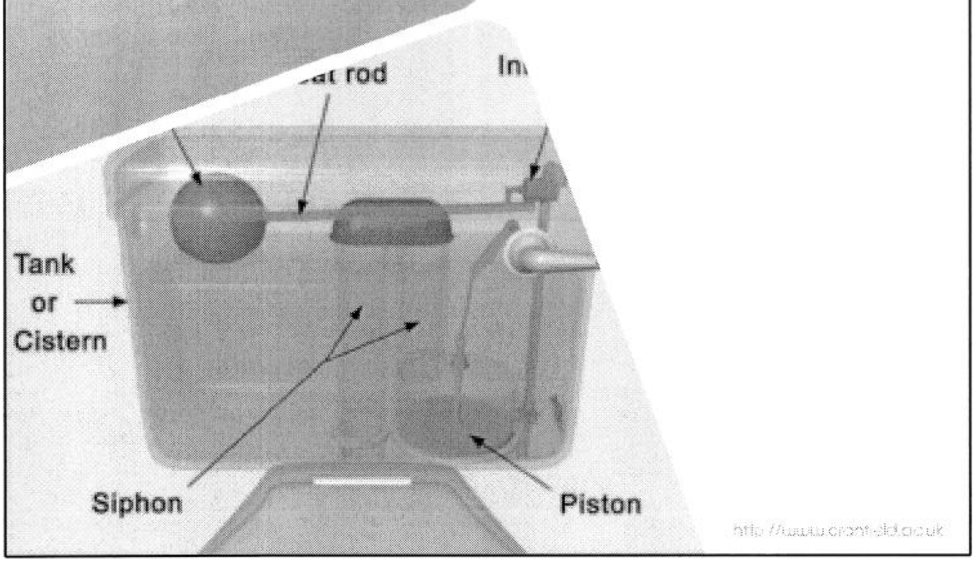
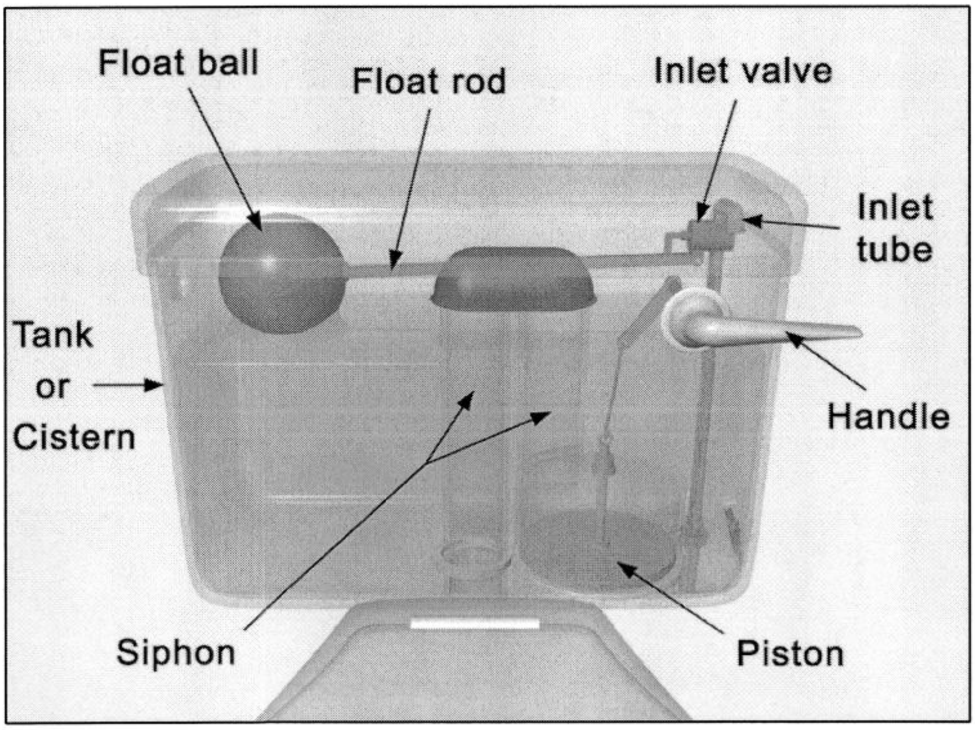
Process control





The key law of control

Good Process control

Rubbish IN = Rubbish OUT

Good input numbers (measurement)

Questions to ask oneself?

WHY
Do I want to make the measurement

WHERE
Is the best place to place the meter

WHO
Is going to use the data

WHEN
Will it get serviced

HOW
Will I install it

Instrument specification

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- Range, turn down and span
- Discrimination
- Accuracy
- Repeatability, reproducibility
- Sensitivity, uncertainty
- Linearity

Definition according to ANS/ISA s51.1 - 1979

Instrument range

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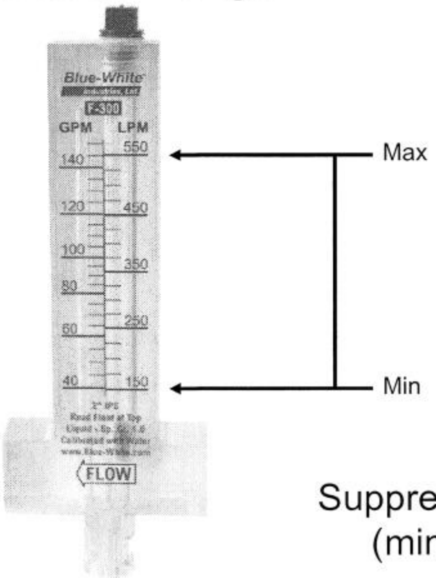

Range:

Limits of measurement

150-550 LPM

Span

Difference between MIN and MAX

400 LPM

Suppressed zero range (min above zero)

Accuracy and Precision

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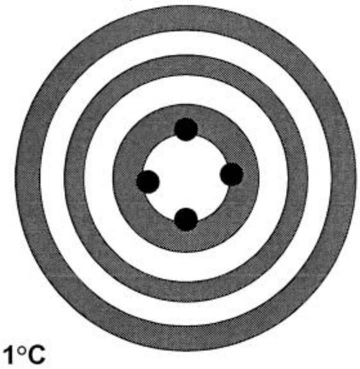

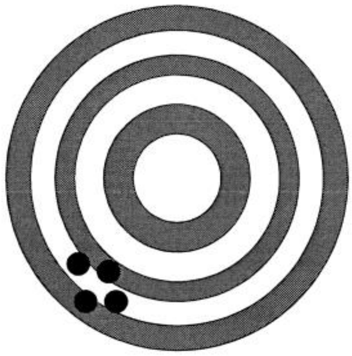

± 1°C

±0.5% span

±0.5% of Max value

±0.5% of scale length

±1% of value

Accuracy

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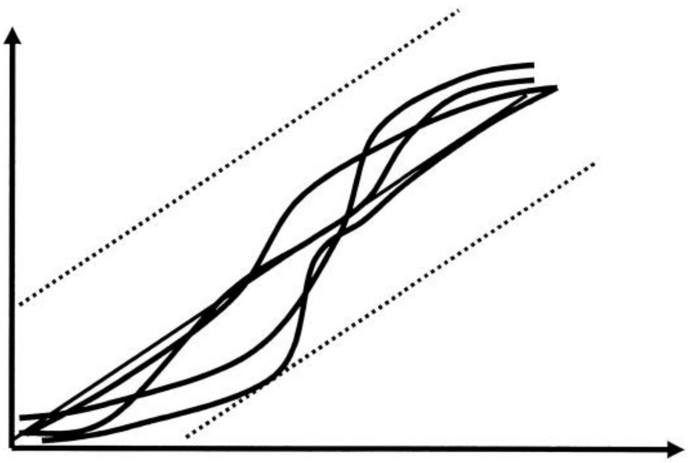

What we want

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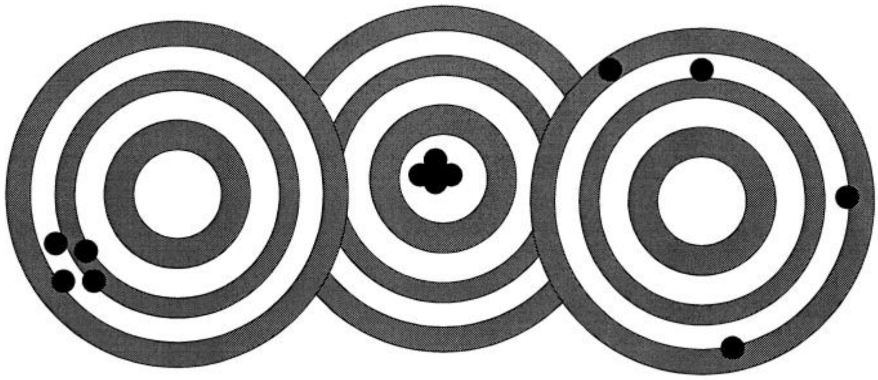

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Classification systems (WRc)

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Type	uncertainty	repeatability
I	±0.5	± 0.1
II	±1.0	±0.2
III	±2.0	±0.4
IV	±5.0	±1.0

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Classification systems (WRc)

Type	Applications
I	Potable: Abstracted flow, treated flow
II	DAF recycle, Chemical addition (potable)
III	Sewage flows
IV	

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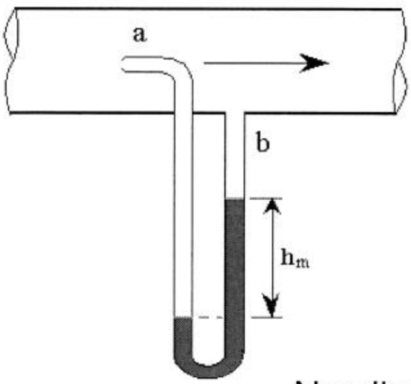
Most flow meters are based on differential pressure

$$Q_V \quad \sqrt{\frac{\Delta P}{\rho}}$$



Non linear
Turn down limited

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Flow meters

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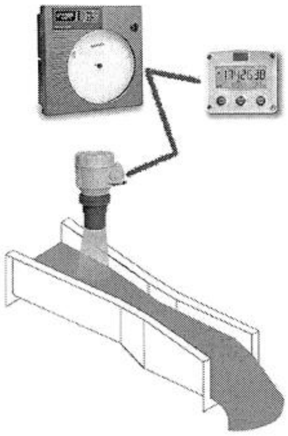

Open channel

Accuracy = ± 1%, turndown= 5:1

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Flow meters

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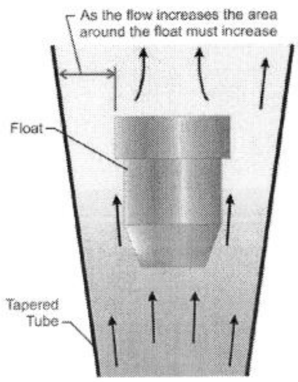
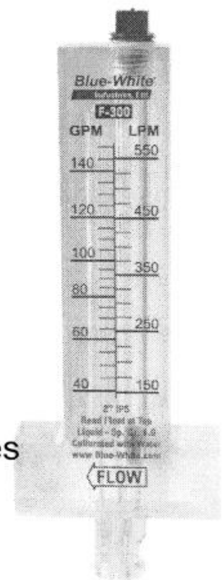


Variable area tubes
Precision 0.2-2%
Turndown 10:1
Vertical
Need steady flow
Not good with particles



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Flow meters

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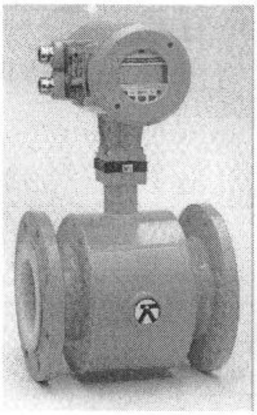
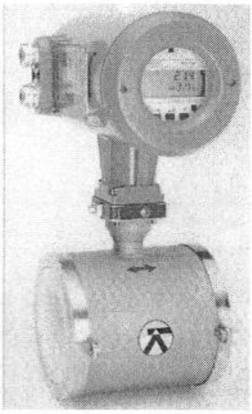
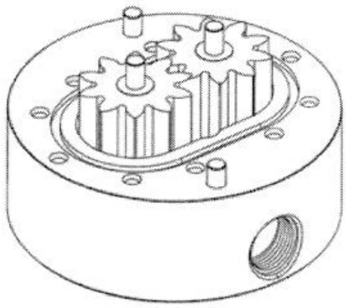




Electro magnetic



Positive displacement
Accuracy = ± 0.5%,
turndown= 20:1

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Comparison

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	Pro	cons
Pressure differential	**Simple** **Low cost**	**Span** **Clogging** **maintenance**
Magnetic	**Low d.p.** **Accuracy** **maintenance**	**Cost** **Lower velocity limit**
Open channel	**Simple** **Good range**	**Intrusive** **Cleaning** **Slow response**

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Pressure

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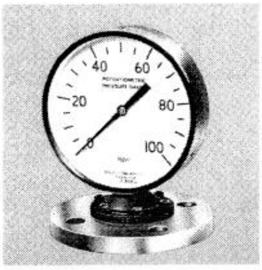
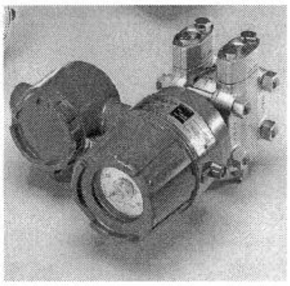


Bourdon tube gauge

Submersible transducer

Differential pressure transmitter



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Level

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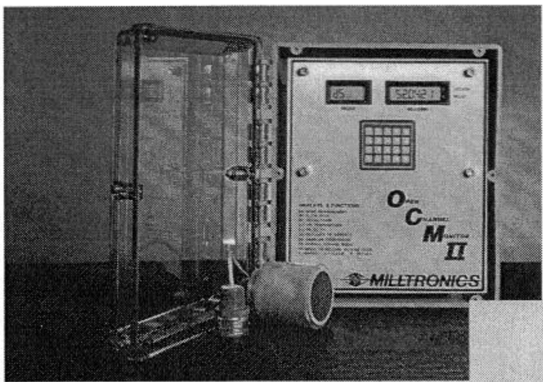
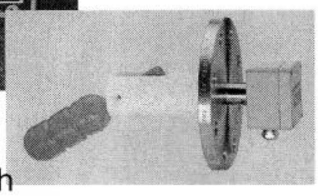


Ultrasonic monitor

Conductivity probe



Float switch

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Concentration

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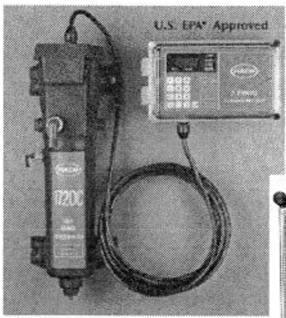
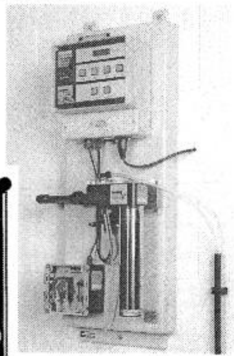
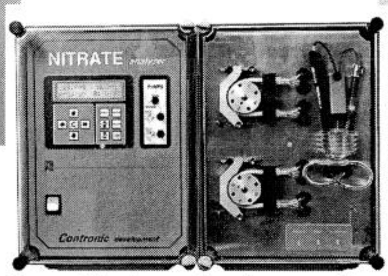


Turbidimeter

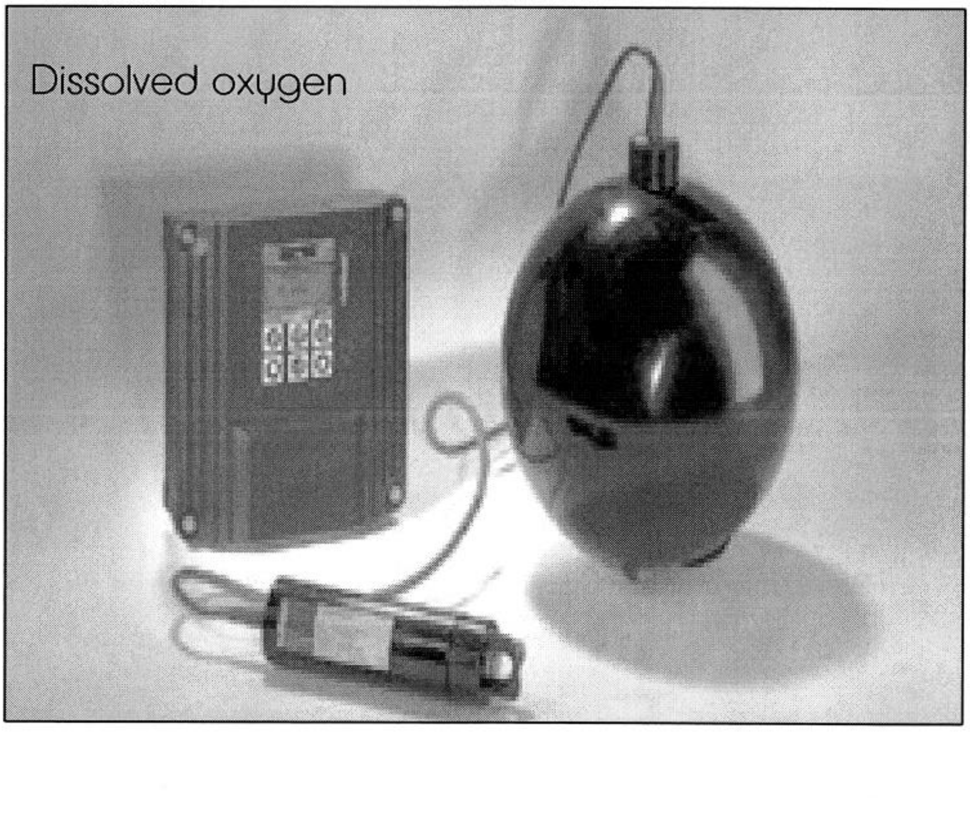
Chlorine residual



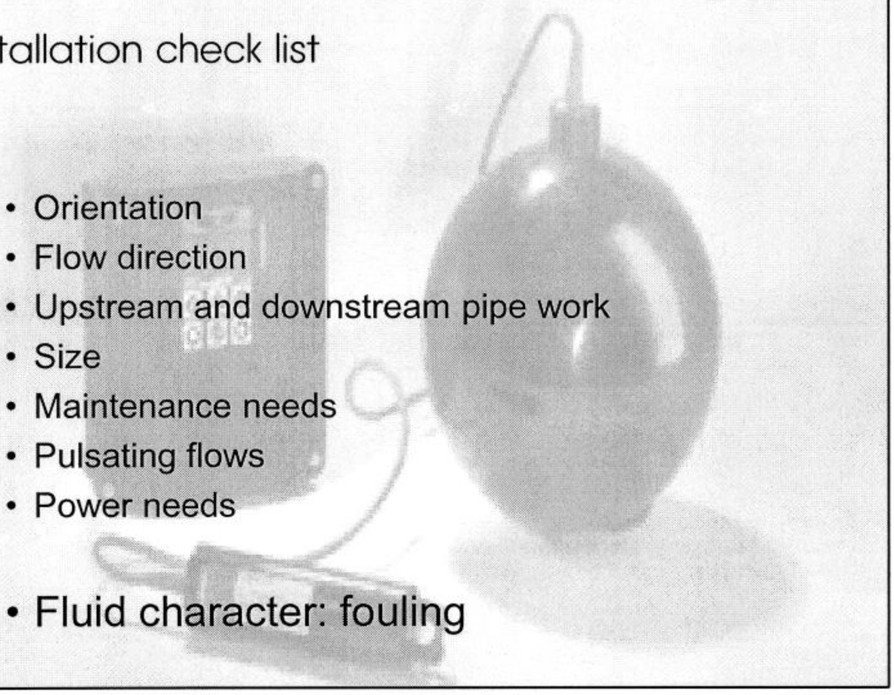


Specific ion nitrate monitor

Dissolved oxygen



Installation check list



- Orientation
- Flow direction
- Upstream and downstream pipe work
- Size
- Maintenance needs
- Pulsating flows
- Power needs

- Fluid character: fouling

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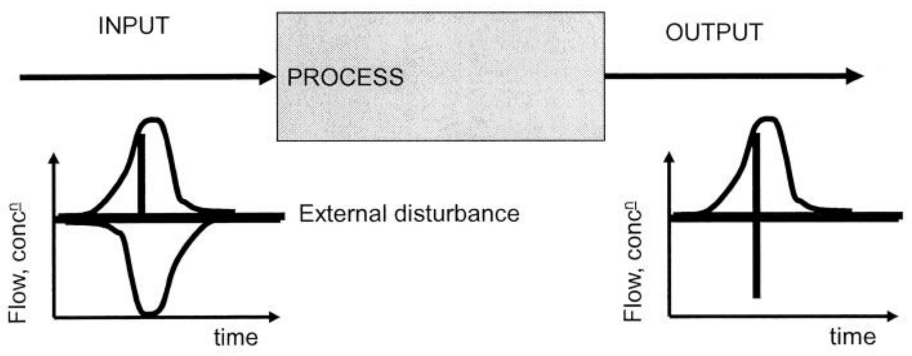
So what is process control



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Manual v automatic

1. Collect sample of MLSS and RAS
2. Transport sample to lab
3. Analyse samples for TSS
4. Lab communicates results back
5. Person responsible for plant determines if sludge wasting rate should be changed
6. Communicate decision to operators
7. Operator changes RAS

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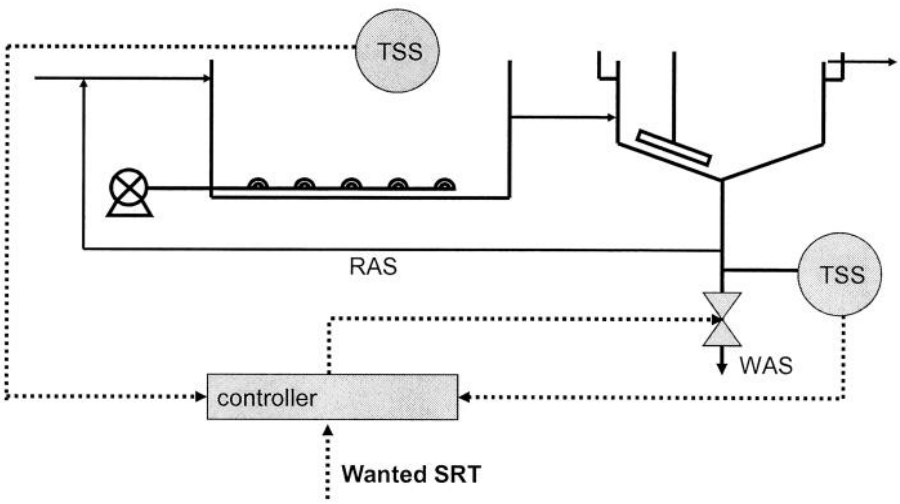
Manual v automatic



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External disturbance

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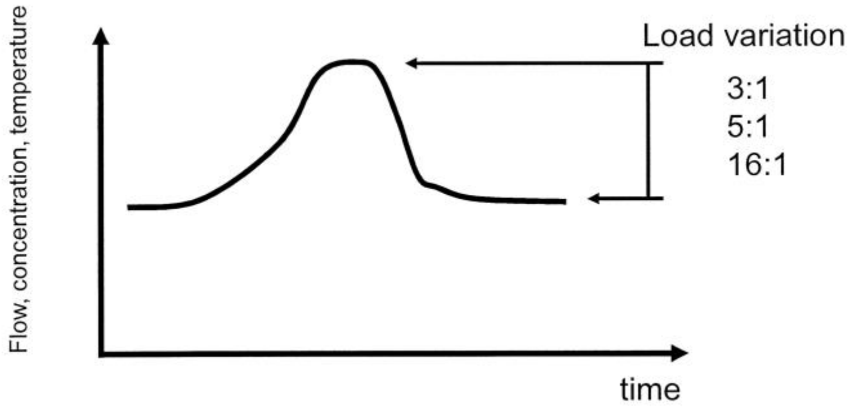

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Internal disturbances

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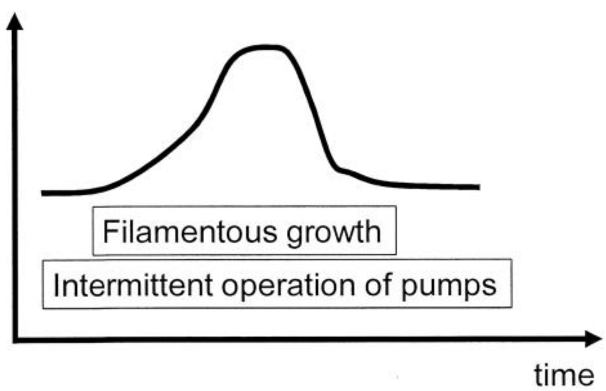

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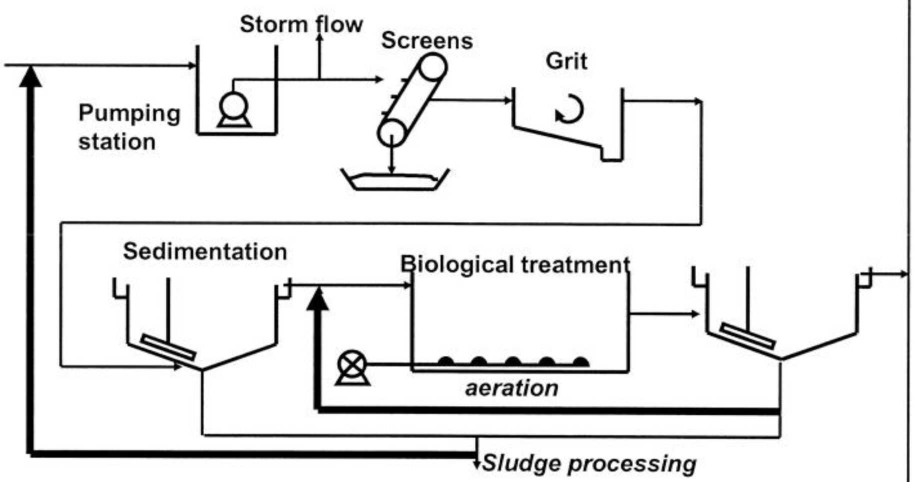
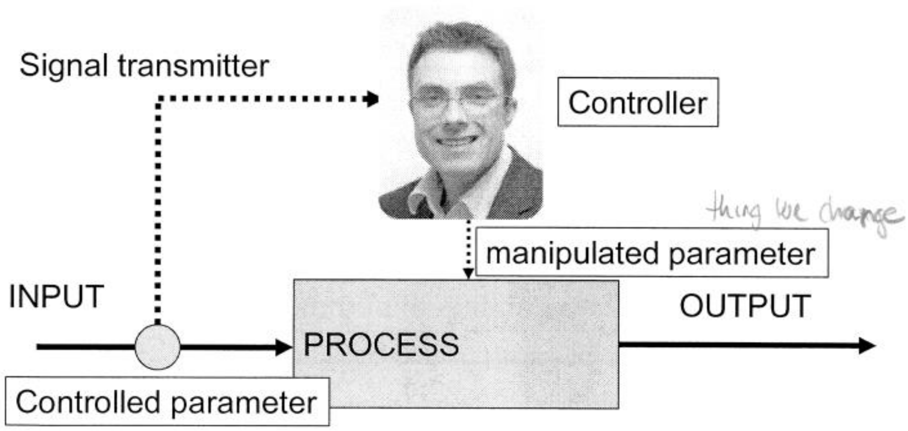
An integrated system



Control loops



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Example parameters

Process	Controlled parameter	Manipulated parameter
AS	DO Sludge depth SRT	Oxygen supply rate Return sludge flow rate Rate of sludge withdrawal
DAF	A/S ratio TSS in effluent	Recycle rate Chemical addition rate
Thickener	Percent solids Capture percentage	Belt solids loading Polymer rate

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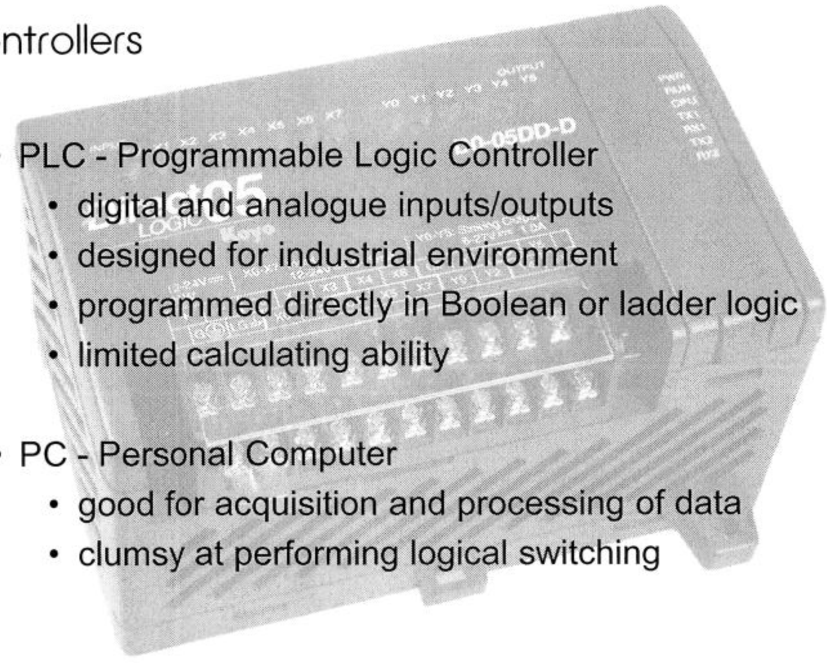
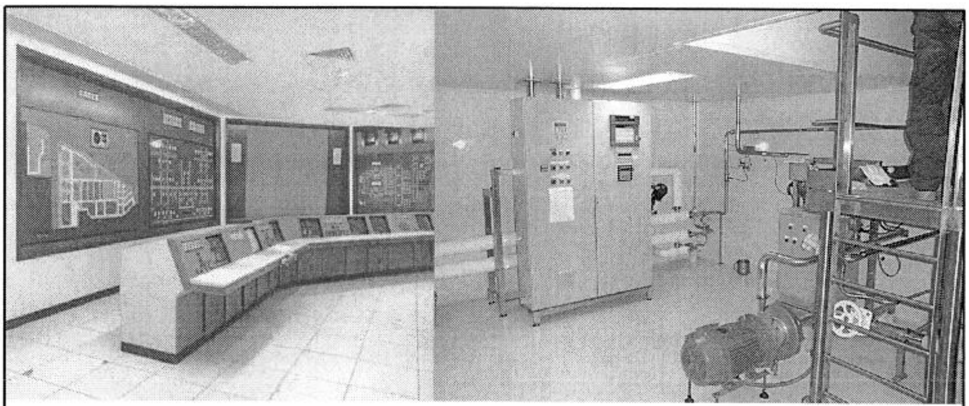
Controllers



- PLC - Programmable Logic Controller
  - digital and analogue inputs/outputs
  - designed for industrial environment
  - programmed directly in Boolean or ladder logic
  - limited calculating ability
- PC - Personal Computer
  - good for acquisition and processing of data
  - clumsy at performing logical switching



Central Control

- signals taken back to a central PLC and PID controllers
- all final control elements controlled directly from PLC

Distributed Control System

- all process unit "packages" controlled locally by individual PLCs
- individual controllers optimised for the process unit

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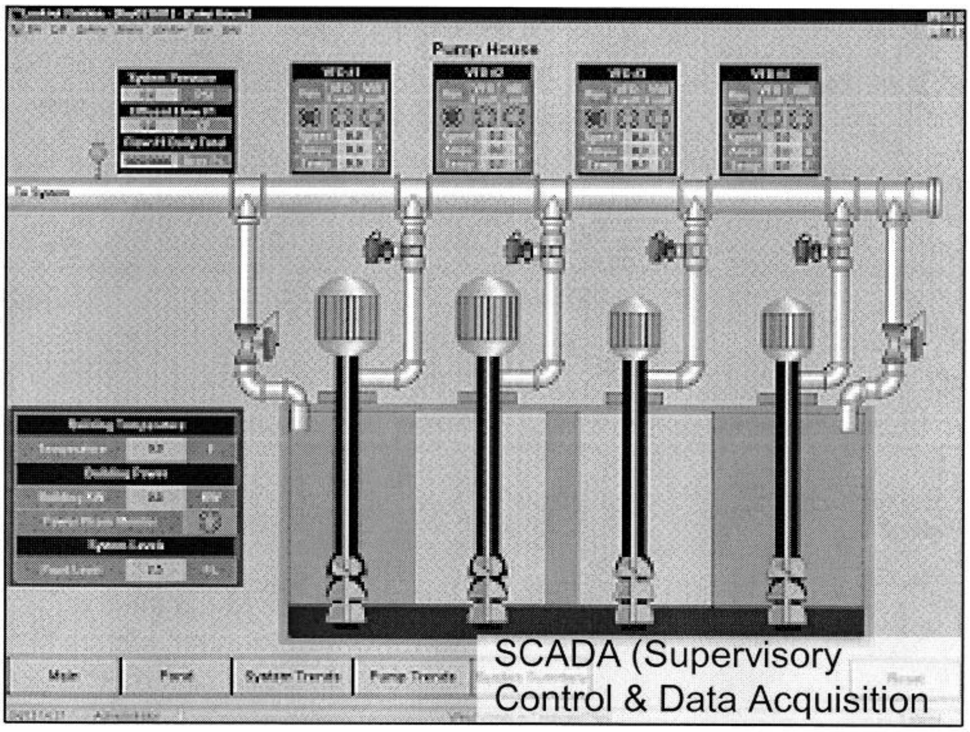
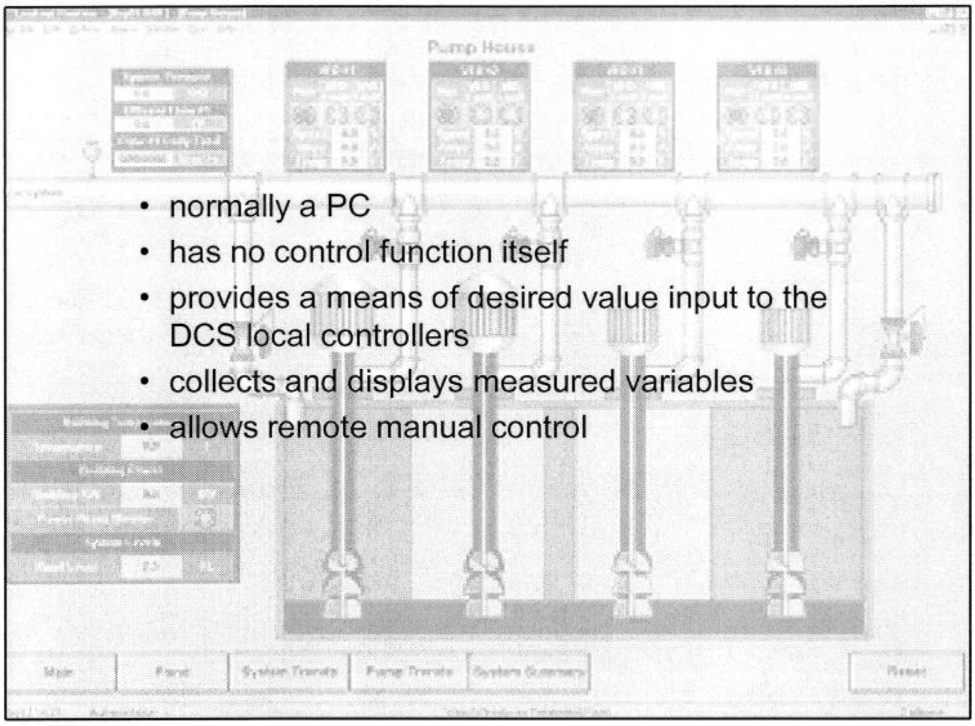


SCADA (Supervisory Control & Data Acquisition

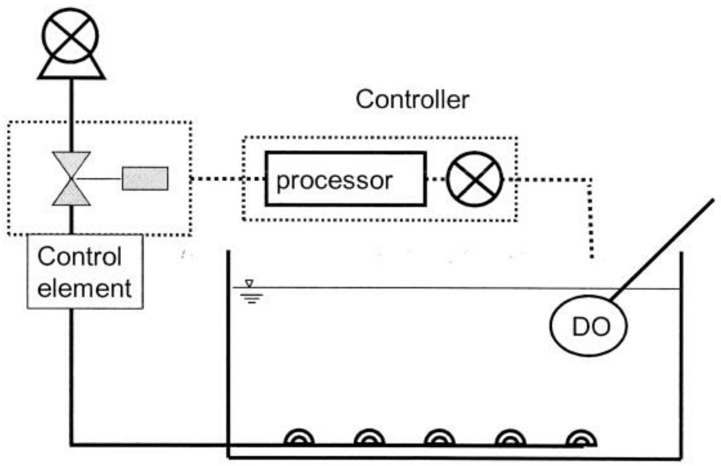


- normally a PC
- has no control function itself
- provides a means of desired value input to the DCS local controllers
- collects and displays measured variables
- allows remote manual control

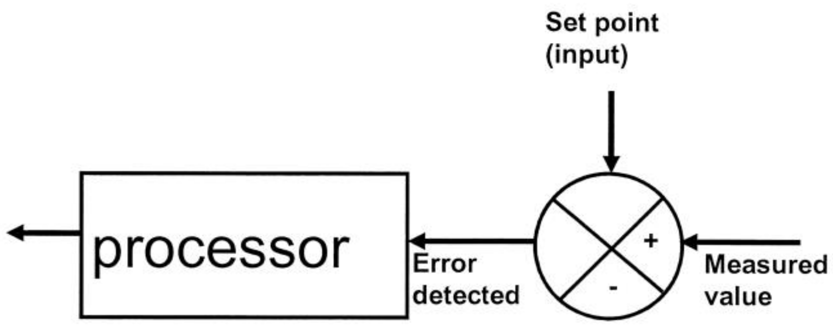
Control elements

Butterfly valve with
Electric actuator
Pneumatic actuator

Process control loops



Controller



Set points: what we want: DO, flow rate, level

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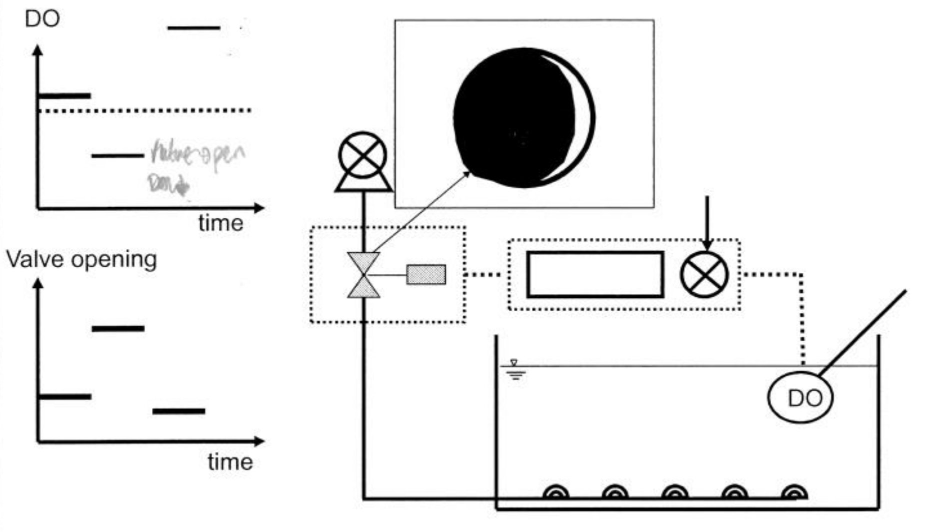
Process control loops



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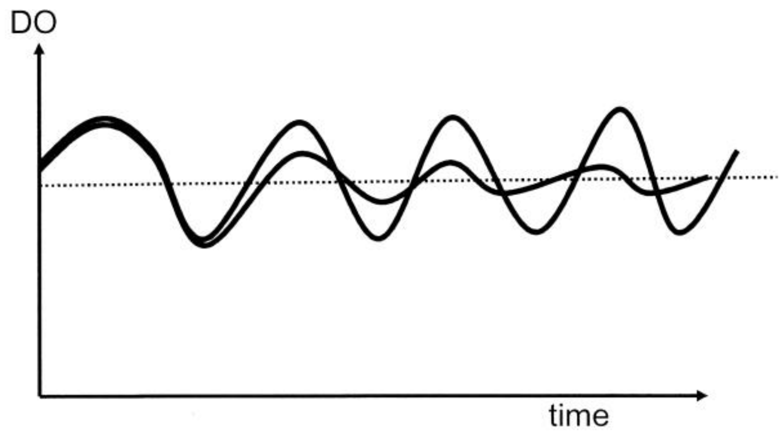
Response



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Types of control

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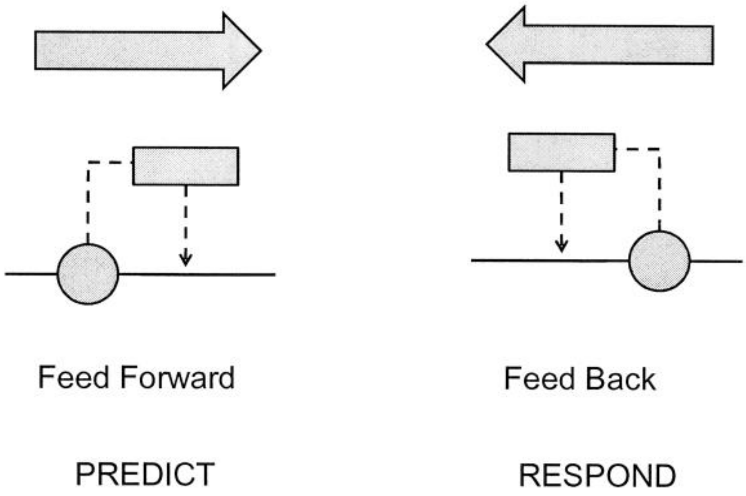

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Feed foward control

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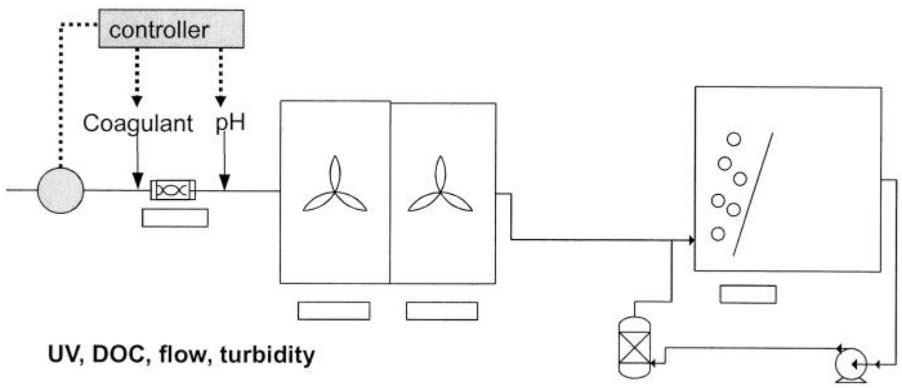

PREDICTIVE: coagulant addition, RAS flow

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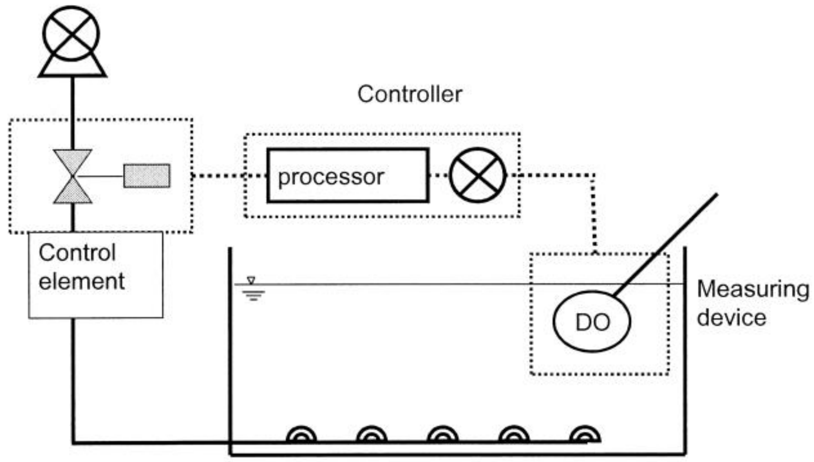
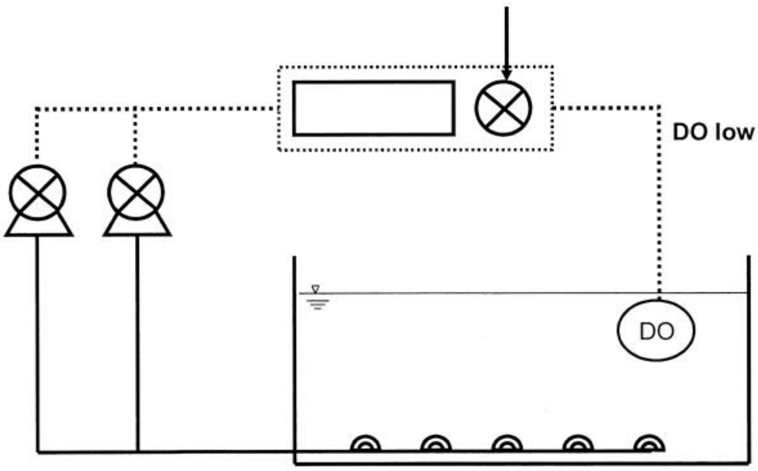
Feedback control

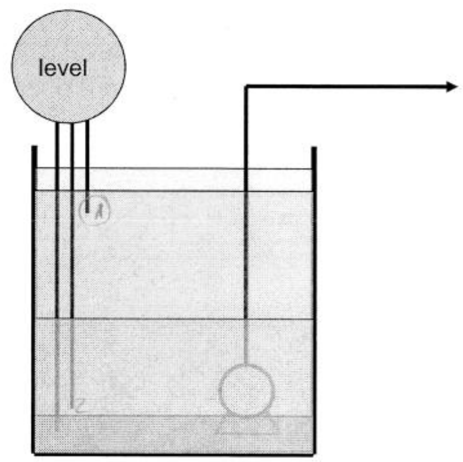


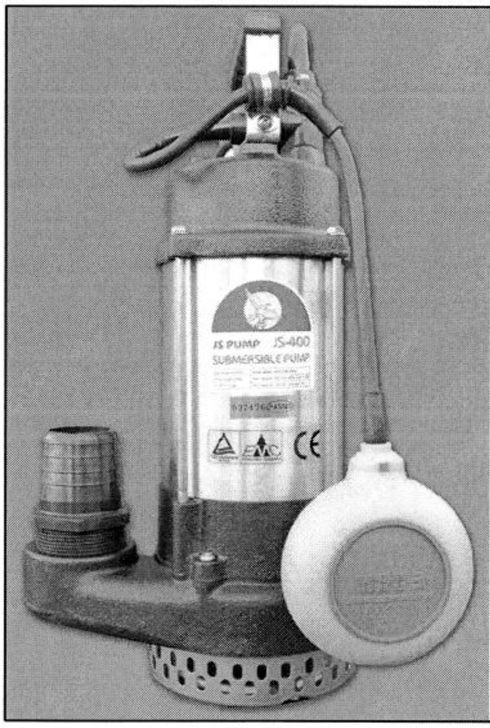
On-off control

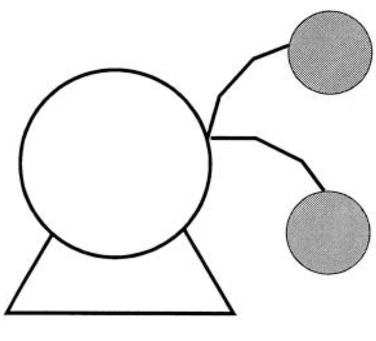


On-off control

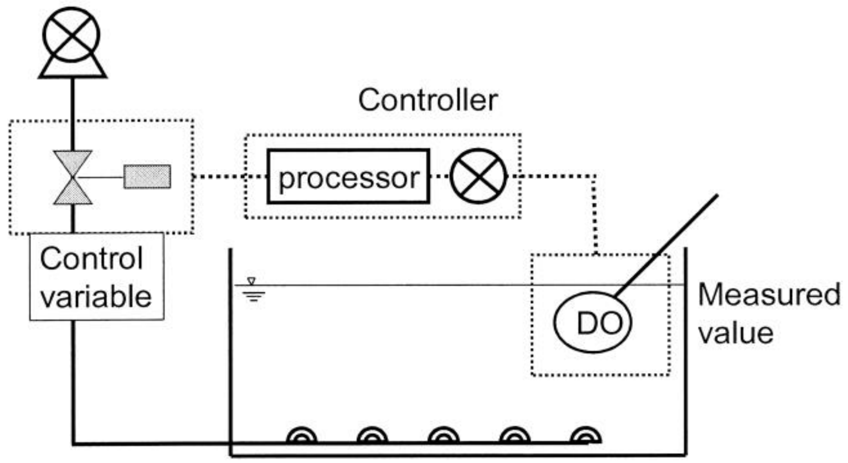
Pump



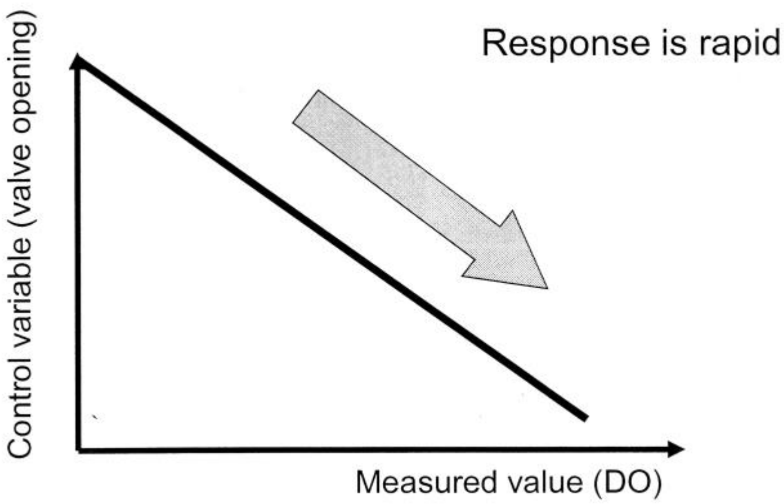


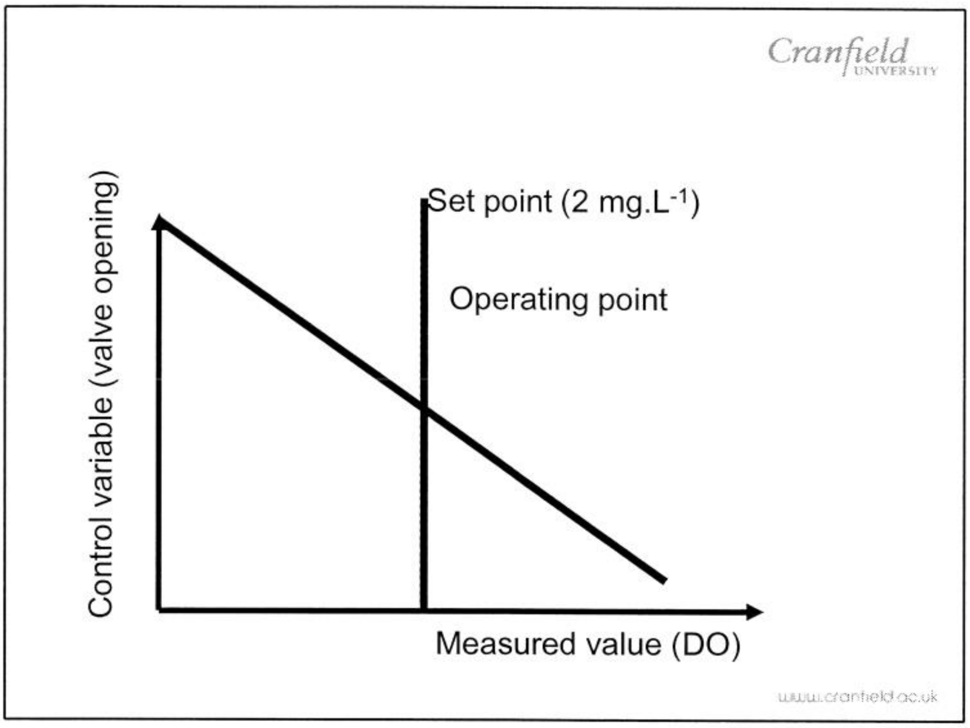


Proportional control



Proportional control ⇒ Speed

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Set point (2 mg.L-1)
Operating point
Control variable (valve opening)
Measured value (DO)
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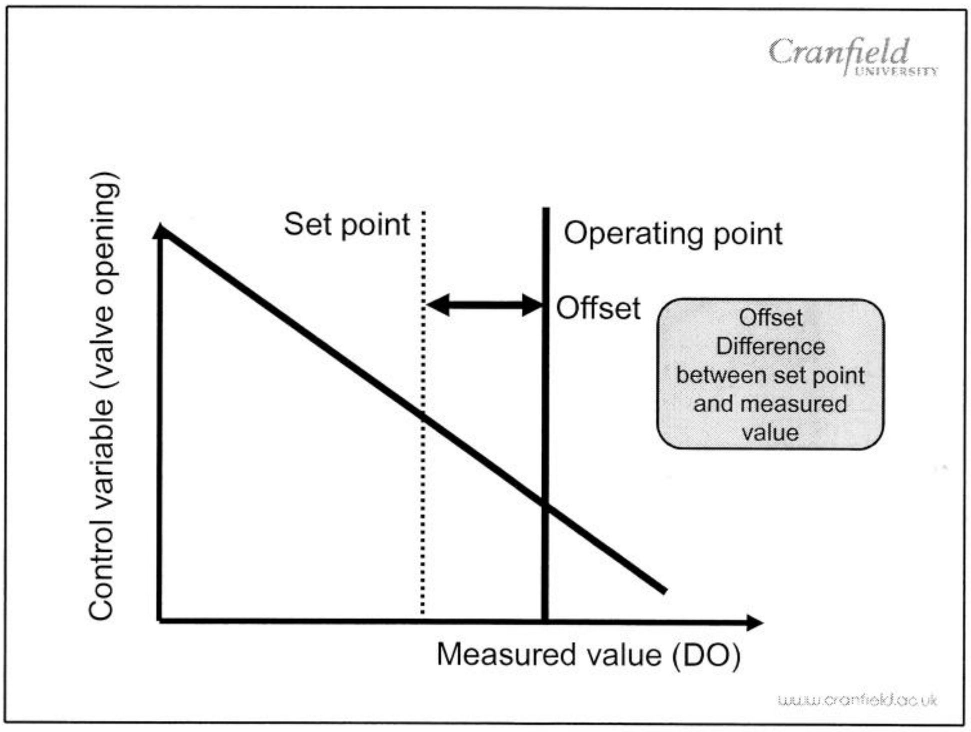
Cranfield UNIVERSITY
Set point
Operating point
Offset
Offset
Difference
between set point
and measured
value
Control variable (valve opening)
Measured value (DO)
www.cranfield.ac.uk

Mathematically speaking

$$Q_{air} = K_P(DO_{set\,point} - DO) + M$$

$$Q_{air} = K_P(\varepsilon) + M$$

Gain coefficient

error

bias

Error
Difference between set point and measured value

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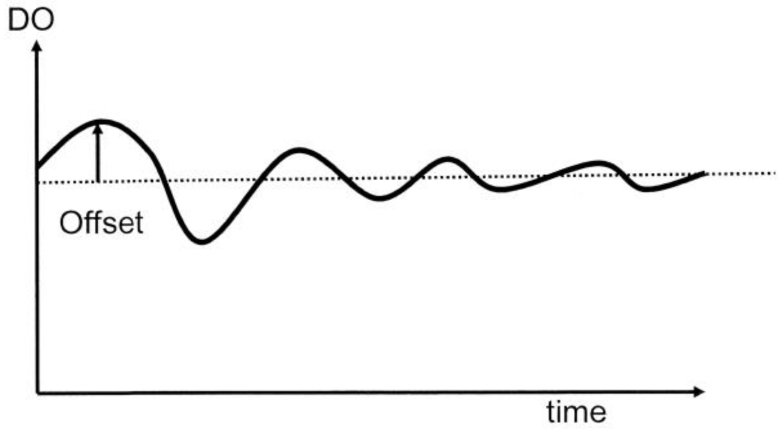
Integral control



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IC | Accuracy

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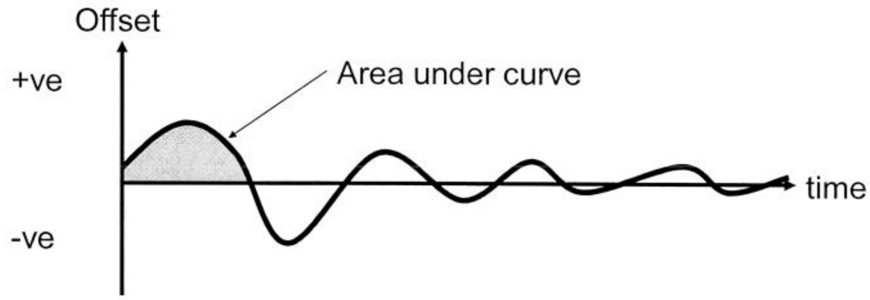

Change is calculated proportionally to area under curve

Eliminate offset

Proportional derivative control => precision

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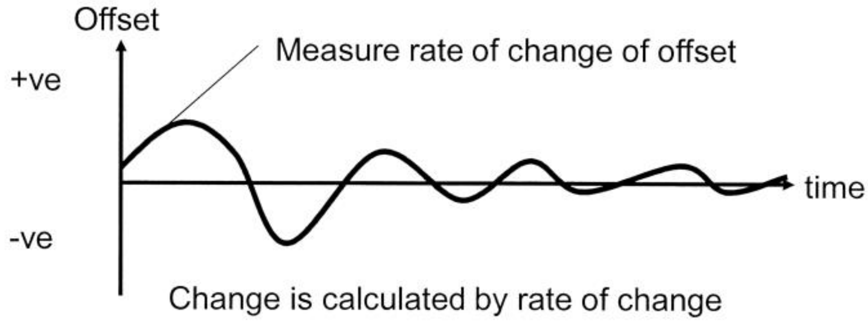

Change is calculated by rate of change

Anticipate change

Good when dynamics of process is fast

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Comparison

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P — Proportional, Speed

I — Integral, Eliminate offset

D — Derivative

P + I → **PI** — Reliable and accurate control

PI + D → **PID** — Sophisticated and effective

Three variables must be adjusted simultaneously

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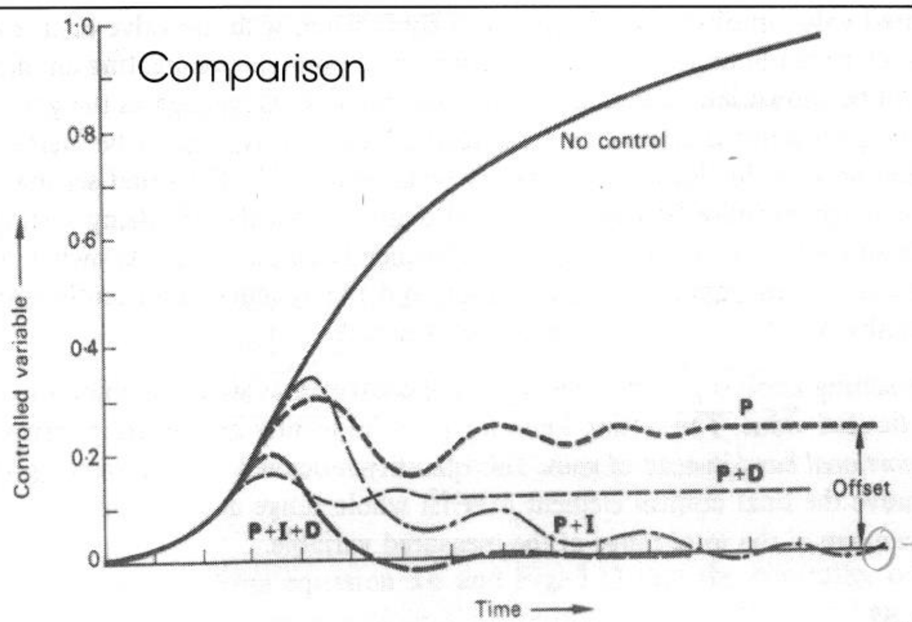
Comparison



Response of controlled variable to step disturbance in load using different control modes

P+D+I very good control

Tuning

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P K_p

I K_I

PI

K_p:K_I

Balance of P and I influence on control

Flow: high I

DO or Level: high P

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Cascade

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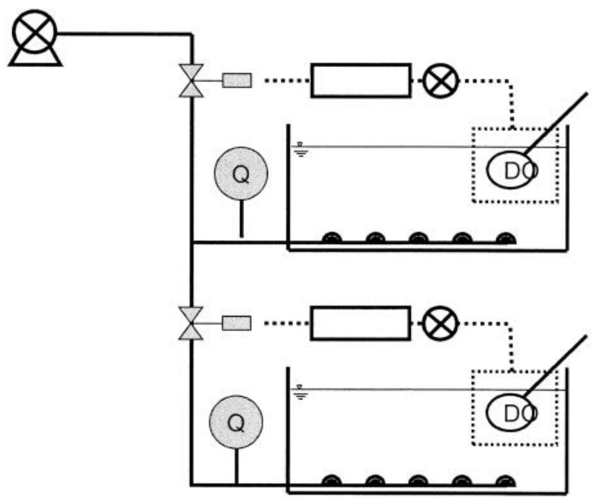

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