Basic Principles of Process Control Systems and Automation – Measurement of Variables Critical to Controlling Processes

<u>Your Objectives:</u>

At the end of this lesson, you should be able to list, categorise and be prepared to appraise the variables.

Pressure System Continuous Control

A bioreactor is typically divided into two areas: **working volume** (the amount of the total tank volume taken up by the cell culture) and **headspace** (the remaining tank volume above the cell culture).

Maintaining positive pressure in the bioreactor at all stages of the cell culture process is an important factor in reducing the risk of contamination. Maintaining positive pressure involves air being pumped into the bioreactor.

Namely, because the bioreactor is maintained at a higher pressure than the atmospheric pressure, in the event of a leak in the vessel headspace, vessel air will flow out through the leak rather than draw air and contaminants into the vessel.

Positive pressure in the vessel, for instance, helps to "thrust" more oxygen into the culture.

Gas Introduction into the Headspace (Overlay Gas)

Gas in the bioreactor is continuously exchanged; that is, "new" gas flows into the bioreactor, and "old" gas flows out through an exhaust line. Gas flowing into the bioreactor is filtered to prevent contaminating organisms from entering the vessel. Gas flowing out of the bioreactor is filtered to prevent organisms in the vessel from contaminating the room air.

Sterile compressed gas is used to establish positive pressure in the vessel headspace and to sweep out by-products in the headspace. This gas is typically comprised of clean air and 2 – 5% CO_2, which helps maintain pH.

The computer controller monitors a pressure setpoint and an overlay compressed gas setpoint. The controller maintains the overlay gas flow rate by adjusting a flow control valve (FCV) on the compressed gas line. The flow rate is maintained consistently at its setpoint.

To maintain the pressure setpoint, the controller receives pressure data from a pressure sensor mounted on the vessel. If the pressure is too high, the controller opens the pressure control valve (PCV) on the exhaust line slightly, to release pressure. If the pressure is too low, the controller closes the PCV slightly.

Dissolved Oxygen (DO) System Continuous Control

The cell culture needs oxygen for it to survive. The purpose of the dissolved oxygen system is to provide the appropriate amount of oxygen to the cell culture to meet oxygen demand and consumption.

What is "Dissolved" Oxygen?

When oxygen or any gas is dissolved in a liquid, it is invisible. The only way oxygen is visible is when it appears as a bubble. Oxygen is "bubbled" into the cell culture by way of the sparge tube.

A sparge tube is a stainless-steel tube with a tip on one end. As the filtered air passes through the tip of the sparge tube, it breaks into tiny bubbles. Two types of sparge tips are used in Biogen's manufacturing processes: porous tips and drilled-hole tips. Each has its advantages for specific processes.

- Porous tips
  - Provide efficient air distribution
  - Minimise **shear**
- Drilled-hole tips
  - Are easier to sterilise
  - Are more efficient at stripping away by-products, especially CO_2

Oxygen transfer is the terminology that describes the movement of oxygen from its introduction into the bioreactor by way of the sparge tube to its dissolution in the media, and its subsequent uptake by the cells.

Gas Introduction into the Cell Culture

Oxygen can be delivered either as 100% pure or then as a fraction of compressed air. A compressor must generate enough pressure to force the air through a filter, a sparge tube, and into the liquid.

The air bubbles rise through the cell culture. It is important that sufficient circulation is provided in the cell culture so that all areas receive proper oxygenation. Air bubbles from the sparge tube are broken up by the impeller blades of the agitator, which facilitates the diffusion of air through the culture.

Different factors affect the rate of diffusion of oxygen in the cell culture. These include, but are not limited to:

- Temperature
- Viscosity of the media
- Concentration of oxygen
- Degree of mixing
- Pressure

Pressure

Pressure Measuring Devices

Two general categories of pressure measuring devices are used in bioprocessing at Biogen: mechanical and electrical. Because bioprocessing equipment is steam-sterilised frequently, a pressure sensor must be able to withstand sterilization temperatures and provide accurate measurements.

Mechanical Pressure Gauges

A diaphragm is a disc made of flexible material. When pressure is applied, the diaphragm flexes and moves a pointer on a scale. Some **diaphragm gauges** are mechanical, and others are electrical.

In bioreactors, diaphragm gauges are typically used to monitor pressure.

Monitoring the pressure within the **chromatography skid** and **chromatography column** is important for two primary reasons:

- The column and its components are only rated to withstand certain operating pressures
- The resin bed can be disturbed or damaged if the operating pressure becomes too great

Various types of mechanical pressure gauge scales, such as pressure, pressure/vacuum, and vacuum, are used at Biogen.

Electrical Pressure Gauges

Biogen's microfiltration system, for instance, is equipped with pressure transducers to measure the retentate and permeate pressure. Pressure transducers are also used in Biogen's purification systems.

Pressure transducers have a tubular body with a pipe fitting at one end, and a cable at the other. Within the transducer, a stainless-steel diaphragm houses a strain gauge. The strain gauge is a sensor whose resistance changes according to the amount of strain placed on it. The transducer transmits a small voltage electrical current through the cable to control equipment to indicate pressure.

All transducers have two sides. Some have sensors on both sides of the diaphragm for measuring differential pressure between the fluids on each side.