CHAPTER 1: INSTRUMENTATION EQUIPMENT

MODULE 1: INTRODUCTION TO INSTRUMENTATION

MODULE OBJECTIVES:

At the end of this module, you will be able to:

1. Explain briefly, in your own words, the need for signal transmission.
2. State the standard range of pneumatic signal in a typical instrumentation loop.
3. State the advantages and disadvantages of using a pneumatic signal transmission system.
4. State the standard range of electronic signals in a typical instrumentation loop.
5. State the advantages and disadvantages of using an electronic signal transmission system.
6. Explain the purpose of the "live zero" as applied in an instrumentation loop.
7. Calculate the value of an electronic signal, given the process condition and the signal range.
8. Calculate the process condition, given the pneumatic or electronic signal value and the signal range.
9. Calculate the values of dropping resistors needed using Ohm's Law, given the range of the current signal and the potential drop required.
10. Explain briefly, in your own words, the meaning of trend recording.

Introduction

- Instrumentation is used in almost every industrial process and generating system, where consistent and reliable operations are required. Instrumentation provides the means of monitoring, recording and controlling a process to maintain it at a desired state.
- A typical industrial plant such as an electric generating station (Figure 1) has many process variables that have to be measured and manipulated. The use of instruments allows the automatic control of such processes.
- Indications may be Local to a process, or they may be cenralized into one single location (i.e. the central control room).
- Advantages of transmitting a signal to a central location include the ability of having controllers that can perform automatic corrective action if the process deviates from the desired operating point, called the setpoint. Also, if abnormal conditions arise, alarm units which are activated by these signals can be used to trigger annunciations in the control room or to cause a process to shut down safely.

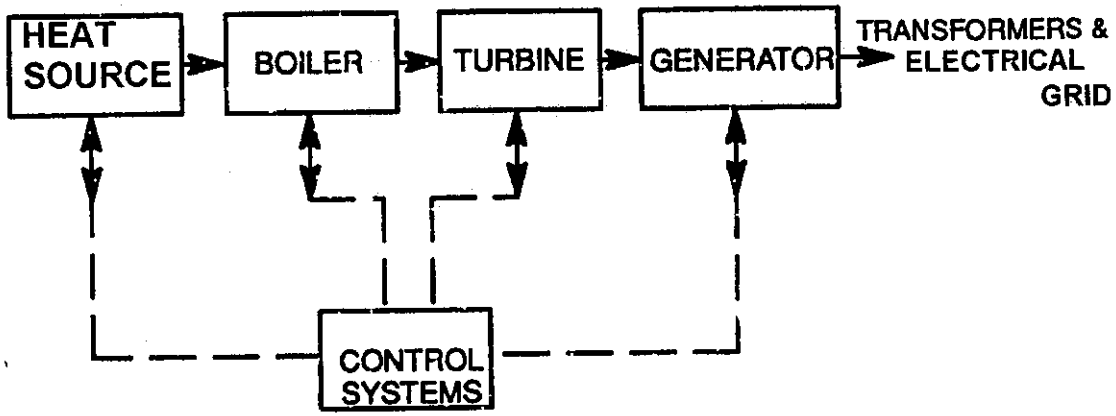


Figure 1: Simplified Electric Generating Station.

- The two standard methods of transmitting a signal are: 1. Pneumatically and 2. Electronically.

Pneumatic Signals

- A pneumatic process sensor is coupled to a transmitter to monitor a process variable.
- The output signal of the pneumatic transmitter is air pressure, the magnitude of which is directly proportional to the process variable being monitored.
- The standard industrial range for pneumatic signals is 20 to 100 kpa(g) which corresponds to a 0% to 100% process condition (kPa(g) = kPa above atmospheric).
- Note that the transmitter output does not start at 0 kPa(g), but at 20 kPa(g).
- This 20 kpa(g) output is called a live zero.
- A live zero allows control room staff to distinguish between a valid process condition of 0% (a 20 kpa(g) reading) and a disabled transmitter or interrupted pressure line (a 0 kpa(g) reading).

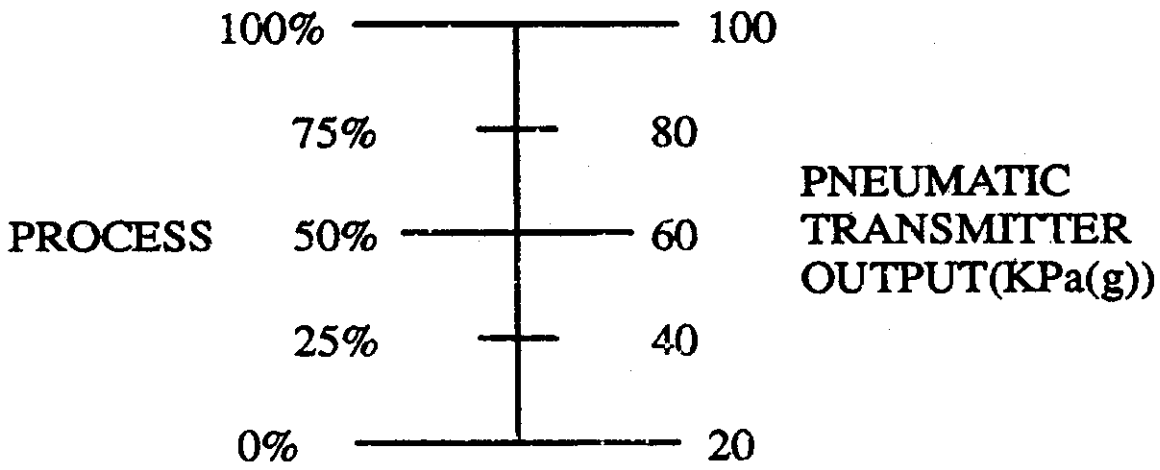


Figure 2: Relationship Between Process Condition and Pneumatic Transmitter Output.

Example

A pneumatic transmitter with output range of 20 - 100 kpa(g) is used to monitor water level inside a tank. Its calibrated range is 100 to 200 cm. of water above the base of the tank. Calculate the output of the transmitter when the water level is at 175 cm. above the base of the tank.

Solution

Span (difference between the upper and lower limit) of the transmitter output

= 100 kPa - 20 kPa

= 80 kpa(g)

Fraction of measurement = $\frac{175 - 100}{200 - 100} = 0.75$

Output Signal = (Fraction of Measurement) x (Signal Span) + Live Zero

= 0.75 x 80 + 20

= 80 kpa(g)

Advantages of Pneumatic systems (over an electronic system):

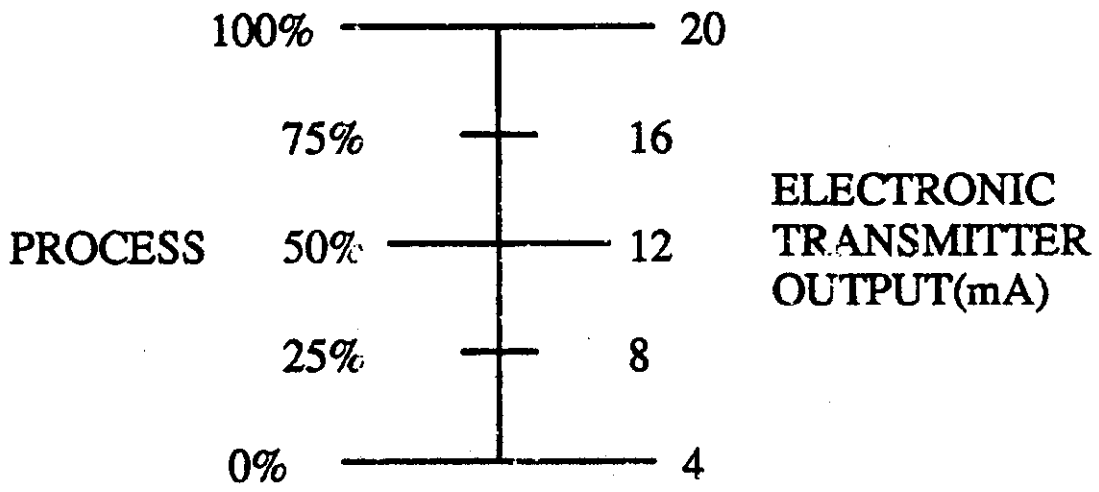
- sparks will not be produced if a malfunction occurs
- there is no electric shock hazard.

Disadvantages of Pneumatic systems:

- a pressurized system can be dangerous if a line ruptures
- pneumatic signal lines are bulky and difficult to install
- the biggest problem with pneumatic systems is that air is compressible, hence a pressure transient due to a process change will only travel in the air line at sonic velocity (approximately 300 m/sec.), therefore long signal lines can cause substantial time delays.

Electronic Signals

- **For large industrial process plants such as generating stations where central control rooms are used, electronic signals are preferred.**
- **The accepted industrial standard for electronic signals is a 4 to 20 mA current signal that represents 0% to 100% process condition.**
- **A live zero (4 mA) is used to distinguish between 0% process (4 mA) and an interrupted signal loop (0 mA).**



1.1.G Figure 3 Relationship Between Process Condition and Electronic Transmitter Output.

Example

An electronic transmitter with an output of 4 - 20 mA is calibrated for a pressure range of 7 - 10 MPa(g). What pressure is represented by a 12 mA signal?

Solution

Span of transmitter 20 mA - 4 mA = 16 mA

Fraction of Measurement Change = $\frac{\text{Output Signal - Live Zero}}{\text{Signal Span}}$

= $\frac{12 - 4}{16}$

= 0.5

Actual Process Change = (Fractional Change) x (Process Span)

= 0.5 x (10 - 7 MPa)

= 1.5 MPa

Actual Process Value = Base Point + Process Change

= 7 + 1.5 MPa

= 8.5 MPa(g)

The rest of this course will deal exclusively with electronic signals.

The 4 - 20 mA Current Loop

- An electronic transmitter can be considered as a variable resistor with resistance altered by the process condition.
- When used in series with a constant voltage power supply, a 4 - 20 mA current will be produced in the loop.
- From Ohm's Law, I = V/R
- By varying the resistance while the power supply voltage is kept at a constant value, the amount of current in a loop can be manipulated.
- The same two wires that power the transmitter also carry the signal.
- Using a current signal minimizes the number of wires needed and the effect of background noise.
- Readout devices which are either current or voltage sensitive provide a signal indication.
- To get a direct indication of the current signal, a milli-ammeter can be connected in series in the loop.
- Alternatively, a voltmeter can be connected in parallel with a dropping resistor.

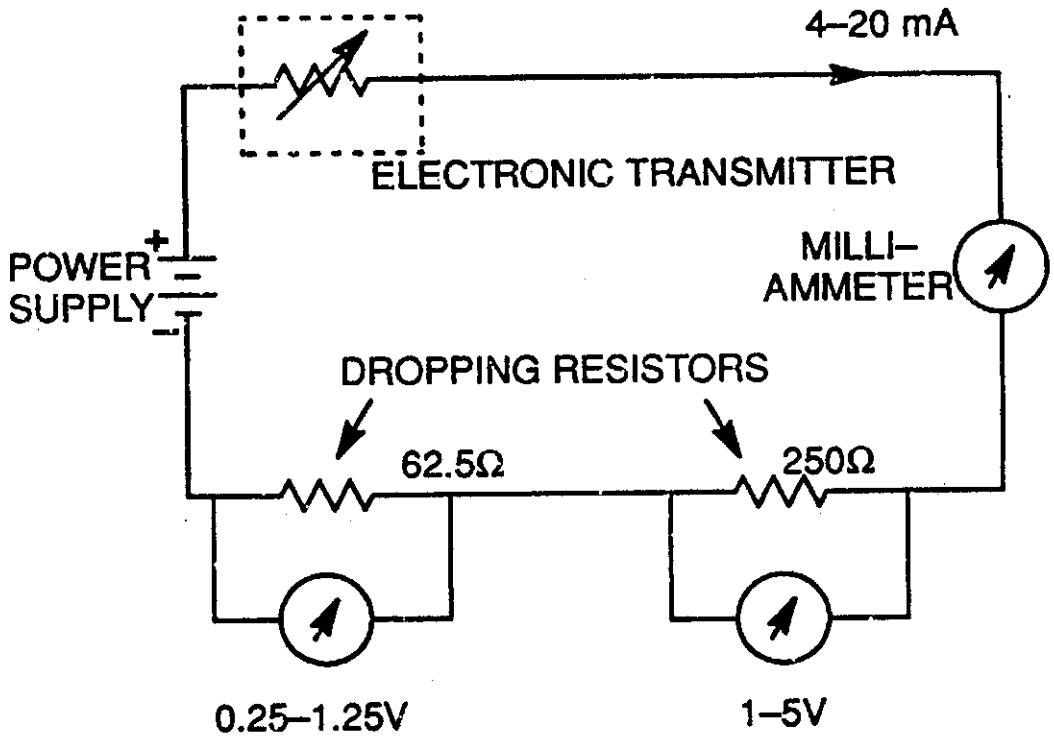


Figure 4: Representative Current Loop.

The 4 - 20 mA Current Loop (continued)

- Voltage sensitive instruments respond to a voltage range of either 0.25 - 1.25V or 1 - 5V.
- To calculate the value of dropping resistor required, Ohm's Law can be used.

Ohm's Law: $V = IR$

or $R = V/I$

where

V = voltage across the resistor (Volt)
I = current (Amp)
R = resistance (Ω)

If the values of V and I are known, R can be calculated.

Example

A dropping resistor is required to generate:

(a) a 0.25 - 1.25 V signal
(b) a 1 - 5 V signal

from a 4 - 20 mA current signal. Calculate its value.

Solution

(a) When current = 20 mA, voltage = 1.25 V

By Ohm's Law, $R = V / I = 1.25V / (20x10\text{-}3)A$

$= 62.5\ \Omega$

(b) When current = 20 mA, voltage = 5 V

By Ohm's Law, $R = V / I = 5\ V / (20x10\text{-}3)A$

$= 250\ \Omega$

ASSIGNMENT

1) Why is signal transmission vital in the operation of large industrial process systems?

2) What is the accepted standard industrial range for pneumatic signals?

3) List two advantages and two disadvantages of a pneumatic system.

4) What is the standard instrument range for electronic signals?

5) Why are electronic signals used almost exclusively in industrial process systems, particularly electrical generating stations?

6) Both pneumatic and electronic signals employ a "live zero". Explain the purpose of this live zero.

7) A standard electronic transmitter is used to monitor the water temperature in a vessel. The transmitter is calibrated such that it responds to the temperature range of 50°C - 100°C. What is the transmitter output when the water temperature is 85°C? (Answer: 15.2 mA)

8) Explain briefly what a trend recorder is, and why one would be utilized.