | 1.285 |
| 8 | 1.19 | 1.202 | 1.214 | 1.227 | 1.239 | 1.252 | 1.256 | 1.264 | 1.276 |
| 10 | 1.181 | 1.193 | 1.206 | 1.218 | 1.23 | 1.243 | 1.247 | 1.255 | 1.267 |
| 12 | 1.173 | 1.185 | 1.197 | 1.21 | 1.222 | 1.234 | 1.238 | 1.246 | 1.258 |
| 14 | 1.165 | 1.177 | 1.189 | 1.201 | 1.213 | 1.225 | 1.229 | 1.238 | 1.25 |
| 16 | 1.157 | 1.169 | 1.181 | 1.193 | 1.205 | 1.217 | 1.221 | 1.229 | 1.241 |
| 18 | 1.149 | 1.161 | 1.173 | 1.185 | 1.2 | 1.209 | 1.212 | 1.221 | 1.232 |
| 20 | 1.141 | 1.153 | 1.165 | 1.177 | 1.188 | 1.2 | 1.204 | 1.212 | 1.224 |
| 22 | 1.133 | 1.145 | 1.157 | 1.169 | 1.18 | 1.192 | 1.196 | 1.204 | 1.216 |
| 24 | 1.126 | 1.137 | 1.149 | 1.161 | 1.172 | 1.184 | 1.188 | 1.196 | 1.208 |
| 26 | 1.118 | 1.13 | 1.141 | 1.153 | 1.165 | 1.176 | 1.18 | 1.188 | 1.2 |
| 28 | 1.111 | 1.122 | 1.134 | 1.145 | 1.157 | 1.168 | 1.172 | 1.18 | 1.192 |
| 30 | 1.103 | 1.115 | 1.126 | 1.138 | 1.149 | 1.161 | 1.164 | 1.172 | 1.184 |
| 32 | 1.096 | 1.107 | 1.119 | 1.13 | 1.142 | 1.153 | 1.157 | 1.165 | 1.176 |
| 34 | 1.085 | 1.098 | 1.11 | 1.122 | 1.135 | 1.147 | 1.151 | 1.159 | 1.172 |

The density of Water and Steam under different temperature and Pressure

| **Pressure** bar | **Temperature** 0 | 25 | 50 | 75 | 100 | 150 | 200 | 250 |
|---|---|---|---|---|---|---|---|---|
| 1 | 999.8 | 997.1 | 988 | 974.9 | 0.5896 | 05164 | 0.4604 | 0.4156 |
| 5 | 1000 | 997.2 | 988.2 | 975 | 958.6 | 917.1 | 2.3537 | 2.1083 |
| 10 | 1000.3 | 997.5 | 988.4 | 975.3 | 958.8 | 917.4 | 4.8566 | 4.8566 |
| 20 | 1000.8 | 997.9 | 988.5 | 975.7 | 959.3 | 917.9 | 865.1 | 8.9757 |
| 30 | 1001.3 | 998.4 | 989.3 | 976.2 | 959.8 | 918.5 | 865.9 | 14.172 |
| 40 | 1001.8 | 998.8 | 989.7 | 976.6 | 960.2 | 919.1 | 866.6 | 799.1 |
| 50 | 1002.3 | 999.3 | 990.2 | 977 | 960.7 | 919.6 | 867.4 | 800.3 |
| 60 | 1002.8 | 999.7 | 990.6 | 977.5 | 961.1 | 960.2 | 868.1 | 801.4 |
| 70 | 1003.3 | 1000.1 | 991 | 977.9 | 961.6 | 920.7 | 868.8 | 802.6 |
| 80 | 1003.8 | 1000.6 | 991.5 | 978.4 | 962.1 | 921.2 | 869.6 | 803.7 |
| 90 | 1004.3 | 1001 | 991.9 | 978.8 | 962.5 | 921.8 | 870.3 | 804.8 |
| 100 | 1004.8 | 1001.5 | 992.3 | 979.2 | .963 | 922.4 | 871 | 805.9 |
| 150 | 1007.3 | 1003.7 | 994.4 | 981.4 | 965.3 | 925.1 | 874.6 | 811.2 |
| 200 | 1009.7 | 1005.3 | 996.5 | 983.5 | 967.5 | 927.7 | 873 | 816.3 |
| 250 | 1012.1 | 1008 | 998.6 | 985.6 | 968.7 | 930.4 | 881.4 | 821.1 |
| 300 | 1014.5 | 1010.1 | 1000.7 | 987.7 | 971.9 | 932.9 | 884.7 | 825.7 |
| 350 | 1016.9 | 1012.2 | 1002.7 | 989.7 | 974 | 935.4 | 887.9 | 830.2 |
| 400 | 1019.2 | 1014.3 | 1004.7 | 991.8 | 976.1 | 937.9 | 891 | 834.4 |
| 450 | 1021.5 | 1016.4 | 1006.7 | 993.8 | 978.2 | 940.3 | 894 | 838.6 |
| 500 | 1023.8 | 1018.4 | 1008.7 | 995.8 | 980.3 | 942.7 | 897 | 842.5 |
| 600 | 1028.3 | 1022.4 | 1012.6 | 999.7 | 984.3 | 947.4 | 902.8 | 850.1 |
| 700 | 1031.7 | 1026.4 | 1016.4 | 1003.5 | 988.3 | 951.9 | 908.3 | 857.3 |
| 800 | 1037 | 1030.3 | 1020.1 | 1007.3 | 992.2 | 956.3 | 913.6 | 864.1 |
| 900 | 1041.2 | 1034.1 | 1023.8 | 1011 | 996 | 960.6 | 918.8 | 870.5 |
| 1000 | 1045.3 | 1037.8 | 1027.4 | 1014.6 | 999.7 | 964.8 | 923.7 | 876.7 |

## The density of water under relative temperature and pressure

| Pressure bar | Temperature 300 | 350 | 400 | 450 | 500 | 600 | 700 | 800 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.379 | 0.3483 | 0.3223 | 0.2999 | 0.2805 | 0.2483 | 0.2227 | 0.2019 |
| 5 | 1.9137 | 1.754 | 1.62 | 1.5056 | 1.4066 | 1.2437 | 1.1149 | 1.0105 |
| 10 | 3.8771 | 3.4502 | 3.2617 | 3.0623 | 2.8241 | 2.4932 | 2.331 | 2.0228 |
| 20 | 7.9713 | 7.2169 | 6.6142 | 6.1153 | 6.6926 | 5.0101 | 4.4794 | 4.0531 |
| 30 | 12.326 | 11.047 | 10.065 | 9.2708 | 8.6076 | 7.5512 | 6.739 | 6.0908 |
| 40 | 17 | 15.052 | 13.623 | 12.497 | 11.571 | 10.117 | 9.0121 | 8.136 |
| 50 | 22.073 | 19.255 | 17.299 | 15.798 | 14.586 | 12.709 | 11.299 | 10.189 |
| 60 | 22.662 | 23.687 | 21.102 | 19.179 | 17.653 | 15.326 | 13.599 | 12.249 |
| 70 | 33.944 | 23.384 | 25.045 | 22.646 | 20.776 | 17.97 | 15.914 | 14.316 |
| 80 | 41.226 | 33.394 | 29.143 | 26.202 | 23.957 | 20.642 | 18.242 | 16.391 |
| 90 | 713.36 | 38.776 | 33.411 | 29.855 | 21.198 | 23.341 | 20.584 | 18.474 |
| 100 | 715.58 | 44.611 | 37.867 | 33.611 | 30.305 | 26.068 | 22.941 | 20.564 |
| 150 | 725.87 | 87.191 | 63.889 | 54.2 | 48.077 | 40.154 | 34.943 | 31.124 |
| 200 | 735.02 | 600.78 | 100.54 | 78.732 | 67.711 | 55.039 | 47.319 | 41.871 |
| 250 | 743.32 | 625.74 | 166.63 | 109.09 | 89.904 | 70.794 | 60.08 | 52.803 |
| 300 | 750.93 | 644.27 | 358.05 | 148.45 | 115.26 | 87.481 | 73.234 | 63.919 |
| 350 | 757.99 | 659.3 | 474.89 | 201.63 | 144.43 | 105.15 | 86.779 | 75.214 |
| 400 | 764.58 | 672.1 | 523.67 | 270.91 | 177.97 | 123.81 | 100.71 | 86.682 |
| 450 | 770.78 | 683.33 | 554.78 | 343.37 | 215.87 | 143.44 | 115.01 | 98.312 |
| 500 | 776.64 | 693.39 | 577.99 | 402.28 | 256.95 | 163.99 | 129.64 | 110.09 |
| 600 | 787.51 | 710.93 | 612.45 | 479.87 | 338.44 | 207.2 | 159.77 | 134.02 |
| 700 | 797.44 | 726 | 633.83 | 528.62 | 405.76 | 251.73 | 190.65 | 158.3 |
| 800 | 806.62 | 739.31 | 659.27 | 563.69 | 456.99 | 295.45 | 221.74 | 182.72 |
| 900 | 815.18 | 751.29 | 677.05 | 591.14 | 496.53 | 336.53 | 252.48 | 207.03 |
| 1000 | 823.21 | 762.21 | 692.58 | 613.8 | 528.21 | 373.93 | 282.36 | 231.03 |

## The temperature and pressure parallel table of saturated vapor

| Absolute pressure ρ bar | Saturated temperatur $t_s$ ℃ | Density of Saturated pressure $\rho''_s$ kg/$m^3$ | Absolute pressure ρ bar | Saturated temperatur $t_s$ ℃ | Density of Saturated pressure $\rho''_s$ kg/$m^3$ | Absolute pressure ρ bar | Saturated temperatur $t_s$ ℃ | Density of Saturated pressure $\rho''_s$ kg/$m^3$ |
|---|---|---|---|---|---|---|---|---|
| 1.0 | 99.09 | 0.580 | 50 | 262.69 | 24.84 | 135 | 332.25 | 80.19 |
| 2.0 | 119.62 | 1.109 | 55 | 268.69 | 27.49 | 140 | 335.10 | 84.53 |
| 3.0 | 132.88 | 1.621 | 60 | 274.28 | 30.18 | 145 | 337.87 | 89.09 |
| 4.0 | 142.92 | 2.124 | 65 | 279.53 | 32.94 | 150 | 340.57 | 93.81 |
| 5.0 | 151.11 | 2.621 | 70 | 284.47 | 35.74 | 155 | 343.19 | 98.77 |
| 6.0 | 158.08 | 3.112 | 75 | 289.16 | 38.62 | 160 | 343.75 | 104.0 |
| 7.0 | 164.17 | 3.600 | 80 | 293.61 | 41.56 | 165 | 348.24 | 109.5 |
| 8.0 | 169.61 | 4.085 | 85 | 297.85 | 44.58 | 170 | 350.67 | 115.3 |
| 9.0 | 174.53 | 4.570 | 90 | 301.91 | 47.66 | 175 | 353.04 | 121.6 |
| 10.0 | 179.04 | 5.053 | 95 | 305.80 | 50.84 | 180 | 355.35 | 128.3 |
| 15 | 197.37 | 7.452 | 100 | 309.53 | 54.11 | 185 | 357.61 | 135.5 |
| 20 | 211.39 | 9.852 | 105 | 313.12 | 57.47 | 190 | 359.81 | 143.4 |
| 25 | 222.91 | 12.27 | 110 | 316.58 | 60.94 | 195 | 361.97 | 152.0 |
| 30 | 232.76 | 14.72 | 115 | 319.92 | 64.50 | 200 | 364.07 | 161.6 |
| 35 | 241.42 | 17.19 | 120 | 323.15 | 68.21 | 210 | 368.15 | 185.7 |
| 40 | 249.18 | 19.70 | 125 | 326.28 | 72.05 | 220 | 372.05 | 226.1 |
| 45 | 256.22 | 22.25 | 130 | 329.31 | 76.05 | | | |

**Australian Electric Control Engineering Pty Ltd**

Add: Unit 2002, 568 Collins Street Melbourne VIC3000
Tel: (03) 5275-7068
Fax: (03) 5275-2083
Web: http://www.aece.com.au
http://www.aece.net.au
E-mail: sales@aece.com.au