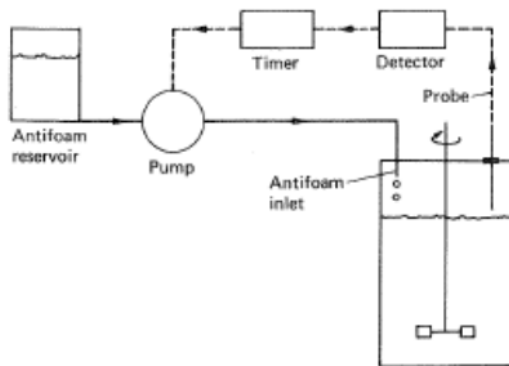
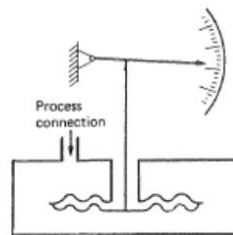


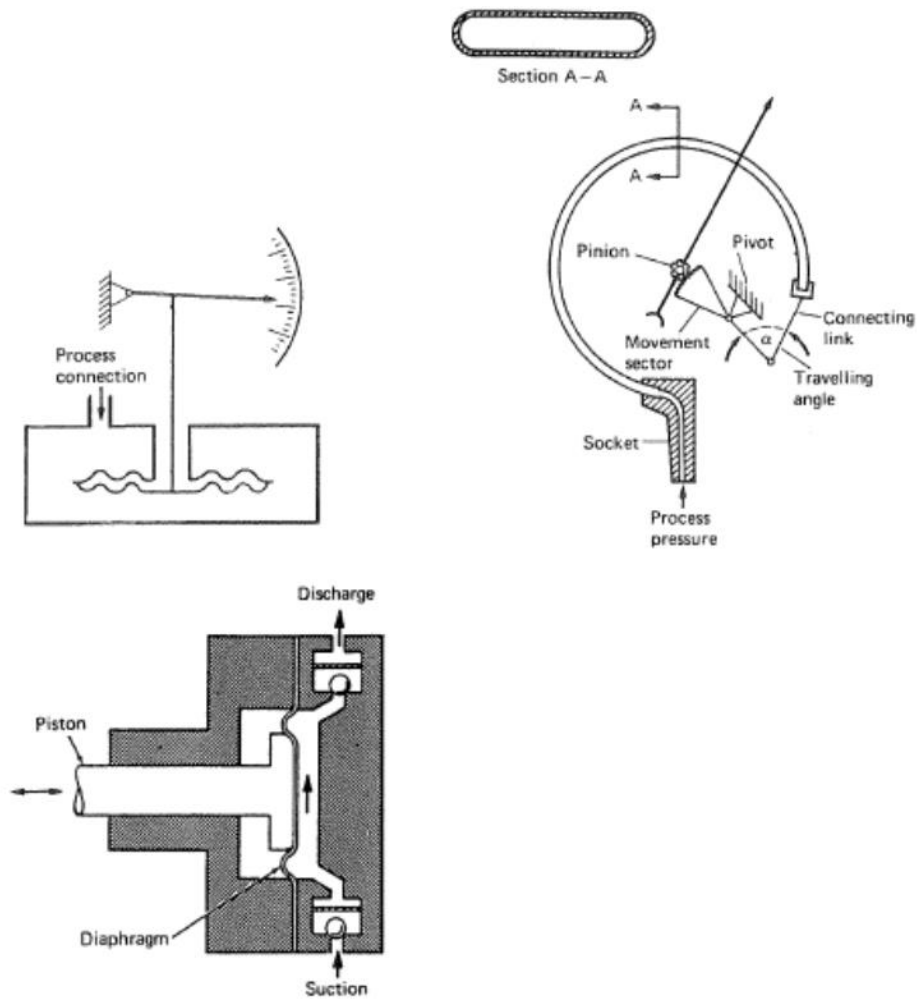
Foam Control

- A mechanical foam disintegrator attached to the agitator shaft often supplements the action of antifoam agents.
- In an antifoam system; if the foam contacts a rubber sheathed electrode, an electric unit actuates a solenoid valve to allow the passage of a sterile antifoam agent into the fermentor.
- A deflection trough is provided to ensure uniform distribution of antifoam agent.
- The action of antifoam agent is supplemented by the centrifugal effect of the foam breaker.
- The amount of antifoam entering fermentor is usually controlled by a timer in the circuit to the solenoid valve.
- Form control



Pressure control





On-line Analysis of Other Chemical Factors

- For good control of process, all chemical factors which can influence growth and product formation ought to be continuously monitored.
- This ideal situation has not yet been achieved but a number of techniques are currently being developed.
- Ion-specific Sensors
- They developed to measure NH_4^+ , Ca^{2+} , K^+ , Mg^{2+} , PO_3^- , SO_2^- , etc.
- Response time of these electrodes ranges from 10 seconds to several minutes depending on the concentration of the ion species, the composition of the sample.

- However, none of these probes is steam sterilizable.

Enzyme and Microbial Electrodes

- Enzyme or microbial cell electrodes can be used in some analyses.
- A suitable enzyme or microbial cell, which produces a change in pH or forms oxygen in the enzyme reaction is chosen and immobilized on a membrane, held in close contact to a pH or oxygen electrode.
- Unfortunately, the oxygen demand of the enzyme may restrict the maximum substrate concentration, which might be detected in a medium.
- Enfors (1981) –overcame this problem of glucose determination by co-immobilizing glucose oxidase and catalase.
- It has been possible to use a ferrocene derivative as an artificial redox carrier to shuttle electrons from glucose oxidase to a carbon electrode, thus making the device largely independent of oxygen concentrations.
- Enzyme electrodes are also commercially available to monitor cholesterol, triglycerides, lactate, acetate, oxalate, methanol, ethanol, creatine, ammonia, urea, amino acids, carbohydrates and penicillin.
- sterilized penicillinase electrodes was prepared by assembling sterile components or by standing assembled components in chloroform before placing in a fermenter.

Near infra-red Spectroscopy

- Hammond and Brookes (1992) developed near infra-red spectroscopy (NIR;460-1200nm) for rapid, continuous and batch analysis of components of fermentation broths.
- They used NIR absorbance bands to simultaneously estimate fat (in the medium), teichoic acid (biomass) and antibiotic (the product) in antibiotic production process.
- Fat analysis has been made possible with a fiber optic sensor placed in situ through a port in the fermenter wall.

- The assay time for an antibiotic has been reduced from 2 hours to 2 minutes.
- The method has also been developed to measure alkaline protease production in broths,
- It has been used to measure glucose, lactic acid and biomass in a lactic acid fermentation.

Mass Spectrometers

- It can be used for on-line analysis, it has a response time of less than 5 seconds for full-scale response and taking about 12 seconds for a sample stream.
- It allows for monitoring of gas partial pressures (O₂ , CO₂, CH₄. etc.) dissolved gases (O₂, CO₂, CH₄, etc.) and volatiles (methanol, ethanol, acetone, simple organic acids, etc.).

Control Systems

- The basic principle of control involves a sensory system linked to a control system and feedback loop.
- Sensors are used to measure and record the events within the bioreactor.
- In conjunction with process control, they maintain the difference between the measured and desired values at a minimum level.
- Overall control can be manual or automated; newer systems have integral and derivative control systems.
- Data recorded from the sensors and control decisions are downloaded to a computer where appropriate calculations can be performed to determine production of biomass and product, overall oxygen and carbon dioxide transfer rates, nutrient utilisation, power usage, etc.
- All of this information may be used to construct a mathematical computer model of the process.

- If a deviation is discovered, appropriate alarm and correctional systems are activated, giving greater control of the fermentation.
- Any control system needs to be calibrated when first installed and then regularly checked to conform to good manufacturing practices (GMP).
- The process parameters may be controlled using control loops.
- A control loop consists of four basic components:
 1. A measuring element.
 2. A controller.
 3. A final control element.
 4. The process to be controlled.
- In the simplest type of control loop (feedback control):
 - The measuring element senses a process property (flow, pressure, temperature, etc) then generates corresponding output signal.
 - The controller compares the measurement signal with the set point and produces an output signal to counteract any differences between the two.
 - The final control element receives the control signal and adjusts the process by changing a valve
 - opening or pump speed and causing the controlled process
 - property to return to the set point.

Manual Control

- A Simple example of control is manual control of a steam valve to regulate the temperature of water flowing through a pipe.
- Labor, cost and should be kept minimum and use automated control as much as possible.

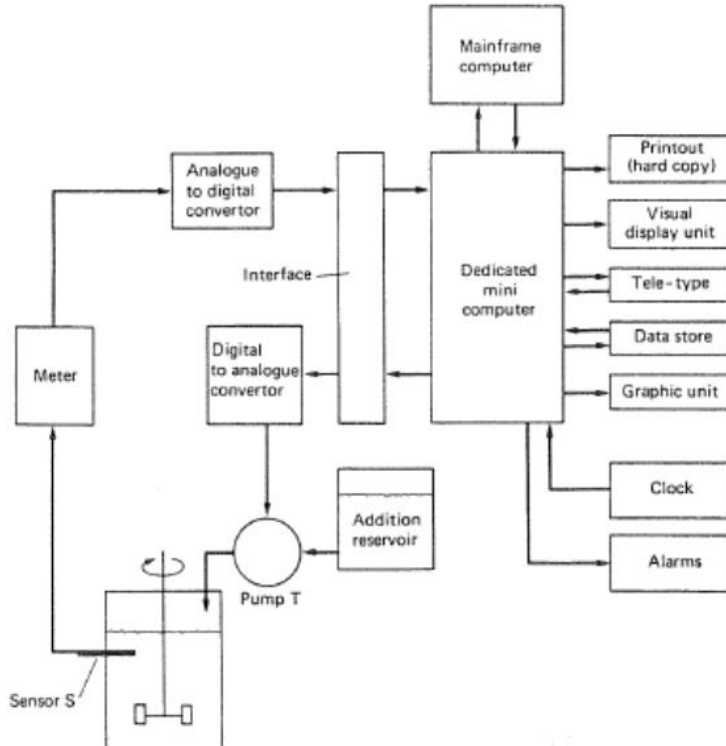
Automatic Control

- When an automatic control loop is used, certain modifications are necessary.
- The measuring element must generate an output signal which can be monitored by an instrument.
- E.g. the thermometer is replaced by a thermocouple, which is connected to a controller which in turn will produce a signal to operate the steam valve.

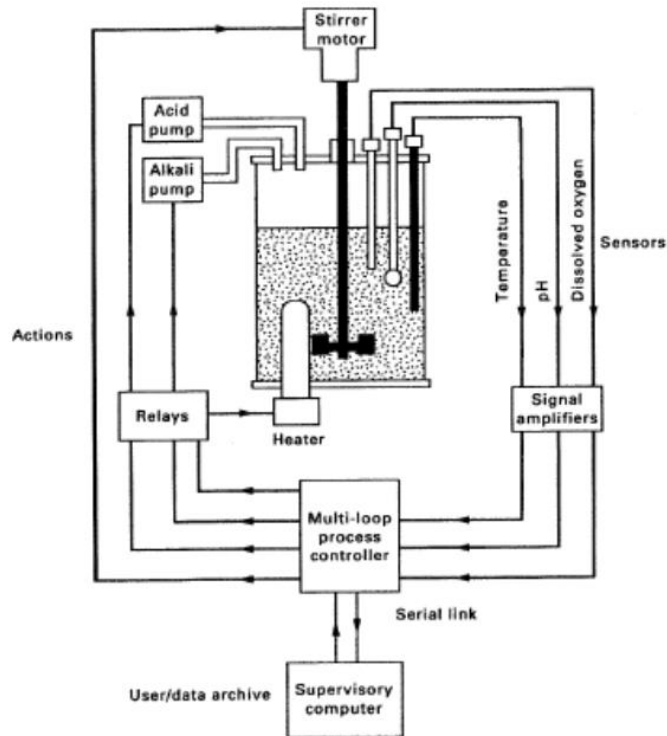
Computer Applications in Fermentation Technology

- Three distinct areas of computer function were recognized:
 1. Logging of process data.
- Data logging is performed by the data acquisition system which has both hardware and software components.
- There is an interface between the sensors and the computer. The software should include the computer program for sequential scanning of the sensor signals and the procedure of data storage.
- 2. Data analysis (Reduction of logged data).
- Data reduction is performed by the data-analysis system, which is a computer program based on a series of selected mathematical equations.
- This analyzed information may then be put on a print out, fed into a data bank or utilized for process control.

LECTURE EIGHT



Simple layout of computer – controlled fermenter with one control loop



SSC- supervisor set point control

- 3. Process control. Process control is also performed using a computer program.
- Signals from the computer are fed to pumps, valves or switches via the interface.
- In addition the computer program may contain instructions to display devices or teletypes, to indicate alarms, etc.
- There are two distinct fundamental approaches to computer control of fermenters.
- 1) Fermenter is under the direct control of the computer software. This is termed Direct Digital Control (DDC).
- 2) The use of independent controllers to manage all control functions of a fermenter and the computer communicates with the controller only to exchange information.
- This is termed Supervisory Set-Point Control (SSC).

Process Control

- Three levels process control that might be incorporated into a system were recognized.
- Each higher level involves more complex programs and needs a greater overall understanding of the process.
- The first level of control, involves sequencing operations, such as manipulating valves or starting or stopping pumps, instrument recalibration, on-line maintenance and fail-safe shut-down procedures.
- In most of these operations the time base is at least in the order of minutes, so that high-speed manipulations are not vital.
- Two applications in fermentation processes are sterilization cycles and medium batching.
- The second level of control involves process control of temperature, pH, foam control, etc. where the sensors are directly interfaced to a computer, Direct Digital Control (DDC).

- When this is done separate controller units are not needed.
- The computer program determines the set point values and the control algorithms, such as PID, are part of the computer software package.
- Computer failure can cause major problems unless there is some manual back-up facility.

- The alternative approach is to use a computer in a pure supervisory role, All control functions are per-formed by an electronic controller using a system illustrated in the figure:
- In such a system the linked computer only logs data from sensors and sends signals to alter set points when instructed by a computer program or manually.
- This system is known as Supervisory Set-Point Control (*SSC*) or *Digital Set-Point Control (DSC)*.
- When SSC is used the modes of control are limited to proportional, integral and derivative because the direct control of the fermenter is by an electronic controller.
- In the event of computer failure the process controller can be operated independently.
- The third (advanced) level of control is concerned with process optimization.
- This will involve understanding a process, being able to monitor what is happening and being able to control it to achieve and maintain optimum conditions.
- Firstly there is a need for suitable on-line sensors to monitor the process continuously.
- A number are now available for dissolved oxygen, dissolved carbon dioxide, pH, temperature, biomass (the bug meter, NADH fluorescence, near infra-red spectroscopy) and some metabolite (mass spectroscopy and near infra-red spectroscopy).
- Secondly, it is important to develop a mathematical model that adequately describes the dynamic behavior of a process.
- This approach with appropriate on-line sensors and suitable model programs has been used to optimize bakers' yeast production, an industrial antibiotic process and lactic acid production.