INDUSTRIAL PROCESS MEASUREMENT – System Performance.

The aim of this unit is to introduce the learner to principles and techniques related to the Performance, Operation and Application of a range of Industrial Transducer Systems.

1 APPLICATION, SELECTION AND OPERATION OF TRANSDUCER TYPES.

When discussing the Application, Selection and Operation of Measurement Systems and individual Transducers, often terms will be referred to which relate to performance. This opening unit, is going to look at some of the commonly used terms which relate to System performance.

Static characteristics are those which occur when an instrument has reached a steady state, whereas dynamic characteristics refer to the instrument behaviour as the measurement quantity changes.

Introduction.

If we were looking to buy a car, it is quite common that our initial choice is based on looks, and in lots of other cases this is true. However, looks alone are not the decision maker. In a process measurement system, it is also vital to consider the performance factors of the item or system. So, when buying a car, things we consider, include – MPG, 0-60, emissions, service intervals, Power etc. Likewise, when choosing an instrument, the right its not all about looks or name.

Specifications

		EJX430A Gauge Pressure Transmitter		
		H Capsule	A Capsule	B Capsule
Range		-100 to 500 kPa (-400 to 2000 inH$_2$O)	-0.1 to 3.5 MPa (-14.5 to 500 psi)	-0.1 to 16 MPa (-14.5 to 2300 psi)
Span		2.5 to 500 kPa (10 to 2000 inH$_2$O)	0.0175 to 3.5 MPa (2.5 to 500 psi)	0.8 to 16 MPa (12 to 2300 psi)
Accuracy		±0.04%	±0.04%	±0.04%
Degrees of protection		IP67, NEMA 4X, and JIS C0920 immersion proof		
Certificates		FM, CENELEC ATEX, CSA, IECEx		
Output		4 to 20 mA DC or FOUNDATION™ fieldbus, 2-wire system with digital communication		
Supply voltage		BRAIN and HART:10.5 to 42 V DC (10.5 to 30 V DC for Intrinsically safe type) Fieldbus:9 to 32 V DC (9 to 24 V DC for Entity and 9 to 17.5 V DC for FISCO)		
Ambient temperature		-40 to 85 deg C (-40 to 185 deg F) (general use type) -30 to 80 deg C (-22 to 176 deg F) (with integral indicator)		
Process temperature		-40 to 120 deg C (-40 to 248 deg F) (general use type)		
Maximum overpressure		16 MPa (2300 psig)		25 MPa (3600 psig)
Mounting		2-inch pipe mounting		
Wetted parts material	Capsule	316L SST(Diaphragm material is Hastelloy C-276), Hastelloy C-276,Tantalum,Monel		
	Cover flange	ASTM CF-8M,Hastelloy C-276,Monel		
Housing		Cast aluminum alloy or ASTM CF-8M stainless steel (option)		

So, before looking at the performance factors of a measuring system, let us first consider what those words mean.

Measuring System

A measuring system exists to provide information about the physical value of some process variable being measured.

The word instrument might be replaced by the word 'device', and if so, the description becomes 'A device, or series of devices that show the extent or amount or quantity or degree of something. And what is 'the something'?

'The something', are conditions known as Process Variables, these are conditions such as the amount of flow through a pipeline, or the level of liquid in a vessel, or the temperature of the process media, or even the pressure inside pipes and vessels.

Due to the nature of process media, the pipes and vessels we see on plant or normally made of material we can not see through, such as metal, or in some cases, plastic. If this is the case, then we are going to rely heavily on devices which can see into and measure these Process variables.

A car has a speedometer, in our language, this is an instrument. This instrument is critical to us remaining on the right side of the law, and given its importance, how much more important is it, that this device works correctly and accurately. Accuracy could therefore be classed as one of its performance characteristics. And it is characteristics like this, that we will consider in this first section, as they are common to all instruments, and instrument systems.

An instrument system, can be just a single instrument, the complexity of its operation makes it not only a single instrument, but a host of complex operations, likewise an instrument system may be made up of several devices connected together. The term 'measuring system' can be used to describe a single device, ie: a gauge, or the many elements of a complete control system.

A 'Transducer' or Sensor, is the part of the measuring system, that comes into direct/ or indirect contact with the process, and produces an output based on its measurement of the process condition. However, such outputs are usually not in an appropriate format, and therefore require the other elements combined into a system to make this measurement measureable and meaningful.

Steady State.

A system or plant item said to be in a **steady state** has numerous properties that are unchanging in time. If a system is in steady state, then the recently observed behaviour of the system it is predicted will continue into the future. In many systems, steady state is not achieved until some time has elapsed after the system is started or initiated. This initial situation is often identified as a transient state, start-up or warm-up period. For example: The flow of fluid through a tube, or electricity through a network, could be in a steady state because there is a constant flow of fluid, or electricity. Conversely, a tank which is being drained or filled with fluid would be an example of a system in transient state, because the volume of fluid contained in it changes with time. Ideally measurements should therefore be taken when the system is steady.

This section looks at some of the common Performance factors, that need to be considered.

System Performance

When selecting an Instrument, or Instrument system, a range of performance characteristics need to be considered. The following are some of the common characteristics which may affect selection. These following items, are likely to affect any instrument or system.

Accuracy/ Inaccuracy (measurement uncertainty).

The accuracy of an instrument is a measure of how closely the output from the device or system is to the correct value being measured. It is more common though to express the potential inaccuracy of a device or system, rather than its accuracy.

Inaccuracy is the amount by which a reading 'maybe' wrong. One way is to quote the inaccuracy as percentage of full scale, ie $\pm$ 1.0 % f.s

If we use the example of a 0-10bar pressure gauge, with an inaccuracy of $\pm$ 1.0 % f.s, this means the maximum amount of expected error of any reading could be 0.1bar. This value could be insignificant if the process pressure is close to the top of the scale, however if the process was around 1bar, this could therefore provide an error which equates to 10%.

The term 'measurement uncertainty' is often used, because the amount of 'inaccuracy' may be uncertain.

Error.

Errors in measurement systems can be divided into; 'those which occur during the measurement process', and, 'those which arise due to corruption of the measurement signal'.

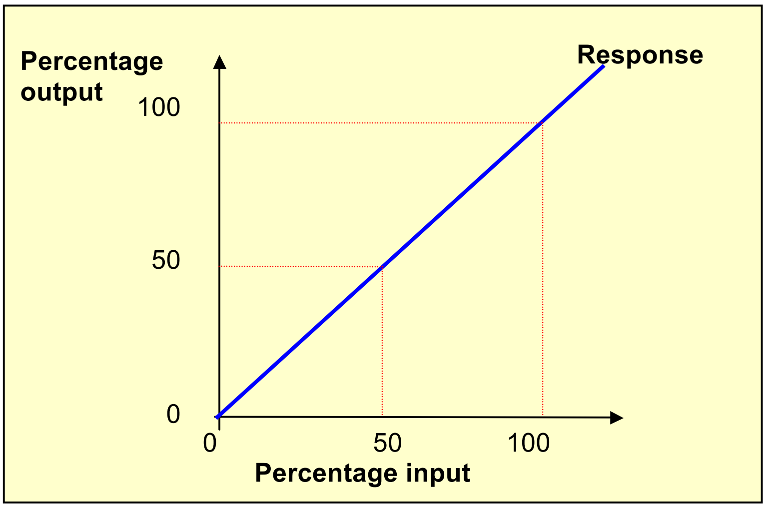
Some errors are said to be 'random', ie, those which are unpredictable, such as an error introduced by an operator who may have to judge or 'best guess' what a reading is, ie, when taken from an analogue meter or gauge.

Systematic error's, are those in the output which are continual. Caused by simple things such as a 'bent pointer', or poor cabling, alternatively they are errors which are inherent through manufacture. They can also arise through 'wear and tear', or effects from the environment.

In any system, it is extremely important to identify all potential sources of error, and where possible to isolate or remove the source.

Desired Response.

It is normally desirable for an output to be linear to the input, as in the diagram below. In some cases readings drawn on a graph may vary slightly above and below the ideal response line, and a 'line of best fit', may still prove the instrument to be overall linear.

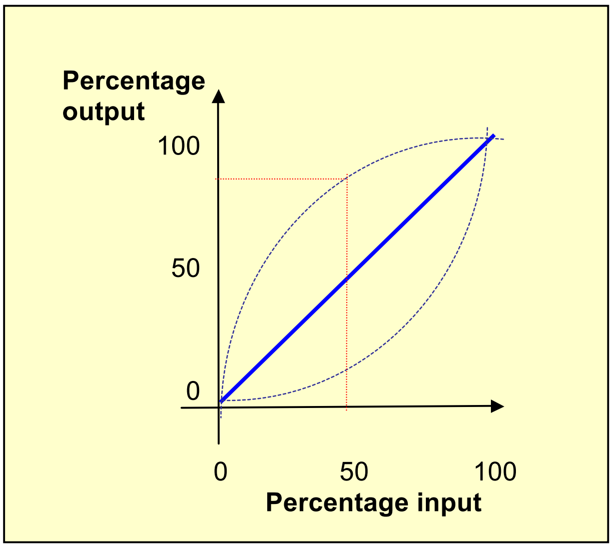


Linearity Error

Some devices may actually produce non linear information naturally (such as some differential pressure flowmeters).

When the output, does not follow the linear relationship, and deviates away, this is said to be non-linear (A linearity error). Often, this error is caused by wear and tear, and in some cases is curable.

This example, shows what typically is the response of an instrument said to have a 'linearity error'.



Reliability.

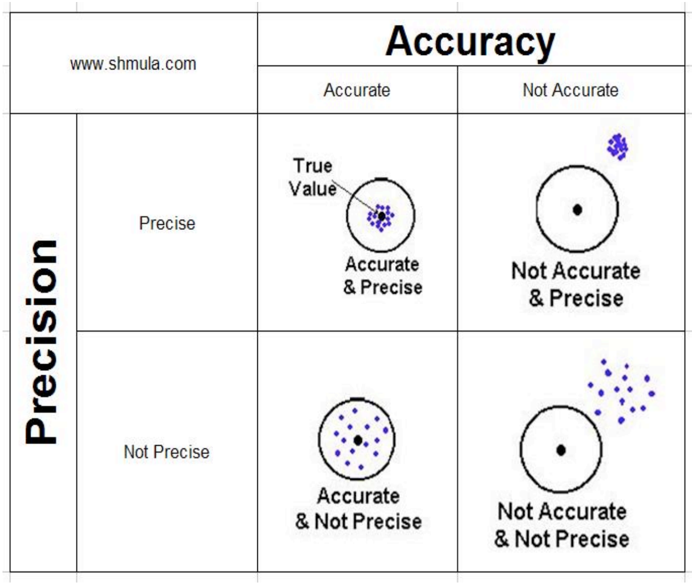
We know that things don't last forever, however, The reliability of a measurement system or transducer can be quantified as 'the mean time between faults occurring'. A fault being an unexpected condition that arises, causing the output of an instrument to be erratic, incorrect or to show no output at all.

Reliability is therefore the ability of a system or instrument to perform its required function within specified conditions for a stated period of time. Unfortunately manufacturing tolerances, and operating conditions, make the absolute faultless operation of any system or instrument impossible to guarantee.

To counter this, reliability is often referred to by statistical probability, ie, that no faults should occur within a specified time period.

Repeatability.

The 'precision' of a measurement system, also called reproducibility or REPEATABILITY. This is the degree to which repeated measurements under unchanged (the same) conditions show the same results.



Sensitivity.

The sensitivity, of a measuring instrument is a measure of the change in instrument output that occurs when the quantity being measured changes by a given amount.

The following table shows the standard resistance values from a PT100 resistance thermometer, for the range of temperature 0 – 100℃

Temperature (℃)	RTD Resistance (Ω)	Thermistor resistance (Ω)
0	100	16,330
50	119.4	5000
100	138.5	1801

As can be seen, for a 100°C change in temperature the resistance of the measuring device increases by 38.5Ω.

Its Measurement sensitivity = Output change/Input change
= 38.5/100 = **0.385Ω/°C**

The sensitivity of the Thermistor = Output change/Input change
= 14529/100 = **145.29Ω/°C**

As can be seen from the table, the Thermistor sensitivity however follows a non linear scale, so this is not completely true, nevertheless it certainly has a higher resistance change, meaning it is also more accurate, but over a far smaller range.

Another factor that can affect sensitivity is the ambient conditions. Quite often, test equipment has sensitivity expressed at a test temperature. When temperature affects sensitivity this is often referred to as sensitivity drift.

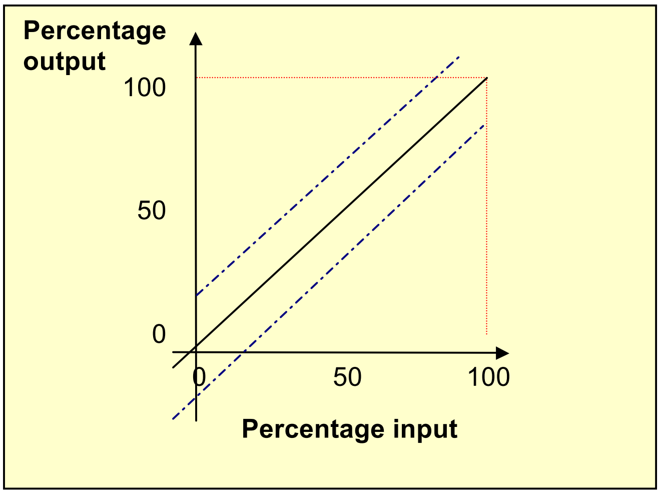
In process control, the term Gain, is also used notify the relationship between the Output and Input of a process controller. The higher the system gain, the more reactive or aggressive its behaviour.

Zero Error

If an instrument is required to show a zero reading, where this is affected by temperature change, this is referred to as Zero drift or bias. Mechanical bathroom scales suffer from a form of zero drift, as when no one is stood on them quite often they will be above or below zero for no apparent reason. Instruments such as voltmeters often suffer from this same experience.

All instruments can be affected by zero error, this is when the instrument is producing a reading either positively or negatively, even though it has no input applied. There can be a number of causes, however it is normally easily resolved through calibration. 'Zero error', can be seen as shown in the following graph.

A graph showing a typical example of a positive and negative zero error



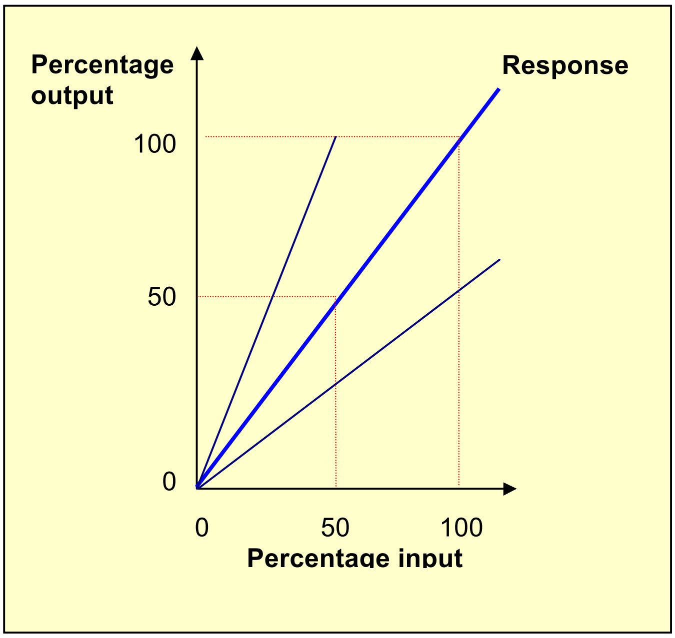
Range Error.

The range (or span) of an instrument refers to the minimum and maximum values that the device is designed to measure. Ie, 0 – 100psi. The range of some instruments may be adjusted through calibration, whereas some have a fixed range.

A range error is one where typically, the device reads ok at zero, and gets progressively worse, as shown in the next diagram.

This type of error, is typically found on a lot of car speedometers, where the reading normally over reads. If you compare the indicated speed of 70mph, with a GPS device you will notice the true speed is around 67mph, representing a range error of around 5%. Obviously this is NOT the same for all cars.

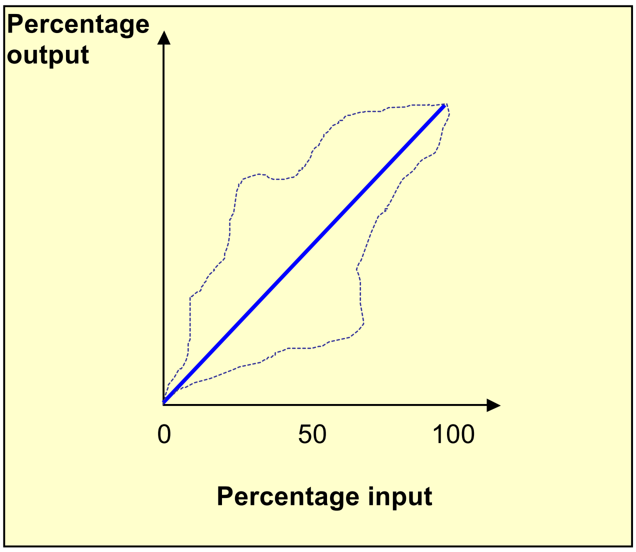
Like zero, and linearity,
this is also curable, through calibration.



Resolution.

This factor refers to how finely a measurement may be worked out to. For example on one pressure gauge the primary values may be at 10psi differences, whereas there may be a couple of increments between the Primary values (as seen on the gauge on the left), or lots of increments (as seen on the gauge on the right), therefore changing the resolution, allowing for a more accurate determination of the measured or displayed value. Judging the values is a little bit like a 'Best guess'. On a digital device there is no dispute, it is what it says.

Hysteresis.



As the diagram above shows, an instrument exhibiting Hysteresis shows little correlation between the input and the output values. Hysteresis is normally caused by wear and tear, and is noticeable in instruments that have springs in them, such as gauges. However, some electrical devices exhibit a hysteresis effect, these are particular in devices which have windings around iron cores, the hysteresis tends to be caused by magnetism in the iron core. Realistically the only cure for an instrument exhibiting hysteresis is replacement of the device or the faulty component parts.

LAG – Dead Space/ dead time.

Dead Space, dead time or dead band, This factor is defined as the range of input where there is no output change, this could be where a switch has to reset, whereas 'lag' occurs as the system output builds to the appropriate PV value. Turbo charged cars also experience a similar issue – turbo lag.

In Instrument terms, lag can also be caused by the Distance between two devices and the velocity of the information or process fluid travelling between them. This is referred to as DV lag. This type of lag, although having an impact, is the result of the positioning of the instrument, not the instrument itself.