Al-Farabi Kazakh National University

Instrumentation and Control of Fermentation process

Lecture 8

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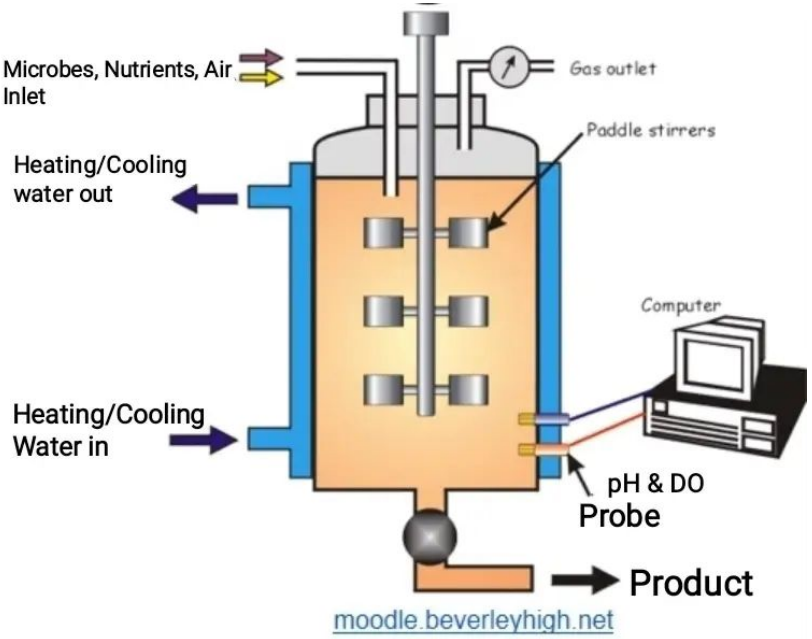
Fermentation systems must be efficiently controlled in order to optimize productivity and product yield, and ensure reproducibility.

The key physical and chemical parameters involved are largely depend on

- the bioreactor,
- its mode of operation
- microorganism being used.

They are primarily

- aeration,
- mixing,
- temperature,
- pH and
- foam control.



Control and maintenance at optimum levels inside the reactor is mediated by sensors (or electrodes), along with compatible control systems and data logging

Table 8.1 Process Sensors and Their Possible Control Functions

Category	Sensor	Possible Control Function
Physical	Temperature	Heat/cool
	Pressure	
	Agitator shaft power	
	rpm	
	Foam	Foam control
	Weight	Change flow rate
	Flow rate	Change flow rate
Chemical	pH	Acid or alkali addition, carbon source feed rate
	Redox	Additives to change redox potential
	Oxygen	Change feed rate
	Exit-gas analysis	Change feed rate
	Medium analysis	Change in medium composition

There are three main classes of sensor:

1. Sensors which penetrate into the interior of the fermenter, for example, pH electrodes, dissolved-oxygen electrodes.

2. Sensors which operate on samples which are continuously withdrawn from the fermenter, for example, exhaust-gas analyzers.

3. Sensors which do not come into contact with the fermentation broth or gases, for example, tachometers, load cells.

It is also possible to characterize a sensor in relation to its application for process control:

In line sensor. The sensor is an integrated part of the fermentation equipment and the measured value obtained from it is used directly for process control.

On line sensor. Although the sensor is an integral part of the fermentation equipment, the measured value cannot be used directly for control. An operator must enter measured values into the control system if the data is to be used in process control.

Off line sensor. The sensor is not part of the fermentation equipment. The measured value cannot be used directly for process control. An operator is needed for the actual measurement (eg, medium analysis or dry weight sample) and for entering the measured values into the control system for process control.

When evaluating sensors to use in measurement and control it is important to consider

- response time,
- gain,
- sensitivity,
- accuracy,
- ease and speed of calibration,
- stability,
- reliability,
- output signal (continuous or discontinuous),
- materials of construction,
- robustness,
- sterilization,
- maintenance,
- availability to purchase and
- cost

METHODS OF MEASURING PROCESS VARIABLES

TEMPERATURE

It may be measured by

- mercury-in-glass thermometers,
- bimetallic thermometers,
- pressure bulb thermometers,
- thermocouples,
- metal-resistance thermometers, or thermistors.

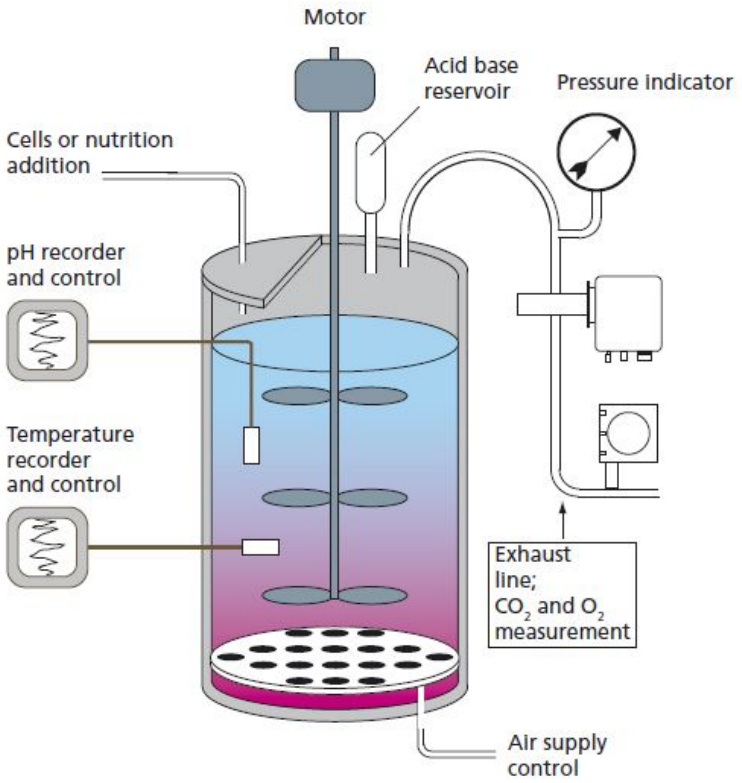
https://eur.vevor.com/wine-barrel-c_10705/53l-wine-fermentation-bucket-fermenter-with-thermometer-beverage-stainless-steel-p_010126762078

PRESSURE MEASUREMENT

Pressure - crucial measurements - safety concerns

Industrial and laboratory equipment - withstand a specified working pressure

Devices needed - to sense, indicate, record and control pressure



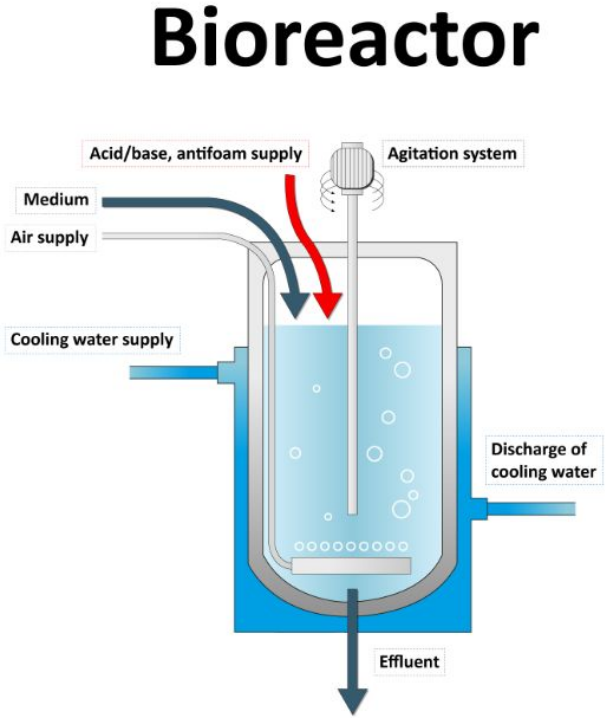
https://www.vaisala.com/en/case/co2-measurements-fermentation

AGITATION CONTROL

Monitor the rate of rotation (rpm) of the stirrer shaft - Tachometer

Detection mechanisms:

- Electromagnetic induction voltage generation
- Light sensing
- Magnetic force



Laboratory fermenters - a.c. slip motor coupled to a thyristor control.

Large fermenters - gear boxes, size of wheels and drive belts, changing drive motor

CONTROL OF OXYGEN AND AERATION

Oxygen supplied - as air

Laboratory-scale cultures - shake-flask technique

Pilot- and industrial-scale - stirred vessels, airlift ferments, bubble column fermenter, etc.

Maximum biomass production - Dissolved oxygen concentration greater than critical level

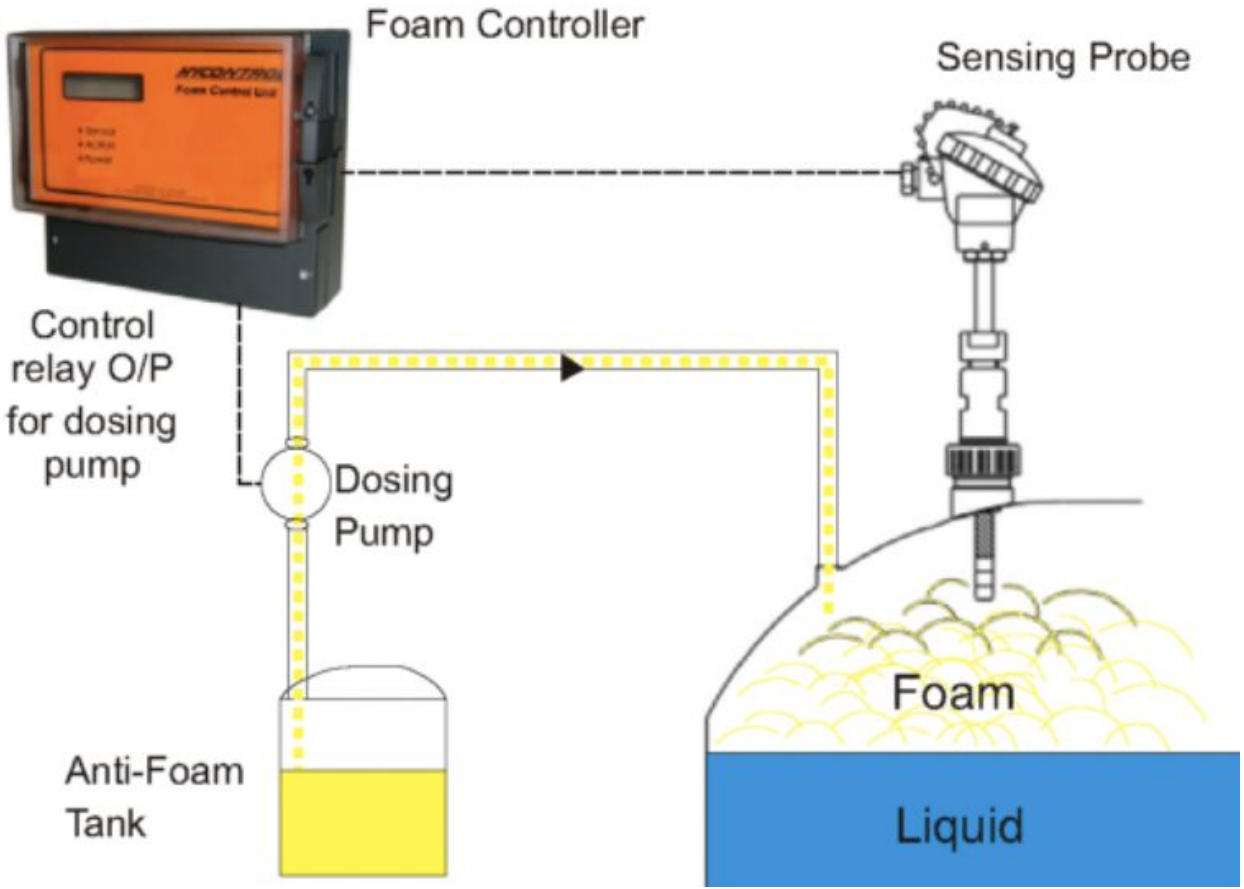
Foam sensing and control

Formation of foam – serious problems if not controlled

Foam sensing and control unit - probe is inserted through top plate of fermenter

- Probe - stainless-steel rod insulated except at tip
- When foam rises and touches probe tip, a current is passed
- Current actuates a pump or valve
- Antifoam is released into the fermenter for a few seconds

Mechanical antifoam devices Discs, propellers, brushes or hollow cones



https://www.southforkinst.com/wp-content/uploads/2018/06/Foam_Measurement_Overview.pdf

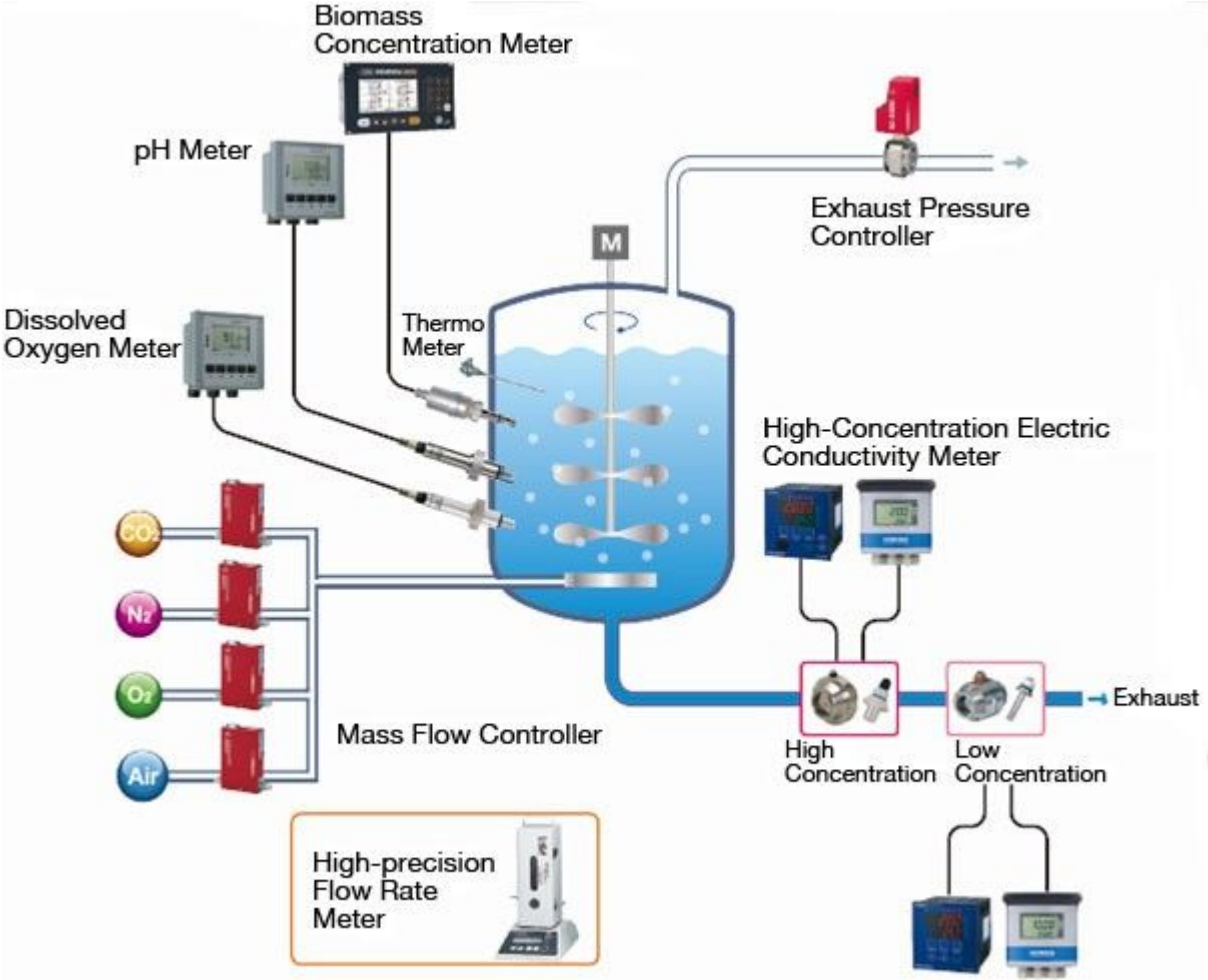
pH measurement and control

pH of an actively growing culture – never constant
Rapid changes in pH - reduced - by design of media, incorporating buffers
pH measurement - combined glass reference electrode
Silver/silver chloride with potassium chloride or Friscolyt as electrolyte

ON/OFF controller

- Signal received
- Pinch valve opened or a pump started
- Acid or alkali pumped into the fermenter for a short period of time
- Addition cycle followed by a mixing cycle
- After mixing cycle another pH reading

https://www.directindustry.com/prod/eit-solutions-co-ltd/product-232981-2347401.html



https://www.linkedin.com/pulse/basics-process-control-bioreactor-fermenter-yogin-patel