


|  |  |   |
|--|--|---|
| <b>KLM Technology Group</b><br><br>Practical Engineering Guidelines for Processing Plant Solutions                         | <br><br><b>Engineering Solutions</b><br><br><a href="http://www.klmtechgroup.com">www.klmtechgroup.com</a> | Page : 1 of 98  |
|  |  | Rev: 02   |
|  |  | Rev 01 March 2007<br>Rev 02 February 2014                     |
| KLM Technology Group<br>#03-12 Block Aronia,<br>Jalan Sri Perkasa 2<br>Taman Tampoi Utama<br>81200 Johor Bahru<br>Malaysia | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b><br><br><b>Fluid Flow Measurement Selection<br/>         and Sizing</b><br><br><b>(ENGINEERING DESIGN GUIDELINE)</b>         | Co- Authors<br><br>Rev 01 A L Ling<br>Rev 2 Reni Mutiara Sari |
|  |  | Editor / Author<br><br>Karl Kolmetz                           |

**KLM Technology Group has developed; 1) Process Engineering Equipment Design Guidelines, 2) Equipment Design Software, 3) Project Engineering Standards and Specifications, 4) Petrochemical Manufacturing Reports and 5) Unit Operations Manuals. Each has many hours of engineering development.**

**KLM is providing the introduction to this guideline for free on the internet. Please go to our website to order the complete document.**

[www.klmtechgroup.com](http://www.klmtechgroup.com)

**KLM Technology Group with their key partners specialize in;**

- 1) Process Engineering Equipment Design Guidelines**
- 2) Training for Refining, Chemicals, Ethylene and Equipment Design**
- 3) Process Engineering Consulting Studies**
- 4) Process Safety Management Consulting**
- 5) HAZOP Facilitation**
- 6) Distillation Equipment Supply (Random and Structured Packing, Trays)**
- 7) Commissioning Assistance**

**KLM Technology Group believes that if you have a design, consulting, or troubleshooting project you should consider our senior consultants.**

|  |  |              |
|--|--|--------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 2 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02      |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014     |

## TABLE OF CONTENT

|   |    |
|---|----|
| <b>INTRODUCTION</b>                         | 6  |
| Scope                                       | 6  |
| General Consideration                       | 7  |
| <b>DEFINITIONS</b>                          | 13 |
| <b>NOMENCLATURE</b>                         | 16 |
| <b>THEORY</b>                               | 17 |
| Selection Criteria of Flowmeter             | 17 |
| Accuracy                                    | 17 |
| Flow Range and Rangeability                 | 18 |
| Discharge Coefficient                       | 19 |
| Reynolds Number                             | 19 |
| <b>Flow Measurement Device</b>              | 20 |
| I. Differential Pressure Flowmeter          | 20 |
| A.Orifice Plate                             | 22 |
| I) Design and Construction                  | 22 |
| II) Flow Calculations of Orifice Plate      | 24 |
| a) Liquid flow                              | 25 |
| b) Gas flow                                 | 27 |
| B.Venturi Tube                              | 27 |
| I) Design and Construction                  | 27 |
| II) Flow Calculations of Orifice Plate      | 29 |
| C. Pitot-Static Tube                        | 30 |
| I) Design and Construction                  | 30 |
| II) Flow Calculation of Pitot - Static Tube | 32 |

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |              |
|--|--|--------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 3 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02      |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014     |

|  |    |
|--|----|
| <b>D. Nozzle</b>   | 33 |
| <b>I) Design and Construction</b>                              | 33 |
| <b>II) Flow Calculations of Nozzle</b>                         | 34 |
| <b>II. Variable Area Flowmeter</b>                             | 36 |
| <b>A. Rotameter</b>  | 36 |
| <b>I) Design and construction</b>                              | 36 |
| <b>II) Flow Calculation Equation (Spherical Ball as Float)</b> | 37 |
| <b>B. Movable Vane Meter</b>                                   | 38 |
| <b>I) Design and construction</b>                              | 38 |
| <b>C. Weirs, Flume</b>   | 39 |
| <b>Weirs</b>   | 39 |
| <b>I) Design and Construction</b>                              | 39 |
| <b>II) Flow Calculations of Weirs</b>                          | 41 |
| <b>Flume</b>   | 42 |
| <b>I) Design and Construction</b>                              | 42 |
| <b>II) Flow Calculations of Flume</b>                          | 44 |
| <b>III. Positive Displacement Flowmeter</b>                    | 45 |
| <b>I) Design and Construction</b>                              | 45 |
| <b>A. Commercially Positive Displacement Types</b>             | 46 |
| <b>IV. Turbine Flowmeter</b>                                   | 50 |
| <b>I) Design and Construction</b>                              | 50 |
| <b>Paddlewheel Flowmeter</b>                                   | 51 |
| <b>V. Electromagnetic Flowmeter</b>                            | 52 |
| <b>I) Design and Construction</b>                              | 52 |
| <b>VI. Ultrasonic Flowmeter</b>                                | 53 |
| <b>I) Design and Construction</b>                              | 53 |
| <b>A. Doppler</b>  | 54 |
| <b>B. Transit-Time Flowmeters</b>                              | 54 |

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |              |
|--|--|--------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 4 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02      |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014     |

|  |    |
|--|----|
| II) Flow Calculations of transit-time                    | 55 |
| VII. Coriolis Flowmeter                                  | 56 |
| I) Design and Construction                               | 56 |
| VIII. Vortex shedding Meter                              | 57 |
| I) Design and Construction                               | 57 |
| General Flowmeters Selection Guide                       | 59 |
| <b>APPLICATION</b>                                       |    |
| Example Case 1: Orifice Sizing for Liquid Flow           | 60 |
| Example Case 2: Orifice Sizing for Gas Flow              | 63 |
| Example Case 3: Venturi Tube Sizing for Liquid Flow      | 66 |
| Example Case 4: Venturi Tube Sizing for Gas Flow         | 69 |
| Example Case 5: Nozzle Sizing for Liquid Flow            | 73 |
| Example Case 6: Nozzle Sizing for Gas Flow               | 76 |
| Example Case 7: Pitot static Tube Sizing for Liquid Flow | 79 |
| Example Case 8: Pitot static Tube Sizing for Gas Flow    | 80 |
| <b>REFERENCES</b>  | 83 |

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |              |
|--|--|--------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 5 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02      |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014     |

### LIST OF TABLE

|  |    |
|--|----|
| Table 1: Variance Orifice plate design and application                               | 23 |
| Table 2: The performance and applications of common differential pressure flowmeters | 35 |
| Table 3: Dimension and Capacities of One=Piece Flume                                 | 44 |
| Table 4: Typical Flowmeter Applicable Services                                       | 59 |

### LIST OF FIGURE

|  |    |
|--|----|
| Figure 1: Range of Error                                   | 18 |
| Figure 2: A Concentric Sharp Edged Orifice Plate Flowmeter | 23 |
| Figure 3: Types of pressure taps for orifices              | 25 |
| Figure 4: A Venturi Tube Flowmeter                         | 28 |
| Figure 5: Simple Pitot tube                                | 30 |
| Figure 6: Averaging Pitot 'annubar'                        | 31 |
| Figure 7: A Nozzle Flowmeter                               | 34 |
| Figure 8: ISA 1932 nozzle and long radius nozzle           | 35 |
| Figure 9: A Cross Sectional of Rotameter                   | 36 |
| Figure 10: Typical Rotameter Bob Geometries                | 37 |
| Figure 11: Rotameter                                       | 38 |
| Figure 12: Movable Vane Meter                              | 39 |
| Figure 13: Weirs   | 40 |
| Figure 14: V-notch Weirs                                   | 40 |
| Figure 15: Perpendicular Weir                              | 41 |
| Figure 16: Flume   | 43 |
| Figure 17: Type of Positive Displacement Flowmeters        | 46 |
| Figure 18: Roots Meter                                     | 48 |
| Figure 19: CVM Meter                                       | 49 |
| Figure 20: Diaphragm Meter                                 | 50 |
| Figure 21: Simplify turbine flowmeter                      | 50 |

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |              |
|--|--|--------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 6 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02      |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014     |

|   |    |
|---|----|
| Figure 22: Selection Guide for displacement and Turbine meter | 51 |
| Figure 23: Paddlewheel Flowmeter                              | 52 |
| Figure 24: Element of electromagnetic flow meter              | 53 |
| Figure 25: Typical Doppler flowmeter operating principle      | 54 |
| Figure 26: Transit-time ultrasonic flowmeter                  | 55 |
| Figure 27: U-shaped Coriolis mass meter                       | 57 |
| Figure 28: Vortex sheddingMeter                               | 58 |

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|   |  |                     |
|---|--|---------------------|
| <p align="center"><b>KLM Technology Group</b></p> <p align="center">Practical Engineering<br/>Guidelines for Processing Plant<br/>Solutions</p> | <p><b>Kolmetz Handbook<br/>of Process Equipment Design</b></p> | <p>Page 7 of 98</p> |
|   | <p><b>Fluid Flow Measurement Selection<br/>and Sizing</b></p>  | <p>Rev: 02</p>      |
|   | <p><b>( ENGINEERING DESIGN GUIDELINES)</b></p>                 | <p>Feb 2014</p>     |

## INTRODUCTION

### Scope

Measurement of a flowing fluid can be a challenge because it requires that the mass or volume of material be quantified as it moves through a pipe or conduit. Problems may arise due to the complexity of the dynamics of fluid flow. Flow measurements draw on a host of physical parameters that are also often difficult to quantify.

This design guideline includes the selection method of the flow measurement instrument depending on the applications. It also assist engineers to size some flow measurement instruments (Orifice plate, Venturi tube, Pitot tube, nozzle, Rotameter, vane meter, positive displacement flow meter and etc) with the engineering calculation, or just key in the require data into the spread sheet provided in this package.

All the important parameters use in the guideline are well explained in the definition section which will help the reader understand the meaning of the parameters or the terms.

This design guideline discusses the method of selection of the several types of the flow measurement instrumentation, such as the differential pressure flow meter, variable area flow meter, positive displacement flow meter, turbine flow meter, and electromagnetic flow meter.

The theory section covers the selection of flow meters and the general theories applied for the sizing for each type of the flow meter. In the application section, several case studied are shown and discussed in detail step by step to the theory for the calculation. The case studied will aid the engineers to do the selection and sizing for the several flow meters base on their own system.

In the end of this guideline, example specification data sheets for the flow measurement are included which is created based on an industrial example. A calculation spreadsheet is included as well to aid the user to apply the theory of calculations.

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |              |
|--|--|--------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 8 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02      |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014     |

## INTRODUCTION

### General Consideration

The importance of industrial flow measurement has grown in the past 50 years, not just because its widespread use for accounting purposes, such as custody transfer of fluid from supplier to customers, but also because of its application in manufacturing processes. Examples of the industries involved in flow measurement included food and beverage, oil and gas industrial, medical, petrochemical, power generation, and water distribution.

In custody transfer metering, being constantly aware that flow measurement equates to dollars changes the perspective accordingly. The goal sought is that custody transfer measurement be converted to dollars  $\pm$  zero. Quantities for custody transfer are treated as absolute when they are billed.

The responsibility for this measurement, then, is to reduce all inaccuracies to a minimum so that a measured quantity can be agreed upon for exchanging custody. Control measurement may be accepted at  $\pm 2\%$ ; operational measurement may require no more than  $\pm 5\%$ , as contrasted with the  $\pm 0\%$  target for custody transfer metering<sup>[5]</sup>.

Flow measurement is the determination of the quantity of a fluid, either a liquid, or vapor, that passes through a pipe, duct or open channel. Flow may be expressed as a rate of volumetric flow (such as gallons per minute, cubic meters per minute, cubic feet per minute), mass rate of flow (such as kilograms per hour, pounds per hour), or in terms of a total volume or mass flow (integrated rate of flow for a given period of time).

Fluid flow measurement can be divided into several types; each type requires specific considerations of such factors as accuracy requirements, cost considerations, and use of the flow information to obtain the required end results. Normally the flow meter is measure flow indirectly by measuring a related property such as a differential pressure across a flow restriction or a fluid velocity in a pipe. A number of different fundamental physical principles are used in flow measurement devices.

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.



|  |  |              |
|--|--|--------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 9 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02      |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014     |

There is various kind of the flowmeter available in market; they can be classifier types as

- i) Difference pressure flow meter
  - a. Orifice plate,
  - b. Venturi tube,
  - c. Pitot tube and
  - d. Nozzle
  
- ii) Variable area flowmeter
  - a. Rotameter
  - b. Movable vane meter, and
  - c. Weir, flume
  
- iii) Positive displacement flowmeter
  - Tri-rotor type PD meter,
  - Birotor PD meter,
  - Piston type PD meter,
  - Oval gear PD meter,
  - Nutating disk type PD meter,
  - Sliding-vane type PD meter,
  - Roots PD meter,
  - The CVM meter ,and
  - Diaphragm meter
  
- iv) Turbine flowmeter
  
- v) Electromagnetic flowmeter
  
- vi) Ultrasonic flowmeter
  - a. Doppler
  - b. Transit- Time

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |               |
|--|--|---------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 10 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02       |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014      |

- vii) Coriolis (Mass) flowmeter
- viii) Vortex Shedding Meter

### Differential Pressure Flowmeter

Approximately 40% of all liquid, gas, and steam measurements made in industry are still accomplished using common types of differential pressure flowmeter (orifice plate, venturi tube, and nozzle). The operation of these flowmeters is based on the observation made by Bernoulli that if an annular restriction is placed in a pipeline, then the velocity of the fluid through the restriction is increased. The increase in velocity at the restriction causes the static pressure to decrease at this section, and a pressure difference is created across the element.

The difference between the pressure upstream and pressure downstream of this obstruction is related to the rate of fluid flowing through the restriction and therefore through the pipe. A differential pressure flowmeter consists of two basic elements: an obstruction to cause a pressure drop in the flow (a differential producer) and a method of measuring the pressure drop across this obstruction (a differential pressure transducer) (4).

### Variable Area Flowmeter

Variable area flowmeters refers to those meters in which the minimum cross-sectional area available to the flow through the meter varies with the flow rate. This type meters include the Rotameter and the movable vane meter used in pipe flows, and the weir or flume used in open-channel flows. The measure of the flow rate is a geometrical quantity such as the height of a bob in the Rotameter, the angle of the vane, or the change in height of the free surface of the liquid flowing over the weir or through the flume.

For pipe flows, variable area flowmeters are most suitable for low flow rates of gases or liquids at moderate temperatures and pressures. Favorable features include rugged construction, high reliability, low pressure drop, easy installation, and low cost. Disadvantages include measurement uncertainty of 1% or more, limited range (10:1), slow response, and restrictions on the meter orientation. A generally good

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|   |  |                      |
|---|--|----------------------|
| <p style="text-align: center;"><b>KLM Technology Group</b></p> <p style="text-align: center;">Practical Engineering<br/>Guidelines for Processing Plant<br/>Solutions</p> | <p><b>Kolmetz Handbook<br/>of Process Equipment Design</b></p> | <p>Page 11 of 98</p> |
|   | <p><b>Fluid Flow Measurement Selection<br/>and Sizing</b></p>  | <p>Rev: 02</p>       |
|   | <p><b>( ENGINEERING DESIGN GUIDELINES)</b></p>                 | <p>Feb 2014</p>      |

price/performance ratio has led to widespread use of these meters in numerous scientific and medical instruments and in many industrial applications for flow monitoring.

### **Positive Displacement (PD) Meters**

Positive displacement (PD) meters measure volumetric flow by continuously separating (isolating) a flow stream into discrete volumetric segments, counting them, and then returning it to the flowing stream. Positive displacement (PD) meters are used for measurement of liquids and gas, primarily liquids for pipeline uses. Two of the most common meters at residences are the water and gas meter, both of which are usually positive displacement meters.

Each design and working mechanism can be noticeably different from another; all positive displacement meters have three components a stationary fluid retaining wall (outer housing), a mechanism (internal mechanism) that momentarily entraps inlet fluid into a partitioned chamber before releasing it to the downstream side of the meter and the display or counter accessories that determines the number of entrapments of fluid in the dividing chamber and infers the flow rate and the total volume of flow through the meter.

Application for the low line pressure, design of the outer housing of the PD flowmeter is single walled, while for higher operating pressures, the housing is double walled where the inner wall is the containment wall for the entrapment chamber and the outer wall is the pressure vessel.

Difference designs it can be due to difference measurement applications. For liquid applications, PD meters work best for liquids with heavy viscosities. Almost all PD meters require precisely machined, high tolerance mating parts; thus, measured fluid must be clean for longevity of the meter and to maintain the measurement precision.

Positive displacement meters will measure with high accuracy over a wide range of flow rates, and are very reliable over long periods on clean fluids or with line filters. In general, PD meters have minimal pressure drop across the meter; hence, they can be installed in a pipeline with very low line pressures.

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |               |
|--|--|---------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 12 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02       |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014      |

## Turbine Flowmeter

Turbine flowmeters measure the velocity of liquids, gases and vapors in pipes, such as hydrocarbons, chemicals, water, cryogenic liquids, air, and industrial gases. High accuracy turbine flowmeters are available for custody transfer of hydrocarbons and natural gas. This flowmeter can be applied to sanitary, relatively clean, and corrosive liquids in sizes up to approximately 24 inches. The flow of corrosive liquids can be measured with proper attention to the materials of construction of all wetted parts, such as the body, rotor, bearings, and fittings.

Applications for turbine flowmeters are found in the water, petroleum, and chemical industries. Water applications include distribution systems within and between water districts. Petroleum applications include the custody transfer of hydrocarbons. Miscellaneous applications are found in the food and beverage, and chemical industries.

## Electromagnetic Flowmeter

Electromagnetic flowmeter measures flow according to Faraday's law of magnetic induction. A full-flow electromagnetic flowmeter is a nonintrusive device that consists of a magnetic coil that encircles the pipe, and two electrodes drilled into the pipe along a diameter flush with the inner surface of the pipe so that the electrodes are in contact with the fluid but do not interfere with the flow and thus do not cause any head loss [fluid mechanical]. In fluid measurement, the "conductor" is the process fluid flow, the faster it flows, the greater the voltage induced across the electrodes of the meter.

## Ultrasonic Flowmeter

Ultrasonic flowmeters normally used to measure flow for pure water, wash water, sewage, process liquids, oils, and other light homogeneous liquids. The basic requirement is that the fluid be capable of ultrasonic wave propagation and have a reasonably axis-symmetrical flow, which flow must be measured without any head losses or any pressure drop.

The basic operating principle of these meters is to detect flow through a pipe, ultrasonic flowmeters use acoustic waves or vibrations of a frequency >20 kHz. Depending on the

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |               |
|--|--|---------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 13 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02       |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014      |

design, they use either wetted or nonwetted transducers on the pipe perimeter to couple ultrasonic energy with the fluid flowing in the pipe.

Compare to electromagnetic flowmeters, it can suit for variety kind of flowing liquid, but electromagnetic flowmeters only for the liquid which have minimum electric conductivity. In addition, the cost of ultrasonic flowmeters is nearly independent of pipe diameter, whereas the price of electromagnetic flowmeters increases drastically with pipe diameter.

### **Coriolis Meter**

Coriolis meters have become widely used in industrial environments because they have the highest accuracy of all types of flowmeters. These meters are used for both custody transfer and control measurement. Its can be used on liquids, gases and can handle corrosive fluids and fluids that contain solids. They measure mass directly, rather than inferentially weight (mass). If the desired measure is volume, then some correction for density at fluid base conditions must be made.

The meter consists of one or two flow tubes enclosed in sensor housing. These tubes are vibrated at their natural frequency by an electromagnetic drive coil located at the center of the bend in the tube. The vibration is similar to that of a tuning fork, completing a full cycle about 80 times each second.

### **Vortex Shedding Meter**

A vortex shedding meter consists of a sharp-edged bluff body (strut) placed in the flow that serves as the vortex generator, and a detector (such as a pressure transducer that records the oscillation in pressure) placed a short distance downstream on the inner surface of the casing to measure the shedding frequency[yunus].

When selecting the flowmeter for the specific applications, certain studied have to be carried out. Review the certain meters service record and reference to industry standards and users within an industry are important points to review in choosing the best meter for the given applications.

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |               |
|--|--|---------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 14 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02       |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014      |

Difference fluid properties (viscosity, type of fluid, velocity profiles, flow profiles, Reynolds number) are the important cause of the differential flow measurement available in market. A lot of flowmeter techniques have been developed with each suit to a particular application, only few flowmeter can used for widespread application and no one single can use for all applications.

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|   |  |                      |
|---|--|----------------------|
| <p style="text-align: center;"><b>KLM Technology Group</b></p> <p style="text-align: center;">Practical Engineering<br/>Guidelines for Processing Plant<br/>Solutions</p> | <p><b>Kolmetz Handbook<br/>of Process Equipment Design</b></p> | <p>Page 15 of 98</p> |
|   | <p><b>Fluid Flow Measurement Selection<br/>and Sizing</b></p>  | <p>Rev: 02</p>       |
|   | <p><b>( ENGINEERING DESIGN GUIDELINES)</b></p>                 | <p>Feb 2014</p>      |

## DEFINITION

**Accuracy** - The ability of a flow measuring system to indicate values closely, approximating the true value of the quantity measured.

**Beta Ratio** - The ratio of the measuring device diameter to the meter run diameter (i.e., orifice bore divided by inlet pipe bore) or can be define as ratio of small to large diameter in orifices and nozzles.

**Capacity** - Is the water handling capability of a pump commonly expressed as either gallon per minute (gal/min) or cubic meter per minute (m<sup>3</sup>/min).

**Coefficients Discharge** - The ratio of the true flow to the theoretical flow. It corrects the theoretical equation for the influence of velocity profile, tap location, and the assumption of no energy loss with a flow area between 0.023 to 0.56 percent of the geometric area of the inlet pipe.

**Coriolis Flowmeter** - Direct mass measurement sets Coriolis flowmeters apart from other technologies. Mass measurement is not sensible to changes in pressure, temperature, viscosity and density. With the ability to measure liquids, slurries and gases, Coriolis flowmeters are universal meters.

**Custody Transfer** - Flow measurement whose purpose is to arrive at a volume on which payment is made/received as ownership is exchanged.

**Diameter Ratio (Beta)** - The diameter ratio (Beta) is defined as the calculated orifice plate bore diameter (d) divided by the calculate meter tube internal diameter (D).

**Differential Pressure-** The drop in pressure across a head device at specified pressure taps locations. It is normally measured in inches or millimeters of water.

**Differential Pressure Flowmeter-** A flowmeter in which the pressure drop across an annular restriction placed in the pipeline is used to measure fluid flow rate. The most common types use an orifice plate, Venturi tube, or nozzle as the primary device.

**Differential Pressure Transmitter-** Secondary device that measures the differential pressure across the primary device and converts it into an electrical signal.

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|   |  |                      |
|---|--|----------------------|
| <p style="text-align: center;"><b>KLM Technology Group</b></p> <p style="text-align: center;">Practical Engineering<br/>Guidelines for Processing Plant<br/>Solutions</p> | <p><b>Kolmetz Handbook<br/>of Process Equipment Design</b></p> | <p>Page 16 of 98</p> |
|   | <p><b>Fluid Flow Measurement Selection<br/>and Sizing</b></p>  | <p>Rev: 02</p>       |
|   | <p><b>( ENGINEERING DESIGN GUIDELINES)</b></p>                 | <p>Feb 2014</p>      |

**Discharge Coefficients-** The ratio of the true flow to the theoretical flow. It corrects the theoretical equation for the influence of velocity profile, tap location, and the assumption of no energy loss with a flow area between 0.023 to 0.56 percent of the geometric area of the inlet pipe.

**Electromagnetic Flowmeter** -An electromagnetic flowmeter operate on Faraday's law of electromagnetic induction that states that a voltage will be induced when a conductor moves through a magnetic field. The liquid serves as the conductor and the magnetic field is created by energized coils outside the flow tube.

**Manometer-** A device that measures the height (head) of liquid in a tube at the point of measurement.

**Mass Meter-** Meter that measures mass of a fluid based on a direct or indirect determination of the fluid's weight rate of flow.

**Measurement-** The act or process of determining the dimensions, capacity, or amount of something.

**Meter Factor (MF)** - The meter factor (MF) is a number obtained by dividing the quantity of fluid measured by the primary mass flow system by the quantity indicated by the meter during calibration. For meters, it expresses the ratio of readout units to volume or mass units.

**Meter Static-** Meters that measure by batch from a flowing stream by fill and empty procedures.

**Non-pulsating (see pulsation)** - Variations in flow and/or pressure that are below the frequency response of the meter.

**Orifice Plate-** A thin plate in which a circular concentric aperture (bore) has been machined. The orifice plate is described as a .thin plate and with sharp edge, because the thickness of the plate material is small compared with the internal diameter of the measuring aperture (bore) and because the upstream edge of the measuring aperture is sharp and square.

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.



|  |  |               |
|--|--|---------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 17 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02       |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014      |

**Pipeline Quality-** Fluids that meet the quality requirements of contaminant as specified in the exchange contract such as clean, non-corrosive, single phase, component limits, etc.

**Positive Displacement Flowmeter** -The positive displacement flowmeter measures process fluid flow by precision-fitted rotors as flow measuring elements. Known and fixed volumes are displaced between the rotors. The rotation of the rotors is proportional to the volume of the fluid being displaced.

**Pulsation-** A rapid, periodic, alternate increase and decrease of pressure and/or flow. The effect on a meter depends on the frequency of the pulsation and the frequency response of the meter.

**Uncertainty** - A statistical statement of measurement accuracy based on statistically valid information that defines 95% of the data points (twice the standard deviation).

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.

|  |  |               |
|--|--|---------------|
| <b>KLM Technology Group</b><br><br>Practical Engineering<br>Guidelines for Processing Plant<br>Solutions | <b>Kolmetz Handbook<br/>         of Process Equipment Design</b> | Page 18 of 98 |
|  | <b>Fluid Flow Measurement Selection<br/>         and Sizing</b>  | Rev: 02       |
|  | <b>( ENGINEERING DESIGN GUIDELINES)</b>                          | Feb 2014      |

## NOMENCLATURE

|       |  |
|-------|--|
| $A_1$ | Sectional area of upstream pipe, ft <sup>2</sup>   |
| $A_2$ | Sectional area of meter bore, ft <sup>2</sup>  |
| $C$   | Correction constant of the design of Pitot-static tube (from vendor of flowmeter), dimensionless |
| $C_d$ | Discharge coefficient, dimensionless   |
| $D$   | Internal diameter of pipe, in  |
| $g$   | Acceleration of gravity, 32.2 ft/s <sup>2</sup>  |
| $h_1$ | Height of flow for upstream, ft  |
| $h_2$ | Height of flow for downstream, ft  |
| $h_L$ | Head loss due to friction in meter, ft   |
| $k$   | Gas isentropic exponent, dimensionless   |
| $P_1$ | Absolute pressure for upstream, psia   |
| $P_2$ | Absolute pressure for downstream, psia   |
| $Q_1$ | Mass flow, gal/min   |
| $q$   | Volumetric flow rate, ft <sup>3</sup> /s   |
| $q_m$ | Mass flow rate, lbm/s  |
| $Re$  | Reynolds number, a dimensionless number  |
| $Y$   | Expansibility factor, for compressible fluid (Liquid =1)   |

## Greek letters

|               |   |
|---------------|---|
| $\beta$       | Beta ratio, ratio of orifice bore diameter to pipe diameter |
| $\varepsilon$ | Equivalent roughness of the pipe wall material, in          |
| $\rho$        | Weight density of fluid, lbm/ft <sup>3</sup>                |
| $\mu$         | Absolute (dynamic) viscosity, cp                            |
| $v_1$         | Velocity for upstream, ft/s                                 |
| $v_2$         | Velocity for downstream, ft/s                               |

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

This document is entrusted to the recipient personally, but the copyright remains with us. It must not be copied, reproduced or in any way communicated or made accessible to third parties without our written consent.