Session 2: Process Variables, Elements, and Instruments – Pressure

Prepare to Teach

Session Overview

Session 2 provides a thorough explanation of the process instrumentation used to sense and measure pressure in industrial processes. Students are provided with a variety of learning methods with which to master the objectives.

Class Preparation Checklist

1. Make copies of handouts (see Appendix).
2. Prepare master class list using Student Information Sheets. Make copies for students.
3. Assemble the following pressure sensing/measuring devices for display during lecture:
   - manometer
   - pressure gauge
   - differential pressure (D/P) cell
   - strain gauge transducer
   - capacitance transducer (optional – not required by the GCPTA)
4. Familiarize yourself with content covered during this session.
5. Arrange for flipchart easel, flipchart paper, and markers OR chalkboard and chalk.
6. Arrange for overhead projector and overheads, if used.
7. Bring texts or other materials to be used in this course.

Objective(s)

Learning Objectives

1. Define pressure.

2. Discuss the formula used to calculate pressure: P = F/A.

3. Identify the three components that affect the force exerted by molecules:
   - speed
   - number of molecules (density)
   - mass (and weight)

4. Define terms associated with pressure and pressure instruments:
   - differential pressure (delta Δ)
   - pressure measurement scales
     - PSIG
     - PSIA
     - bars
     - Inches H_20
     - Inches Hg
     - atmospheres.

5. Identify common types of pressure-sensing/measuring instruments used in the process industry:
   - manometers
   - pressure gauges (internals)
   - differential pressure (D/P) cells
   - strain gauge transducers
   - capacitance transducers (optional – not required by the GCPTA)

6. Describe the purpose and operation of pressure-sensing/measuring instruments used in a lab or industrial setting.

7. Given a standard calculator and conversion formulas convert between the following pressure scales:
   - pounds per square inch gauge (psig) and pounds per square inch absolute (psia)
   - inches of mercury (in. Hg) and inches of water. (in. H_2O)

Agenda

Activity	Estimated Time
1. Agenda	5
2. Learning Objectives	5
3. Introduction to Pressure Variables/Terms	50
BREAK	10
4. Pressure Sensing/Measurement Instruments	50
BREAK	10
5. Pressure Conversions	40
6. Summary and Wrap-Up	10

BREAK	10
7. Additional Activities	50
BREAK	10
8. Lab Activity	50

Background

1. Pressure, defined as force per unit area (force ÷ area = pressure), directly affects the boiling point of a substance. Because of this principle, process industry facilities must account for pressure in the mixing, creation, or separation of chemical properties. Pressure is one of the major process variables that Process Technicians are responsible for monitoring and controlling. Failure to adequately control pressure can have disastrous consequences.

Begin Lesson

1. Agenda

Time: 5 minutes

DISPLAY SLIDE #1

OR

Write the slide contents on the flipchart or whiteboard.

Slide 1: Explain what you intend to accomplish in today’s class.

2. Learning Objectives

Time: 5 minutes

DISPLAY SLIDE #2	*OR*	Write the slide contents on the flipchart or whiteboard.

Slide 2: Discuss the lesson's objectives with the learners in order to provide them with clear-cut guidelines for what is to be learned during the instructional session. Explain to them that test questions are based on these objectives; therefore, if they can master the objectives, they will perform well on the test.

3. Introduction to Process Variables/Terms

Time: 50 minutes

1. Distribute the note-taking materials provided in this session's appendix. Have students use these note-taking sheets to capture content from this session. Explain that the first sheet they will use is for **"Key Terms".**

2. Review the concept of process variables from Session 1. Explain that during this session, you will focus on the variable of pressure and how pressure can affect the conditions within the facility and product quality and safety.

DISPLAY SLIDE #3	*OR*	Write the slide contents on the flipchart or whiteboard.

Slide 3: Pressure

Pressure can be defined as a force applied to a unit of area.

- Discuss the formula used to calculate pressure: P = F/A
  - P = pressure (PSI)
  - F = force (pounds)
  - A = area (square inches)

DISPLAY **SLIDE #4**	***OR***	**Write the slide contents on the flipchart or whiteboard.**

Slide 4: Discuss force or show an appropriate film or slide presentation that covers these concepts:

- **Force**: a push or pull exerted on an object which causes the object to change direction
- **Mass**: the amount of matter in a body or object Mass has to do with the size of the molecules. As the mass of the individual molecules increases, the force exerted in the collisions increases. Because the mass of the different molecules can vary greatly, the force can also vary. It takes more energy to get the "massive" molecules in motion and up to any velocity. Energy input that is converted to mass in motion becomes energy that is given off in the form of pressure or force when a molecule collides with something else.
- **Density (the number of molecules per unit volume):** More molecules means more collisions will occur. The force created increases as the number of molecules increases due to the number of collisions within the material.
- **Speed**: Molecular speed changes as a result of numerous factors. Energy, normally in the form of heat energy, may change, which will increase/decrease molecular speed. Speed can also be affected by collisions with other molecules. The collisions may be with molecules from the material (for example a product being agitated) or from other molecules (for example the walls of a vessel).

Instructional Strategy

Audiovisual presentations, such as films and slide presentations, appeal to more than one of the senses as well as addressing more than one adult learning style; therefore, whenever possible, it is recommended that you incorporate these presentations into the lesson.

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SLIDE #5

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Write the slide contents on the flipchart or whiteboard.

Slide 5: Pressure Measurement

- **<u>Differential pressure:</u>** the difference in pressure between two distinct points.
- **<u>PSIG:</u>** pounds per square inch gauge; the contained pressure as indicated by a gauge
- **<u>PSIA:</u>** pounds per square inch absolute; the absolute scale at absolute vacuum is considered to be 14.7 lbs below atmospheric pressure
- **<u>Bars</u>**: measurement of pressure equal to 0.987 atmospheres
- **<u>Inches H_2O:</u>** inches of water is a very small measurement of pressure equal to 0.036 pounds per square inch at 4 degrees Celsius
- **<u>Inches Hg:</u>** inches of mercury; most common measurement scale for a manometer, which measures the level of mercury in pounds per cubic inch
- **<u>Atmospheres</u>**: the pressure at any point in the atmosphere due solely to the weight of the atmospheric gases above the point concerned; 14.7 psia is at sea level.

Break 10 minutes

4. Pressure Sensing/Measurement Instruments

Time: 50 minutes

1. Summarize the following information to explain why pressure must be measured and sometimes controlled within process systems. Direct students to use the "Types of Pressure Devices Worksheet" for note taking.

   One of the most common process variables encountered is process pressure. Many devices are used to indicate the pressure of the process, one of the most common being the pressure gauge. In process industries, three types of pressure are measured: absolute, gauge, and vacuum. All pressure is actually the weight exerted on a certain area. For example, if we were at sea level and examined a one-square-inch area at the surface, we would find that the pressure or force would be 14.7 lbs. This means that a column of air one square inch and extending from the surface to the space beyond our atmosphere would weigh 14.7 lbs. This is referred to as atmospheric pressure (weight of the air comprising the atmosphere) and is considered to be 14.7 lbs. per square inch and is used as the basic reference point for pressure gauges. In other words, if the gauge reads zero, there is actually 14.7 psi on the gauge element. If the gauge reading increased to 50 psi, the pressure would now be 50 psi above 14.7 psi and is actually the pressure above 14.7 psi, which is referred to as "gauge pressure".

If it were possible to remove all the pressure from a line or vessel so that it is actually 14.7 psi below atmospheric pressure or zero pressure, we say our pressure is now "absolute zero" and any pressure measured above this absolute zero point is called absolute pressure. For example, if the gauge above were replaced with an absolute pressure gauge, it would read 64.7 psia instead of the 50 psi.

In industry, we are sometimes interested in maintaining pressures less than atmospheric; this is referred to as "vacuum". Vacuum is measured from the 14.7 psi atmospheric pressure point in units of inches or millimeters of mercury vacuum.

2. **Display** the following pressure sensing/measuring instruments as you discuss their purpose and operation. When possible, **demonstrate** the operation of the device.

DISPLAY SLIDE #6	*OR*	**Write the slide contents on the flipchart or whiteboard.**

Slide 6: Manometers

- U-shaped tube gauges filled with a liquid or mercury and two fluid chambers that are connected by the U-shaped tube so that fluid is free to move between them.
  - **Purpose**: Visual type, reliable pressure measuring device primarily used as indicating instrument.
  - **Operation**: When additional pressure is applied to one chamber, the fluid in that chamber flows through the connecting tube into the other chamber causing its level to rise until the head pressure created by the offset equals the pressure applied to the other chamber. Manometers are called gravity-balanced pressure devices because of this characteristic.

DISPLAY SLIDE #7	*OR*	**Write the slide contents on the flipchart or whiteboard.**

Slide 7: Pressure Gauges

- A sensing and measuring device, which contains a plastic or steel body, a metallic strip, a pointer, and a scale, marked in units of pressure. The scale markings determine what type of pressure the gauge measures. Four types of gauges include pressure gauges, absolute pressure gauges, vacuum gauges and compound gauges.
  - **Purpose**: Like manometers, they are used primarily used as local indicators.

- **Operation**: The metallic strip flexes when pressure is applied. The pointer is connected to the metallic. As the metallic strip flexes, the pointer moves along the scale to indicate the pressure.

DISPLAY SLIDE #8	*OR*	**Write the slide contents on the flipchart or whiteboard.**

Slide 8: Differential pressure (D/P) cells

- A simple mechanical type sensor normally found in pneumatic transmitters. A more sophisticated transducer type is found in electronic transmitters.
  - **Purpose**: Measures the difference between two pressure points and produces a corresponding output signal. Can be used to measure level and flow rate.
  - **Operation**: D/P transmitters have two pressure measuring sensors. One sensor is considered as the high-side pressure sensor and the other the low-side pressure sensor. The difference in pressure is measured and the output signal transmitted.

DISPLAY SLIDE #9	*OR*	**Write the slide contents on the flipchart or whiteboard.**

Slide 9: Strain Gauge Transducers

- A measuring device consisting of a group of wires that stretch when pressure is applied.
  - **Purpose:** Strain gauges are transducers (a device that changes one energy form – a process measurement - into another – an electronic signal) that respond to strain.
  - **Operation:** The group of wires that stretch when pressure is applied. As current flows through the wires, resistance changes proportionally to the stress or strain applied. Strain is the act of changing the dimensions of a solid. When a strain gauge's dimensions are changed, its resistance also changes. This is the premise on which strain gauges operate.

DISPLAY
SLIDE #10

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Write the slide contents on the flipchart or whiteboard.

Slide 10: Capacitance transducers (optional)

- A device containing a measurement diaphragm and capacitor plates.
  - **Purpose**: Like strain gauges, capacitance transducers serve as pressure measurement transducers.
  - **Operation**: When pressure is applied to the measurement diaphragm, it causes the capacitor plates to move closer together. Since capacitance is inversely proportional to the distance between the plates, as the plates get closer together the capacitance will increases.

Break 10 minutes

5. Pressure Conversions

Time: 40 minutes

DISPLAY
SLIDE #11

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Write the slide contents on the flipchart or whiteboard.

Slide 11: Gauge and absolute Pressure

Let's compare gauge pressure to absolute pressure. In the earlier definitions, it was stated that the absolute pressure scale begins at true zero pressure (a total vacuum), whereas zero on the gauge pressure scale is equal to whatever atmospheric pressure is. The average pressure at sea level is 14.7 PSIA and 0 PSIG. Gauge pressure always sets zero at atmospheric pressure. For example, if the atmospheric pressure in Denver, Colorado is 14.2 PSIA, it is still 0 PSIG.

So, why do we need two scales? The answer is that the gauge pressure scale was the only one that made sense at one point in time. It is important to be concerned about how much pressure was inside a vessel compared to the outside pressure. In time, it became important to know and control pressure at an exact point, independent from atmospheric pressure variations. Scientist needs an absolute scale.

Process technicians need to know how to move easily between the two scales. Here are the mathematical relationships:

PSIA = PSIG + 14.7 PSI

PSIG = PSIA – 14.7 PSI

DISPLAY SLIDE #12	*OR*	**Write the slide contents on the flipchart or whiteboard.**

Slide 12: Inches Water and Inches Mercury Pressure

In a simpler world, there would be only one pressure unit. But this is no more reasonable that having one denomination of money. If the public had only one-dollar bills to use for currency, people would have to pack a suitcase to purchase a car and would have to spend an entire dollar just to buy a stick of gum. This doesn't make any more sense that having only one pressure unit to fit all situations. PSI works fine for most pressure measurements, but sometimes its just too large. Take the example of measuring the pressure of flue gases leaving a boiler. The pressure of flue gasses is about 0.1 to 0.2 PSI of pressure. Obviously, one pressure unit can't possible provide adequate resolution at both extremes.

To accommodate low-pressure measurements, or small measurement spans, several scales have been developed. Two commonly used scales are the inches water (in. H_2O) and inches mercury (in. Hg). Recall that manometers are highly accurate pressure-measuring devices. This leads to a natural inclination to use their column heights as pressure units. In fact, that is what has happened. These column inches are self-defining. It is the pressure equal to that exerted by one inch of their prospective liquid heights.

Here are the pressure equivalents compared to 1 PSI:
1 PSI = 27.7 in H_2O = 2.04 in. Hg

1. Refer students to use **"Pressure Conversion Exercises"** handout. Write the following conversion formulas on the board, while explaining each concept and providing an example of each concept.

   - psig to psia = psig +14.7
   - psia to psig = psia – 14.7
   - psig to inches H20 = psig x 27.7
   - psig to inches of Hg = psig x 2.04
   - inches of H20 to psig = height of liquid ÷ 27.7
   - inches Hg to psig = height of liquid ÷ 2.04

2. Explain why conversions must be calculated in the industry.

3. Have students work in teams or pairs to work the following problems. Instruct them to use the handout to capture their work.

   - 150 psig to psia (164.7 psia)
   - 150 psia to psig (135.3 psig)
   - 42 psig to inches H20 (1163.40 in. H20)
   - 55 psig to inches of Hg (112.20 in. Hg)
   - 300 inches of H20 to psig (10.83 psig)
   - 100 inches of Hg to psig (49.02 psig)

6. Summary and Wrap-Up

Time: 10 minutes

1. Use learning objectives to summarize material presented during this session.

2. Encourage questions over any concepts that students do not understand.

3. Assign homework:
   - Complete **"More Pressure Conversion Exercises"** (see Appendix). Inform students that homework will be due at the beginning of the next class.
   - Read appropriate text pages on Temperature, to be presented during the next session.

Break 10 minutes

7. Additional Activities

Time: 50 minutes

If your campus offers 4 lecture hours per week, select additional films, audio-visual programs, or lab activities as appropriate to reinforce the concepts already covered. Do not cover additional objectives other than those listed in this session.

Break 10 minutes

8. Lab Activity

Time: 50 minutes

Lab Activity:

Select an appropriate lab activity from the Lab Activity Section of the Instructor's Guide.