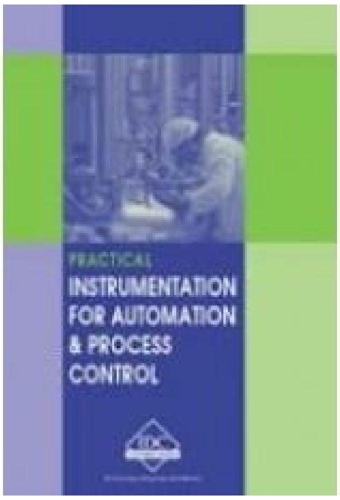
IP-E - Instrumentation for Automation and Process Control



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Short Description

The manual focuses on real applications, with attention to special installation considerations and application limitations when selecting or installing different measurement or control equipment.

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Practical Instrumentation for Automation and Process Control - Introduction

1 Introduction

In a time of constant and rapid technological development, it would be quite ambitious to develop and present a course that claimed to cover each and every industrial measuring type of equipment. This course is not intended to be an encyclopedia of instrumentation and control valves, but rather a training guide for gaining experience in this fast changing environment.

This course is aimed at providing engineers, technicians and any other personnel involved with process measurement, more experience in that field. It is also designed to give students the fundamentals on analysing the process requirements and selecting suitable solutions for their applications.

1.1 Basic measurement and control concepts

The basic set of units used on this course is the SI unit system. This can be summarised in Table 1.1.

Table 1.1

SI units

Quantity	**Unit**	**Abbreviation**
Length	metre	m
Mass	kilogram	kg
Time	second	s
Current	ampere	A
Temperature	degrees Kelvin	°K
Voltage	volt	V
Resistance	ohm	W
Capacitance	farad	F
Inductance	henry	H
Energy	joule	J

Power	watt	W
Frequency	hertz	Hz
Charge	coulomb	C
Force	newton	N
Magnetic Flux Magnetic Field Density	weber	Wb
	webers/metre^2	Wb/m^2
	kilogram/metre^3	kg/m^3

1.2 Basic measurement performance terms and specifications

There are a number of criteria that must be satisfied when specifying process measurement equipment. Below is a list of the more important specifications.

1.2.1 Accuracy

The accuracy specified by a device is the amount of error that may occur when measurements are taken. It determines how precise or correct the measurements are to the actual value and is used to determine the suitability of the measuring equipment.

Accuracy can be expressed as any of the following:

- error in units of the measured value
- percent of span
- percent of upper range value
- percent of scale length
- percent of actual output value

Accuracy generally contains the total error in the measurement and accounts for linearity, hysteresis and repeatability. Figure 1.1 shows errors in measurement.

Reference accuracy is determined at reference conditions, i.e. constant ambient temperature, static pressure, and supply voltage. There is also no allowance for drift over time.

Figure 1.1

Accuracy terminology

1.2.2 Range of Operation

The range of operation defines the high and low operating limits between which the device will operate correctly, and at which the other specifications are guaranteed. Operation outside of this range can result in excessive errors, equipment malfunction and even permanent damage or failure.

1.2.3 Budget/Cost

Although not so much a specification, the cost of the equipment is certainly a selection consideration. This is generally dictated by the budget allocated for the application. Even if all the other specifications are met, this can prove an inhibiting factor.

1.3 Advanced measurement performance terms and specifications

More critical control applications may be affected by different response characteristics. In these circumstances the following may need to be considered:

1.3.1 Hysteresis

Hysteresis is the difference in the output for given input when the input is increasing and output for same input when input is decreasing. In other words, it is the difference in the way device works when moving from 0% to 100%, compared to the way the device works when moving from 100% to 0%. When input of any instrument is slowly varied from zero to full scale and then back to zero, its output varies. One example is shown in Figure 1.2. This is where the accuracy of the device is dependent on the previous value and the direction of variation. Hysteresis causes a device to show an inaccuracy from the correct value, as it is affected by the previous measurement.

Figure 1.2

Hysteresis

1.3.2 Linearity

Linearity expresses the deviation of the actual reading from a straight line. If all outputs are in the same proportion to corresponding inputs over a span of values, then input output plot is straight line else it will be non linear as shown in Figure 1.3. For continuous control applications, the problems arise due to the changes in the rate the output differs from the instrument. The gain of a non-linear device changes as the change in output over input varies. In a closed loop system changes in gain affect the loop dynamics. In such an application, the linearity needs to be assessed. If a problem does exist, then the signal needs to be linearised.

Figure 1.3

Linearity

1.3.3 Repeatability

Repeatability defines how close a second measurement is to the first under the same operating conditions, and for the same input. Repeatability is generally within the accuracy range of a device and is different from hysteresis in that the operating direction and conditions must be the same.

Continuous control applications can be affected by variations due to repeatability. When a control system sees a change in the parameter it is controlling, it will adjust its output accordingly. However if the change is due to the repeatability of the measuring device, then the controller will over-control. This problem can be overcome by using the deadband in the controller as shown in Figure 1.4; however repeatability becomes a problem when an accuracy of say, 0.1% is required, and a repeatability of 0.5% is present.

Figure 1.4

Repeatability

Ripples or small oscillations can occur due to overcontrolling. This needs to be accounted for in the initial specification of allowable values.

1.3.4 Response

When the output of a device is expressed as a function of time (due to an applied input) the time taken to respond can provide critical information about the suitability of the device. A slow responding device may not be suitable for an application. This typically applies to continuous control applications where the response of the device becomes a dynamic response characteristic of the overall control loop. However in critical alarming applications where devices are used for point measurement, the response may be just as important. Figure 1.5 shows response of the system to a step input.

Figure 1.5

Typical time response for a system with a step input.

1.4 Definition of terminology

Below is a list of terms and their definitions that are used throughout this manual.

Ambient

The surrounding or environment in reference to a particular point or object.

Attenuation

A decrease in signal magnitude over a period of time.

Calibration

The procedure of comparing and determining the performance accuracy is called calibration. To configure a device so that the required output represents (to a defined degree of accuracy) the respective input.

Closed loop

Relates to a control loop where the process variable is used to calculate the controller output. In a closed loop system the control action is independent on desired output.

Temperature Coefficient of Resistance

The change in electrical resistance per degree change temperature is called the temperature coefficient of resistance.

Coefficient(temperature)

A coefficient is typically a multiplying factor. The temperature coefficient defines how much change in temperature there is for a given change in resistance (for a temperature dependent resistor).

Cold junction

The thermocouple junction, which is at a known reference temperature.

Compensation

A supplementary device used to correct errors due to variations in operating conditions.

Controller

A device, which operates automatically to regulate the control of a process with a control variable.

Elastic

The ability of an object to regain its original shape, when an applied force is removed. When a force is applied that exceeds the elastic limit, then permanent deformation will occur.

Excitation

The energy supply required to power a device for its intended operation.

Gain

This is the ratio of the change of the output to the change in the applied input. Gain is a special case of sensitivity, where the units for the input and output are identical and the gain is unitless.

Hunting

Generally an undesirable oscillation at or near the required setpoint is called hunting. Hunting typically occurs when the demands on the system performance are high and possibly exceed the system capabilities. The output of the controller can be overcontrolled due to the resolution of accuracy limitations.

Ramp

Defines the delayed and accumulated response of the output for a sudden change in the input.

Range

The region between the specified upper and lower limits where a value or device is defined and operated.

Reliability

The probability that a device will perform within its specifications for the number of operations or time period specified.

Reproducibility

The similarity of one measurement to another over time, where the operating conditions have varied within the time span, but the input is restored.

Resolution

The smallest interval that can be identified as a measurement varies.

Resonance

The frequency of oscillation is maintained due to the natural dynamics of the system.

Self Heating

The internal heating caused within a device due to the electrical excitation. Self-heating is primarily due to the current draw and not the voltage applied, and is typically shown by the voltage drop as a result of power (I^2R) losses.

Sensitivity

This defines how much the output changes, for a specified change in the input to the device.

Setpoint

Used in closed loop control, the setpoint is the ideal process variable. It is represented in the units of the process variable and is used by the controller to determine the output to the process.

Span Adjustment

The difference between the maximum and minimum range values. When provided in an instrument, this changes the slope of the input-output curve.

Steady state

Used in closed loop control where the process no longer oscillates or changes and settles at some defined value.

Stiction

Shortened form of static friction, and defined as resistance to motion. More important is the force required (electrical or mechanical) to overcome such a resistance.

Stiffness

This is a measure of the force required to cause a deflection of an elastic object.

Thermal shock

An abrupt temperature change applied to an object or device.

Time constant

The time constant of a first order system is defined as the time taken for the output to reach 63.2% of the total change, when subjected to a step input change.

Transducer

An element or device that converts information from one form (usually physical, such as temperature or pressure) and converts it to another (usually electrical, such as volts or millivolts or resistance change). A transducer can be considered to comprise a sensor at the front end (at the process) and a transmitter.

Transient

A sudden change in a variable, which is neither a controlled response, nor long lasting.

Transmitter

A device that converts one form of energy to another. Usually from mechanical to electrical for the purpose of signal integrity for transmission over longer distances and for suitability with control equipment.

Variable

Generally, this is some quantity of the system or process. The two main types of variables that exist in the system are the measured variable and the controlled variable. The measured variable is the measured quantity and is also referred to as the process variable as it measures process information. The controlled variable is the controller output which controls the process.

Vibration

This is the periodic motion (mechanical) or oscillation of an object.

Zero adjustment

The zero in an instrument is the output provided when no, or zero input is applied. The zero adjustment produces a parallel shift in the input-output curve.

1.5 P&ID (Process and Instrumentation Diagram) symbols

The Piping & Instrumentation Diagram (&ID) is a multi-disciple drawing (typically controlled by the process or chemical engineers), which may also be referred to as the Process & Instrumentation Diagram. It gives a graphical representation of the process including hardware (Piping, Equipment) and software (Control systems); this information is used for the design construction and operation of the facility. Other synonyms for the P&ID are:

- MFD – Mechanical Flow Diagram: Used where materials handling is predominant
- EFD – Engineering Flow Diagram
- UFD – Utility Flow Diagram

The P&ID also provides important information needed by the constructor and manufacturer to develop the other construction input documents (the isometric drawings, or orthographic physical layout drawings, etc.). The P&ID provides direct input to the field for the physical design and installation of field-run piping. For clarity, it is usual to use the same general layout of flow paths on the P&ID as used in the flow diagram.

The P&ID ties together the system description, the flow diagram, the electrical control schematic, and the control logic diagram. It accomplishes this by showing ALL of the piping, equipment, principal instruments, instrument loops, and control interlocks. The P&ID contains a minimum amount if text in the form of notes (the system description minimizes the need for text on the P&ID). The first P&ID in the set for the job should contain a legend defining all symbols used; if some symbols are defined elsewhere, it may be appropriate only to reference their source. The P&ID is also used by the start-up organizations for preparing flushing, testing, and blow-out procedures for the piping system and by the plant operators to operate the system. The correctness and completeness of the P&ID drawings are critical to the success of a plant start-up program.

There are three parts to process measurement and control functions as shown on a P&ID. These are:

- Letter (which describe WHAT the device is)
- Symbols or instrumentation bubbles (which describe WHERE the device is)
- Lines connecting the bubbles (which show HOW the data is moved)

First consider the letters. The first letter ALWAYS corresponds to the parameter being measured. The subsequent letters describe what is being done with the parameter

Identifying letters for Process measurement and control functions are listed below:

First letter	Second letter
A Analysis	Alarm
B Burner	
C Conductivity	Control
D Density	
E Voltage	Primary element
F Flow	
G Glass (sight tube)	
H Hand	
I Current (electric)	Indicate
J Power	
K Time	Control station
L Level	Light
M Moisture[1]	
O	Orifice
P Pressure	Point
Q Quantity	
R Radioactivity	Record, Relief
S Speed	Switch, Safety

T	Temperature	Transmit
U	Multivariable	Multifunction
V	Viscosity	Valve
W	Weight	Well
Y		Relay (transformation)
Z	Position	Drive[2]

[1] Moisture is not the normal use of the letter “M”, and is not conform to ISO-5, but it is one of the most common uses of the letter “M”.

[2] In many industries, “Z” as the second letter is used to show a safety device. This is often done when the control system is completely separate from the safety system.

Some examples …

Letters	**Meaning**
<u>PT</u>	Pressure Transmitter
PI	Pressure Indicator
PIT	Pressure Indicating Transmitter
LV	Level Valve
FQI	Flow Quantity Indicator (shows the total quantity)

The difference between a PT and a PIT is simple … you will not get an indication of the pressure with a PT

The second portion of the way instrumentation logic is represented on a P&ID is the “instrumentation bubble”. This shows where the device is located. In addition, a series of horizontal lines is used to further define the location, and to show who has access to the information. The letters are placed in the top portion, and the device number is placed in the bottom portion.

Discrete Instruments

Shared Display (typically in a control room or a DCS)

Shared Logic (typically in a PLC)

Computer Function (typically used for advanced control)

The modifying horizontal lines have the following meaning:

- Solid Line = unrestricted access
- Dashed Line = restricted access
- Single Line = Primary Location
- Double Line = Auxiliary Location
- No Line = Field Mounted

Some examples are as follows;

A field mounted pressure indicator with tag number 221

A level switch high (tag number 855) in an auxiliary PLC. Access to the set point is limited (for example, only the control systems engineer has access to the setpoint)

A temperature indicating controller (tag number 642) with a shared display (for example, a control room with multiple control displays). Everyone has access to the reading and the setpoint.

The third portion of the instrumentation represented on the P&ID is the way the data is moved from process to device or device to device. This is done with a set of lines connecting either the process device itself (for example, a pipe) to the instrument bubble, or connecting instrument bubbles. The following figure shows some of the ISA standard line symbols.

Figure 1.6

Instrument representation on flow diagrams (b)

Some examples:

The information from Level Indicating Controller 442 is transferred via a data link (software) within the DCS to Level Alarm High 442

The information from Level Indicating Controller 442 is transferred via an unguided electromagnetic signal (such as WiFi) to a Level Alarm High 442, which is located in a separate PLC

This is not possible. By using a software link, we are representing programming. By showing one device in a DCS, and the other in a separate PLC, they are separate “computers” and using a software link for them to communicate is impossible.

Flow elements have some special requirements. Sometimes we need only a primary device to measure the flow. Other times we need a primary and a secondary device. For example, consider measuring glow with an orifice meter. The primary element is the orifice plate (this is a flow element, so it would be labelled “FE”). The secondary element could be a differential pressure transmitter, but because it is in flow service, it would be a Flow transmitter (FT). We can use the instrument symbol to better define what type of flow meter is being used.

Figure 1.7

Some P& ID symbols for flow measurements

Finally, the control valve itself can have different actuators. ISA has developed some symbols to show the different actuators. Some examples are as follows:

Figure 1.8

1.6 Effects of selection criteria

1.6.1 Advantages

Wide operating range

The range of operation not only determines the suitability of the device for a particular application but also can be chosen for a range of applications. This can reduce the inventory in a plant as the number of sensors and models decrease. This also increases system reliability as sensing equipment can be interchanged as the need arises.

An increased operating range also gives greater over and under-range protection, should the process perform outside of specifications.

Widening the operating range of the sensing equipment may be at the expense of resolution. Precautions also need to be made when changing the range of existing equipment. In the case of control systems, the dynamics of the control loop can be affected.

Fast Response

With a fast response, delays are not added into the system. In the case of continuous control, lags can accumulate with the various control components and result in poor or slow control of the process. In a point or alarming application, a fast speed of response can assist in triggering safety or shutdown procedures that can reduce the amount of equipment failure or product lost.

Often a fast response is achieved by sacrificing the mechanical protection of the transducer element.

Good Sensitivity

Improved sensitivity of a device means that more accurate measurements are possible. The sensitivity also defines the magnitude of change that occurs. High sensitivity in the measuring equipment means that the signal can be read easily by a controller or other equipment.

High Accuracy

This is probably one of the most important selection criteria. The accuracy determines the suitability of the measuring equipment to the application, and is often a trade off with cost.

High accuracy means reduced errors in measurement; this also can improve the integrity and performance of a system.

High Over range Protection

This is more a physical limitation on the protection of the equipment. In applications where the operating conditions are uncertain or prone to failure, it is good practice to ‘build-in’ suitable protection for the measuring equipment.

High over range protection is different to having a wide operating range in that it does not measure when out of range. The range is kept small to allow sufficient resolution, with the overrange protection ensuring a longer operating life.

Simple Design and Maintenance

A simple design means that there are less “bits that can break”. More robust designs are generally of simple manufacture.

Maintenance is reduced with fewer pieces to wear, replace or assemble. There are also savings in the time it takes to service, repair and replace, with the associated procedures being simplified.

Cost

Any application that requires a control solution or the interrogation of process information is driven by a budget. It therefore is no surprise that cost is an important selection criterion when choosing measurement equipment.

The cost of a device is generally increased by improvements in the following specifications:

- Accuracy
- Range of operation
- Operating environment (high temperature, pressure etc.)

The technology used and materials of construction do affect the cost, but are generally chosen based on the improvement of the other selection criteria (typically those listed above).

Repeatability

The ability of the measurement system to give same output for same input repeatedly. Good repeatability ensures measurements vary according to process changes and not due to the limitations of the sensing equipment.

Size

This mainly applies to applications requiring specifically sized devices and has a bearing on the cost.

Small devices have the added advantage of:

- Can be placed in tight spaces
- Limited obstruction to the process
- Very accurate location of the measurement required (point measurement)

Large devices have the added advantage of:

- Area measurements

Stable

If a device drifts or loses calibration over time then it is considered to be unstable. Drifting can occur over time, or on repeated operation of the device. In the case of thermocouples, it has been proven that drift is more extreme when the thermocouple is varied over a wide range quite often, typically in furnaces that are repeatedly heated to high temperatures from the ambient temperature.

Even though a device can be recalibrated, there are a number of factors that make it undesirable:

- Labour required
- Possible shutdown of process for access
- Accessibility

Resolution

The resolution is the smallest measurable difference between two consecutive measurements.

Robust

This has the obvious advantage of being able to handle adverse conditions. However this can have the added limitation of bulk.

Self Generated Signal

This eliminates the need for supplying power to the device. Most sensing devices are quite sensitive to electrical power variations, and therefore power is required it generally needs to be conditioned.

Temperature Corrected

Ambient temperature variations often affect measuring devices. Temperature correction eliminates the problems associated with these changes.

Intrinsic Safety

Required for specific service applications. This requirement is typically used in environments where electrical or thermal energy can ignite the atmospheric mixture.

Simple to Adjust

This relates to the accessibility of the device. Helpful if the application is not proven and constant adjustments and alterations are required.

A typical application may be the transducer for ultrasonic level measurement. It is not uncommon to weld in brackets for mounting, only to find the transducer needs to be relocated.

Suitable for Various Materials

Selecting a device that is suitable for various materials not only ensures the suitability of the device for a particular application, but also can it to be used for a range of applications. This can reduce the inventory in a plant as the number of sensors and models are decreased. This also increases system reliability as sensing equipment can be interchanged as the need arises.

Non Contact

This is usually a requirement based on the type of material being sensed. Non-contact sensing is used in applications where the material causes build-up on the probe or sensing devices. Other applications are where the conditions are hazardous to the operation of the equipment. Such conditions may be high temperature, pressure or acidity.

Reliable Performance

This is an obvious advantage with any sensing device, but generally is at the expense of cost for very reliable and proven equipment. More expensive and reliable devices need to be weighed up against the cost of repair or replacement, and also the cost of loss of production should the device fail. The costs incurred should a device fail, are not only the loss of production (if applicable), but also the labour required to replace the equipment. This also may include travel costs or appropriately certified personnel for hazardous equipment or areas.

Unaffected by Density

Many applications measure process materials that may have variations in density. Large variations in the density can cause measurement problems unless accounted for. Measuring equipment that is unaffected by density provides a higher accuracy and is more versatile

Unaffected by Moisture Content

Applies primarily to applications where the moisture content can vary, and where precautions with sensing equipment are required. It is quite common for sensing equipment, especially electrical and capacitance, to be affected by moisture in the material.

The effect of moisture content can cause problems in both cases, i.e. when a product goes from a dry state to wet, or when drying out from a wet state.

Unaffected by Conductivity

The conductivity of a process material can change due to a number of factors, and if not checked can cause erroneous measurements. Some of the factors affecting conductivity are:

- pH
- salinity
- temperature

Mounting External to the Vessel

This has the same advantages as non-contact sensing. However it is also possible to sense through the container housing, allowing for pressurised sensing. This permits maintenance and installation without affecting the operation of the process.

Another useful advantage with this form of measurement is that the detection obstructions in chutes or product in boxes can be performed unobtrusively.

High Pressure Applications

Equipment that can be used in high pressure applications generally reduces error by not requiring any further transducer devices to retransmit the signal. However the cost is usually greater than an average sensor due to the higher pressure rating.

This is more a criteria that determines the suitability of the device for the application.

High Temperature Applications

This is very similar to the advantages of high pressure applications, and also determines the suitability of the device for the application.

Dual Point Control

This mainly applies to point control devices. With one device measuring two or even three process points, ON-OFF control can be performed simply with the one device. This is quite common in level control. This type of sensing also limits the number of tapping points required into the process.

Polarity Insensitive

Sensing equipment that is polarity insensitive generally protects against failure from incorrect installation.

Small Spot or Area Sensing

Selecting instrumentation for the specific purpose reduces the problems and errors in averaging multiple sensors over an area, or deducing the spot measurement from a crude reading.

Generally, spot sensing is done with smaller transducers, with area or average sensing being performed with large transducers.

Remote Sensing

Sensing from afar has the advantage of being non-intrusive and allowing higher temperature and pressure ratings. It can also avoid the problem of mounting and accessibility by locating sensing equipment at a more convenient location.

Well Understood and Proven

This, more than anything, reduces the stress involved when installing new equipment, both for its reliability and suitability.

No Calibration Required

Pre-calibrated equipment reduces the labour costs associated with installing new equipment and also the need for expensive calibration equipment.

No Moving Parts

The advantages are:

- Long operating life
- Reliable operation with no wear or blockages

If the instrument does not have any moving or wearing components, then this provides improved reliability and reduced maintenance.

Maintenance can be further reduced if there are no valves or manifolds to cause leakage problems. The absence of manifolds and valves results in a particularly safe installation, an important consideration when the process fluid is hazardous or toxic.

Complete Unit Consisting of Probe and Mounting

An integrated unit provides easy mounting and lowers the installation costs, although the cost of the equipment may be slightly higher.

FLOW APPLICATIONS

Low Pressure Drop

A device that has a low pressure drop presents less restriction to flow and also has less friction. Friction generates heat, which is to be avoided. Erosion (due to cavitation and flashing) is more likely in high pressure drop applications.

Less Unrecoverable Pressure Drop

If there are applications that require sufficient pressure downstream of the measuring and control devices, then the pressure drops across these devices needs to be taken into account to determine a suitable head pressure. If the pressure drops are significant, then it may require higher pressures. Equipment of higher pressure ratings (and higher cost) is then required.

Selecting equipment with low pressure losses results in safer operating pressures with a lower operating cost.

High Velocity Applications

It is possible in high velocity applications to increase the diameter of the section, which gives the same quantity of flow, but at a reduced velocity. In these applications, because of the expanding and reducing sections, suitable straight pipe runs need to be arranged for suitable laminar flow.

Operate in Higher Turbulence

Devices that can operate with a higher level of turbulence are typically suited to applications where there are limited sections of straight length pipe.

Fluids Containing Suspended Solids

These devices are not prone to mechanical damage due to the solids in suspension, and can also account for the density variations.

Require Less Straight Pipe Up and Downstream

This is generally a requirement applied to equipment that can accommodate a higher level of turbulence. However the device may contain straightening vanes, which assist in providing laminar flow.

Price does not Increase Dramatically with Size

This consideration applies when selecting suitable equipment, and selecting a larger instrument sized for a higher range of operation.

Good Rangeability

In cases where the process has considerable variations (in flow for example), and accuracy is important across the entire range of operation, the selecting of equipment with good rangeability is vital.

Suitable for Very Low Flow Rates

Very low flow rates provide very little energy (or force) and as such can be a problem with many flow devices. Detection of low flow rates requires particular consideration.

Unaffected by Viscosity

The viscosity generally changes with temperature, and even though the equipment may be rated for the range of temperature, problems may occur with the fluidity of the process material.

No Obstructions

This primarily means no pressure loss. It is also a useful criterion when avoiding equipment that requires maintenance due to wear, or when using abrasive process fluids.

Installed on Existing Installations

This can reduce installation costs, but more importantly can avoid the requirement of having the plant shutdown for the purpose or duration of the installation.

Suitable for Large Diameter Pipes

Various technologies do have limitations on pipe diameter, or the cost increases rapidly as the diameter increases.

1.6.2 Disadvantages

The following is a discussion of effects of the disadvantages and reasons for the associated limitations.

Hysteresis

Hysteresis can cause significant errors. The errors are dependent on the magnitude of change and the direction of variation in the measurement. One common cause of hysteresis is thermoelastic strain.

NOTE: Sometimes Hysteresis is desirable. For a pressure relief valve, hysteresis helps ensure the valve does not “chatter”.

Linearity

This affects the resolution over the range of operation. For a unit change in the process conditions, there may be a 2% change at one end of the scale, with a 10% change at the other end of the scale. This change is effectively a change in the sensitivity or gain of the measuring device.

In point measuring applications this can affect the resolution and accuracy over the range. In continuous control applications where the device is included in the control loop, it can affect the dynamic performance of the system.

Indication Only

Devices that only perform indication are not suited for automated control systems as the information is not readily accessible. Errors are also more likely and less predictable as they are subject to operator interpretation.

Sensitive to Temperature Variations

Problems occur when equipment that is temperature sensitive is used in applications where the ambient temperature varies continuously. Although temperature compensation is generally available, these devices should be avoided with such applications.

Shock and Vibration

These effects not only cause errors but also can reduce the working life of equipment, and cause premature failure.

Transducer Work Hardened

The physical movement and operation of a device may cause it to become harder to move. This particularly applies to pressure bellows, but some other devices do have similar problems.

If it is unavoidable to use such equipment, then periodic calibration needs to be considered as a maintenance requirement.

Poor Over range Protection

Care needs to be taken to ensure that the process conditions do not exceed the operating specifications of the measuring equipment. Protection may need to be supplied with additional equipment.

Poor over range protection in the device may not be a problem if the process is physically incapable of exceeding the operating conditions, even under extreme fault conditions.

Unstable

This generally relates to the accuracy of the device over time. However the accuracy can also change due to large variations in the operation of the device due to the process variations. Subsequently, unstable devices require repeated calibration over time or when operated frequently.

Size

Often the bulkiness of the equipment is a limitation. In applications requiring area or average measurements then too small a sensing device can be a disadvantage in that it does not “see” the full process value.

Dynamic Sensing Only

This mainly applies to shock and acceleration devices where the impact force is significant. Typical applications would involve piezoelectric devices.

Special Cabling

Measurement equipment requiring special cabling bears directly on the cost of the application. Another concern with cabling is that of noise and cable routing. Special conditions may also apply to the location of the cable in reference to high voltage, high current, high temperature, and other low power or signal cabling.

Signal Conditioning

Primarily used when transmitting signals over longer distances, particularly when the transducer signal requires amplification. This is also a requirement in noisy environments. As with cabling, this bears directly on the cost and also may require extra space for mounting.

Stray Capacitance Problems

This mainly applies to capacitive devices where special mounting equipment may be required, depending on the application and process environment.

Maintenance

High maintenance equipment increases the labour, which become a periodic expense. Some typical maintenance requirements may include the following:

- Cleaning
- Removal/replacement
- Calibration

If the equipment is fragile then there is the risk of it being easily damaged due to repeated handling.

Sampled Measurement Only

Measurement equipment that requires periodic sampling of the process (as opposed to continual) generally relies on statistical probability for the accuracy. More pertinent in selecting such device is the longer response and update times incurred in using such equipment.

Sampled measurement equipment is mainly used for quality control applications where specific samples are required and the quality does not change rapidly.

Pressure Applications

This applies to applications where the measuring equipment is mounted in a pressurised environment and accessibility is impaired. There are obvious limitations in installing and servicing such equipment. In addition are the procedures and experience required for personnel working in such environments.

Access

Access to the process and measuring equipment needs to be assessed for the purpose of:

- The initial installation
- Routine maintenance

The initial mounting of the measuring equipment may be remote from the final installation; as such the accessibility of the final location also needs to be considered. This may also have a bearing on the orientation required when mounting equipment.

Requires Compressed Air

Pneumatic equipment requires compressed air. It is quite common in plants with numerous demands for instrument air to have a common compressor with pneumatic hose supplying the devices.

The cost of the installation is greatly increased if no compressed air is available for such a purpose. More common is the requirement to tap into the existing supply but this still requires the installation of air lines.

Material Build-up

Material build-up is primarily related to the type of process material being measured. This can cause significant errors, or degrade the operating efficiency of a device over time. There are a number of ways to avoid or rectify the problems associated with material build-up:

- Regular maintenance
- Location (or relocation) of sensing equipment
- Automated or self cleaning (water sprays)

Constant Relative Density

Measurement equipment that relies on a constant density of process material is limited in applications where the density varies. Variations in the density will not affect the continued operation of the equipment, but will cause increased errors in the measurement. A typical example would be level measurement using hydrostatic pressure.

Radiation

The use of radioactive materials such as Cobalt or Cesium often gives accurate measurements. However, problems arise from the hazards of using radioactive materials, which require special safety measures. Precautions are required when housing such equipment, to ensure that it is suitably enclosed and installation safety requirements are also required for personal safety.

Licensing requirements may also apply with such material.

Electrolytic Corrosion

The application of a voltage to measuring equipment can cause chemical corrosion to the sensing transducer, typically a probe. Matching of the process materials and metals used for the housing and sensor can limit the effects; however in extreme mismatches, corrosion is quite rapid.

Susceptible to Electrical Noise

In selecting equipment, this should be seen as an extra cost and possibly more equipment or configuration time is required to eliminate noise problems.

More Expensive to Test and Diagnose

More difficult and expensive equipment can also require costly test and diagnosis equipment. For ‘one-off’ applications, this may prove an inhibiting factor. The added expense and availability of specialised services should also be considered.

Not Easily Interchangeable

In the event of failure or for inventory purposes, having interchangeable equipment can reduce costs and increase system availability. Any new equipment that is not easily replaced by anything already existing could require an extra as a spare.

High Resistance

Devices that have a high resistance can pick up noise quite easily. Generally high resistance devices require good practice in terms of cable selection and grounding to minimise noise pickup.

Accuracy Based on Technical Data

The accuracy of a device can also be dependent on how well the technical data is obtained from the installation and data sheets. Applications requiring such calculations are often subject to interpretation.

Requires Clean Liquid

Measuring equipment requiring a clean fluid do so for a number of reasons:

- Constant density of process fluid
- Sensing equipment with holes can become easily clogged
- Solids cause interference with sensing technology

Orientation Dependent

Depending on the technology used, requirements may be imposed on the orientation when mounting the sensing transducer. This may involve extra work, labour and materials in the initial installation. A typical application for mounting an instrument vertically would be a variable area flowmeter.

Unidirectional Measurement Only

This is mainly a disadvantage with flow measurement devices where flow can only be measured in the one direction. Although this may seem like a major limitation, few applications use bi-directional flows.

Not Suitable with Partial Phase Change

Phase change is where a fluid, due to pressure changes, reverts partly to a gas. This can cause major errors in measurements, as it is effectively a very large change in density.

For those technologies that sense through the process material, the phase change can result in reflections and possibly make the application unmeasurable.

Viscosity Must be Known

The viscosity of a fluid is gauged by the Reynolds number and does vary with temperature. In applications requiring the swirling of fluids and pressure changes there is usually an operating range of which the fluids viscosity is required to be within.

Limited Life Due to Wear

Non-critical service applications can afford measuring equipment with a limited operating life, or time to repair. In selecting such devices, consideration needs to be given to the accuracy of the measurement over time.

Mechanical Failure

Failure of mechanical equipment cannot be avoided; however the effects and consequences can be assessed in determining the suitable technology for the application. Flow is probably the best example of illustrating the problems caused if a measurement transducer should fail. If the device fails, and it is of such a construction that debris may block the line or a valve downstream, then this can make the process inoperative until shutdown and repaired.

Filters

There are two main disadvantages with filters:

- Maintenance and cleaning
- Pressure loss across filter

The pressure loss can be a process limitation, but from a control point of view can indicate that the filter is in need of cleaning or replacement.

Flow Profile

The flow profile may need to be of a significant form for selected measuring equipment. Note that the flow profile is dependent on viscosity and turbulence.

Acoustically Transparent

Measuring transducers requiring the reflection of acoustic energy are not suitable where the process material is acoustically transparent. These applications would generally require some contact means of measurement.

1.7 Measuring instruments and control valves as part of the overall control system

Figure 1.9 shows how instrument and control valves fit into the overall control system structure. The topic of controllers and tuning forms part of a separate workshop.

Figure 1.9

Instruments and control valves in the overall control system

1.8 Typical applications

Some typical applications are listed below.

HVAC (Heating, ventilation and air conditioning) Applications

- Heat transfer
- Billing
- Axial fans
- Climate control
- Hot and chilled water flows
- Forced air
- Fumehoods
- System balancing
- Pump operation and efficiency

Petrochemical Applications

- Co-generation
- Light oils

- Petroleum products
- Steam
- Hydrocarbon vapours
- Flare lines, stacks

Natural Gas

- Gas leak detection
- Compressor efficiency
- Fuel gas systems
- Bi-directional flows
- Mainline measurement
- Distribution lines measurement
- Jacket water systems
- Station yard piping

Power Industry

- Feed water
- Circulating water
- High pressure heaters
- Fuel oil
- Stacks
- Auxiliary steam lines
- Cooling tower measurement
- Low pressure heaters
- Reheat lines
- Combustion air

Emissions Monitoring

- Chemical incinerators
- Trash incinerators
- Refineries
- Stacks and rectangular ducts
- Flare lines