INSTRUCTION MANUAL

PCT23-MkII

PROCESS PLANT TRAINER

PCT23-MKII

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ARMFIELD LIMITED
OPERATING INSTRUCTIONS AND EXPERIMENTS
PCT23-MKII

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1. SAFETY IN THE USE OF EQUIPMENT SUPPLIED BY ARMFIELD

Before proceeding to install, commission or operate the equipment described in this Instruction Manual we wish to alert you to potential hazards so that they may be avoided.

Although designed for safe operation, any laboratory equipment may involve processes or procedures which are potentially hazardous. The major potential hazards associated with this particular equipment are listed below.

INJURY THROUGH MISUSE
INJURY FROM ELECTRIC SHOCK
INJURY FROM INCORRECT HANDLING
INJURY FROM ROTATING COMPONENTS
BURNS FROM COMPONENTS AT HIGH TEMPERATURES
SCALDING FROM BOILING LIQUIDS OR HOT VAPOURS (E.G. STEAM)
DAMAGE TO EYESIGHT
DAMAGE TO CLOTHING
RISK OF INFECTION DUE TO LACK OF CLEANLINESS

Accidents can be avoided provided that equipment is regularly maintained and staff and students are made aware of potential hazards. Armfield suggests that a comprehensive list of Laboratory Safety Precautions and Rules be made available to all laboratory users. Local laws or regulations related to laboratory practice or laboratory safety must be incorporated in these safety rules.

Please also refer to the following notes regarding the Control of Substances Hazardous to Health Regulations.

The Control of Substances Hazardous to Health Regulations (1988)

The COSHH regulations impose a duty on employers to protect employees and others from substances used at work which may be hazardous to health. The regulations require you to make an assessment of all operations which are liable to expose any person to hazardous solids, liquids, dusts, vapours, gases or micro-organisms. You are also required to introduce suitable procedures for handling these substances and keep appropriate records.

Since the equipment supplied by Armfield may involve the use of substances which can be hazardous (for example, cleaning fluids used for maintenance or chemicals used for particular demonstrations) it is essential that the laboratory supervisor or some other person in authority is responsible for implementing the COSHH regulations.

Part of the above regulations are to ensure that the relevant Health and Safety Data Sheets are available for all hazardous substances used in the laboratory. Any person using a hazardous substance must be informed of the following:

- Physical data about the substance
- Any hazard from fire or explosion
- Any hazard to health
Appropriate First Aid treatment
Any hazard from reaction with other substances
How to clean/dispose of spillage
Appropriate protective measures
Appropriate storage and handling

Although these regulations may not be applicable in your country, it is strongly recommended that a similar approach is adopted for the protection of the students operating the equipment. Local regulations must also be considered.

1.1 Water-Borne Infections

The equipment described in this Instruction Manual involves the use of water which under certain conditions can create a health hazard due to infection by harmful micro-organisms.

For example, the microscopic bacterium called Legionella pneumophila will feed on any scale, rust, algae or sludge in water and will breed rapidly if the temperature of water is between 20 and 45°C. Any water containing this bacterium which is sprayed or splashed creating air-borne droplets can produce a form of pneumonia called Legionnaires Disease which is potentially fatal.

Legionella is not the only harmful micro-organism which can infect water, but it serves as a useful example of the need for cleanliness.

Under the COSHH regulations, the following precautions must be observed:

Any water contained within the product must not be allowed to stagnate, i.e. the water must be changed regularly.

Any rust, sludge, scale or algae on which micro-organisms can feed must be removed regularly, i.e. the equipment must be cleaned regularly.

Where practicable the water should be maintained at a temperature below 20°C or above 45°C. If this is not practicable then the water should be disinfected if it is safe and appropriate to do so. Note that other hazards may exist in the handling of biocides used to disinfect the water.

A scheme should be prepared for preventing or controlling the risk incorporating all of the actions listed above.

Further details on preventing infection are contained in the publication "The Control of Legionellosis including Legionnaires Disease" - Health and Safety Series booklet HS (G) 70.

1.2 Use of an Earth Leakage Circuit Breaker as an electrical safety device

The equipment described in this Instruction Manual operates from a mains voltage electrical supply. The equipment is designed and manufactured in accordance with appropriate regulations relating to the use of electricity. Similarly, it is assumed that regulations applying to the operation of electrical equipment are observed by the end user.

However, to give increased operator protection, Armfield Ltd have incorporated a Residual Current Device or RCD (alternatively called an Earth Leakage Circuit
Breaker - ELCB) as an integral part of this equipment. If through misuse or accident the equipment becomes electrically dangerous, an RCD will switch off the electrical supply and reduce the severity of any electric shock received by an operator to a level which, under normal circumstances, will not cause injury to that person.

At least once each month, check that the RCD is operating correctly by pressing the TEST button. The circuit breaker MUST trip when the button is pressed. Failure to trip means that the operator is not protected and the equipment must be checked and repaired by a competent electrician before it is used.
2. INTRODUCTION

The Armfield Process Plant Trainer is a miniature version of a real industrial process, having typical problems of dynamics and stability for which control strategies have to be devised and operated.

The following process characteristics are incorporated:

- Multiple inputs and outputs
- Presence of dead time
- Recycling to minimise energy needs
- Alarms with corrective actions
- Operational sequencing from start up to shut down

The trainer allows the user to investigate various control techniques associated with process plant. These techniques range progressively from single-loop analogue control through to multi-loop PLC systems and ultimately to distributed supervisory control of the whole process by a remotely located PC station.

The Process Plant Trainer incorporates an electrical console which provides access to the various signals associated with measurement and control of the process allowing a variety of control possibilities:

- Manual operation
- Data logging using a PC or chart recorder
- Manual control via a PC, using a mimic diagram
- Direct digital control using a PC
- Use of industrial, PID or programmable controllers
- Use of customer-provided controllers
- Use of serial communications for supervisory control of individual controllers (SCADA)

Computer software is supplied with the Process Plant Trainer which allows control and/or data logging using a PC.
3. RECEIPT OF EQUIPMENT

3.1 Sales in the United Kingdom

The apparatus should be carefully unpacked and the components checked against the
Advice Note. A copy of the Advice Note is supplied with this Instruction Manual for
reference.

Any omissions or breakages should be notified to Armfield Ltd within three days of
receipt.

3.2 Sales Overseas

The apparatus should be carefully unpacked and the components checked against the
Advice Note. A copy of the Advice Note is supplied with this Instruction Manual for
reference.

Any omissions or breakages should be notified immediately to the Insurance Agent
stated on the Insurance Certificate if the goods were insured by Armfield Ltd.

Your own insurers should be notified immediately if insurance was arranged by
yourselves.
4. DESCRIPTION

The PCT23 Process Plant Trainer consists of a bench-mounted process unit which is connected to a dedicated control console.

4.1 Process Unit

All numerical references in brackets relate to the diagrams on page 11.

The PCT23-MkII process unit consists of two feed vessels (6), a three stage indirect plate heat exchanger (3), a holding tube arrangement (4), and a hot water vessel (2), mounted on an ABS plinth (1). The process liquid (water) is pumped at a pre-set flow rate from one of the two storage tanks to the heat exchanger, where its temperature is raised to a predetermined value. The liquid stream is then maintained at this temperature for a given period of time using the insulated ‘holding tube’, effectively a distance/velocity lag or ‘dead time’. Fluid exiting the holding tube passes through a temperature activated diverter valve (SOL1) which allows only fluid of the correct temperature to progress through the process, the remainder being rejected. The process fluid is then cooled to the lowest possible temperature by firstly exchanging otherwise wasted heat with incoming feed (regeneration) and subsequently by the use of externally supplied cooling water.

The plate heat exchanger consists therefore of three separate but interconnected sections: feed preheat/regeneration, heating and cooling. The heating section is supplied with circulatory hot water from the electrically heated reservoir.

The equipment incorporates provision for a typical ‘washing’ operation as part of a predetermined sequence of start-up/preheat/product processing/washing/shutdown procedures.

The process description actually corresponds to continuous, high-temperature-short time pasteurisation, where the process fluid is in reality milk, fruit juice or other liquid food product requiring heat treatment for bacteriological purposes. Very similar heat transfer arrangements are used in other unit process operations, in certain environmental control systems and indeed in any process requiring indirect heating and cooling over a prescribed temperature-time profile. All such processes are constrained by the ever increasing importance of energy minimisation and safe plant operation.

The process unit incorporates solenoid operated valves to allow remote control via the control console or PC:

- Product divert solenoid valve (SOL 1)
- Feed select solenoid valve, tank A/tank B (SOL 2)
- Product cooling solenoid valve, (SOL 3)
- Tank A fill solenoid valve, (SOL 4)
- Tank B fill solenoid valve, (SOL 5)

Two peristaltic pumps are provided on the process unit:

- Feed pump (N1)
- Hot Water pump (N2)
A Pressure reducing valve (PRV1) and a flow control valve (V1) control the flow of cold water to the feed tanks and cooling section.

The Process Unit incorporates the following measurement sensors:

**Temperature Sensors**

Temperatures are monitored by four temperature sensors (T1-T4) at key points in the process. The signal from each sensor gives a direct measurement of temperature in the process pipework 0-150°C. The usual positions of these sensors provide the following information:

- **T1** Holding tube exit
- **T2** Hot water temperature
- **T3** Product exit temperature
- **T4** Heated feed exit temperature

**C1 Conductivity Sensor**

A sensor (C1) measures the conductivity of the cooled process fluid (0-200 mS/cm).

**F1 Flow Sensor**

A turbine type flow sensor (F1) is installed in the product stream. This measures the product flow rate at the entrance to the holding tube (0-500 ml/min). An inline filter (FILTER) is incorporated upstream of the flow sensor to prevent debris from entering the sensor.

**L1 Level Sensor**

A pressure sensor (L1) is connected to a tapping in the base of feed tank A. The signal from this sensor gives a direct measurement of level in the tank (0-250mm).

**LL Float Switch**

A fixed float switch (LL) detects low level in Feed Tank B.

**HL Float Switch**

A float switch (HL) detects high level in Feed Tank B. The float switch can be adjusted in height by sliding the support rod through the gland in the base of the tank.
4.2 Control Console

The front panel of the control console is shown on page 12.

The control console provides access to the various signals associated with measurement and control of the process and allows a variety of control techniques to be demonstrated, including industrial controllers or direct digital control using a PC microcomputer. Controllers supplied by Armfield may be used or a customer may use his own controller(s) provided that the input and output signals are conditioned to 5Vdc.

Controllers available from Armfield include:

- PCT19BR    Allen Bradley SLC500 Programmable Logic Controller
- PCT20H    Honeywell UDC3200 PID Controller

The console power supply is switched on using the mains switch (1). A multi-purpose display (2) shows the value from the sensor selected on the multi position switch (3). The level sensor reading can be calibrated using the zero (27) and span (28) potentiometers above. Four sets of 0-5V output sockets are supplied (4), the signal to one of which (6) is selectable using a second multi position switch (5).

The hot water circulating pump is controlled by a ten turn potentiometer (7) and an ON/OFF switch (8). Alternatively, the selector switch (9) can be used to allow control of the pump via the two sets of input sockets provided (10), or via the I/O Port on the rear of the console. Similar controls (11-14) are provided for the feed pump.

The water heater is also controlled by a ten turn potentiometer (15) and ON/OFF switch (16) when in manual mode. LEDs show fault conditions for over temperature (17) and low level (18). Other control modes are selected by the multi position switch (19), and input sockets are provided for 0-5V and ON/OFF control (20).

The solenoid valves on the PCT23 are controlled using switches (22), (23), (24), (25) and (26) when in manual mode. When the switch (21) is in I/O PORT position, the valves are controlled from the one of the ports at the rear of the console.
Electrical faults may be introduced into any of the low voltage measurement or control signals using the Signal Fault Simulator and DC Fault Simulator, situated on the side of the control console. Faults may be inserted individually or in combination to suit the students' ability. The quick release fittings used throughout the process allow faults to be introduced into the process pipework if required. See page 38 for details of operation of the fault insertion module.

Signal Fault Switches
The rear of the PCT23 Console (page 14) houses the mains connection socket (29) and outlet (30). A Residual Current Circuit Breaker and three Miniature Circuit Breakers (31) are fitted for user protection.

Connections to the process unit are made via four thermocouple input sockets (32), a 40-way process connector (33), two heater connectors (34) and a DC Output (35).

Signal connections can be made using either the 50-way data I/O Port (36) or the USB port (37). When the USB port is connected to the computer, the red power LED (38) and the green active LED (39) will illuminate, indicating that the USB is used for all control functions. When the LEDs are not illuminated, the 50-way connector is used for control functions.
4.3 Software

The PCT23 Process Plant Trainer includes software on CD-ROM, suitable for use with PC. Data transfer to and from the PC is via the USB port on the rear of the console.

The software allows monitoring of process variables in real time, displayed within a mimic diagram (process schematic) of the process plant. In addition to data logging, a variety of control strategies have been developed for the process unit, including single PID loops, alarm actions, cascade and multiple PID loops.

The minimum specification for the user provided PC is as follows:

- Pentium processor or equivalent
- 16 MB RAM
- 10MB Hard Disk space
- CD-ROM Drive
- USB Port
- SVGA Display (800 x 600, high colour recommended)
- Windows 98 / 2000 / XP or later

4.4 Heat Exchanger Flow Path
5. INSTALLATION REQUIREMENTS

5.1 Electromagnetic Compatibility

This apparatus is classified as Education and Training Equipment under the Electromagnetic Compatibility (Amendment) Regulations 1994. Use of the apparatus outside the classroom, laboratory or similar such place invalidates conformity with the protection requirements of the Electromagnetic Compatibility Directive (89/336/EEC) and could lead to prosecution.

5.2 Facilities Required

The Process Plant Trainer PCT23 is designed to be bench mounted and requires only a sturdy, level bench or table top for siting. The trainer comprises a Process Unit and Control Console which must be positioned adjacent to each other. A bench space 1.8 metres long by 0.65 metres deep is required to accommodate the Process Plant Trainer. Space must be available alongside the Control Console to allow process controllers, computers etc. to be connected as required. Additional bench space 1.00 metre long is suggested.

A single phase fused electrical supply is required for connection to the Electrical Console. An integral electrical lead, 4 metres long, is permanently attached.

The trainer should be situated close to a clean, cold water supply and drain. The water requirement for the Process Plant Trainer depends on whether or not tap water is being used for cooling purposes. The maximum flow of cold water is 5 litres/minute at a minimum pressure of 2 bar (gauge).

NOTE: The supply of cold water is required for refilling the feed tanks and cooling the product leaving the heat exchanger. If a permanent supply of cold water is not available, the equipment may still be used by filling the feed tanks using a suitable container. In this instance cooling of the final product will not be possible.

Installation may be carried out using a basic tool kit.
6. ASSEMBLY

Refer to the ‘Connection to Services’ section of this Instruction Manual before connecting an electrical supply to the console.

The Process Plant Trainer is supplied as an assembled Process Unit and Control Console which must be connected together.

The Control Console can be positioned on either side of the Process Unit. The user should make sure that the unit is positioned conveniently for water supply, drains and electrical supply. Ensure that adequate space is available along side the Electrical Console for process controllers, PC microcomputer etc.

Place the Control Console in the required location along side the Process Unit.

Connect the integral heater lead from the function box at the rear of the hot water tank (3) on the Process Unit to the circular connector marked ‘HEATERS’ at the rear of the control console (34).

Connect process umbilical to the circular process connector (33). Connect the four thermocouple leads to the appropriate socket on the console (32).

Connect the USB cable to the USB Port (37) and locate the free end in a suitable position for connection to the PC.

Connect the flexible tube for Diverted Product to the side connection on the Divert Solenoid Valve (SOL 1).

Connect the flexible tube for Finished Product to the side connection on the Divert Solenoid Valve (SOL 1).

Connect the flexible tube for Finished Product to the connection at the right hand end of the heat exchanger(s) - tapping - shared with T3.

Connect the flexible tube for Cold Water Discharge to the connection at the rear right hand end of the heat exchanger (5).

The Process Plant Trainer is ready for connection to the appropriate services.
7. CONNECTION TO SERVICES

7.1 Electrical Supply

Electrical Supply For Version PCT23-A:
The equipment requires connection to a single phase, fused electrical supply. The standard electrical supply for this equipment is 220-240V, 50Hz. Check that the voltage and frequency of the electrical supply agree with the label attached to the supply cable on the equipment. Connection should be made to the supply cable as follows:-

GREEN/YELLOW - EARTH
BROWN - LIVE (HOT)
BLUE - NEUTRAL
Fuse Rating - 13 AMP

Electrical Supply For Version PCT23-B:
The equipment requires connection to a single phase, fused electrical supply. The standard electrical supply for this equipment is 120V, 60Hz. Check that the voltage and frequency of the electrical supply agree with the label attached to the supply cable on the equipment. Connection should be made to the supply cable as follows:-

GREEN/YELLOW - EARTH
BROWN - LIVE (HOT)
BLUE - NEUTRAL
Fuse Rating - 20 AMP

7.2 Cold Water

Before connecting cold water to the equipment ensure that the Pressure Reducing valve (PRV1) is set to minimum (fully anticlockwise). Open flow control valve (V1) fully. The cold water inlet connection to the equipment is located at the rear of the Process Unit behind the rear feed tank (B). Ensure that the hose (not supplied) used to connect the water supply is securely attached to the inlet of the pressure reducing valve using appropriate pipe clips.

The water supply will normally be taken from a laboratory tap. A minimum of 2 bar pressure and a maximum flow of 5 litres/minute is required. Pressure reducing valve PRV1 reduces the operating pressure to protect the solenoid valves from over-pressurisation (the valves will not operate if the water pressure is too high).

NOTE: If a permanent supply of cold water is not available, the equipment may still be used by filling the feed tanks using a suitable container. In this instance, cooling of the final product will not be possible.

7.3 Drain

An ordinary laboratory sink drain can be used to take away the cooling water, hot water etc. which will be produced at various times during the operation of the process. The flexible tubing attached to the product outlet, cooling water outlet and diverter valve outlet should be directed to the drain.

The Process Plant Trainer is ready for commissioning.
8. COMMISSIONING

All references in brackets relate to the diagrams on pages 11 and 12.

Check that the equipment has been installed, assembled and connected to the appropriate services as detailed in the preceding sections.

The following procedure is intended as a series of checks to ensure that the equipment is operating correctly.

1. Configure the console for manual operation:
   Before switching on the console set the switches as follows:
   - All function switches to ‘MANUAL’
   - All control potentiometers to minimum (fully anticlockwise)
   - Valve control switch for SOL 1 to ‘DIVERT’
   - Valve control switch for SOL 2 to ‘FEED A’
   - Valve control switch for SOL 3 to ‘STOP’
   - Valve control switch for SOL 4 to ‘STOP’
   - Valve control switch for SOL 5 to ‘STOP’

2. Power up the console:
   - Switch on the three circuit breakers (switches UP).
   - Switch on the RCCB (switch UP). Press the test button in the RCCB and check that the RCCB trips (if the RCCB fails to trip it should be checked by a competent electrician before proceeding).
   - Switch on the RCCB. Switch on the mains switch (1).
   - Check that the console is powered (Liquid Crystal Display operates).
   - Observe that the RED ‘LOW LEVEL’ LED is illuminated on the Water Heater section of the console (the hot water tank is empty).

3. Fill hot water tank:
   - Place the tube with hooked end marked ‘DRAIN’ in the breather hole in the top of the hot water vessel. Switch SOL3 to cool position to fill tank.
   - Fill the tank with water until the heater element is covered by at least 10mm of water. The ‘LOW LEVEL’ LED will go out on the Console.

4. Adjust cold water:
   - Set valve control switch SOL 4 to ‘Fill A’.
   - Ensure that flow control valve (V1) is fully open (fully clockwise).
   - Ensure that pressure reducing valve (PRV1) is set to minimum pressure (fully anticlockwise when knob is pulled out).
   - Gradually increase the pressure from (PRV1) by turning the knob clockwise until a steady stream of water fills Feed Tank (A). Push the knob on (PRV1) down to lock the setting.
   - Repeatedly start and stop the flow into tank A by operating valve control switch SOL 4. If the flow into tank A fails to restart then it is likely that the pressure set in PRV1 is too high (turn PRV1 anticlockwise to correct).
Allow feed tank A to fill then stop the flow by setting Valve Control switch SOL 4 to ‘STOP’.

**NOTE:** If a supply of water is not available fill feed tank A by pouring water into the tank from a suitable container.

5. Check operation of the hot water circulating pump:

Ensure that the flexible tubing from the top outlet in the hot water tank is loaded into the peristaltic pump head (N2) and the pump head is clamped on to the tubing (pivot the clamp forwards and downwards).

Switch the water pump on (8), then gradually increase the speed of the pump by rotating the speed control (7) clockwise. Set the control to approximately half speed (5.00 on the dial).

6. Check operation of the product Feed Pump:

Ensure that the flexible tubing from SOL 2 to the heat exchanger is loaded into the peristaltic pump head (N1) and the pump head is clamped onto the tubing (pivot the clamp forwards and downwards).

Switch the feed pump on (12) then gradually increase the speed of the pump by rotating the speed control (11) clockwise. Set the control to approximately half speed (5.00 on the dial).

Check that water exits from the outlet on the side of the diverter solenoid valve.

7. Check operation of the diverter valve:

Set Valve Control switch SOL1 to ‘NORMAL’. Check that water stops flowing from the side outlet on the diverter solenoid valve SOL1. After filling the heat, recovery and cooling sections of the heat exchanger check that water exits from the finished product outlet at the right hand end of the heat exchanger.

8. Check flow of cooling water:

Set Valve Control switch SOL3 to ‘COOL’. Check that cooling water flows through the heat exchanger and exits at the front left hand outlet of the exchanger.

9. Check the system for leaks:

Check all of the pipework connections in the system for leaks. Tighten any leaking threaded connection. Most of the connections are quick release and can be sealed by pushing the pipework firmly into the fitting.

If there are leaks from the heat exchanger gaskets, the nuts on the ends of the stud bolts of the heat exchanger may need to be tightened. These nuts must be tightened carefully in a diagonal sequence until the leak stops.

10. Check operation of the Water Heater:

Set the display selector switch (3) to PWR. Switch the water heater on (16) then gradually increase the power to the heaters by rotating the power control (15) clockwise. Adjust the control to give a reading of approximately 1.00 kW on the LCD display.
Set the display selector switch(3) to T2 to indicate the temperature in the hot water tank.

Check that the temperature of the water in the tank increases (indicated by T2).

11. After use:

Release the clamp on the peristaltic pump heads to prevent permanent distortion of the flexible tubing.

Set all controls on the console to minimum/OFF, then switch off the console.

The Process Plant Trainer has been checked for satisfactory operation using the manual controls on the control console. Refer to the operating notes in this manual for details on operating the trainer using the front panel input sockets or I/O Port at the rear of the Electrical Console.
9. ROUTINE MAINTENANCE

To preserve the life and efficient operation of the equipment it is important that the equipment is properly maintained. Regular servicing/maintenance of the equipment is the responsibility of the end user and must be performed by qualified personnel who understand the operation of the equipment.

In addition to regular maintenance the following notes should be observed:-

1. After use, release the heads of the peristaltic pumps (N1 and N2) by pivoting the clamp on the pump head upwards and backwards on either side to the upright position. This takes the pressure off the flexible tubing and will prolong the life of the tubing.

2. Disconnect the equipment from the electrical supply when not in use.

3. When not in use for an extended period, drain all water from the equipment.

4. After prolonged use (or shorter if hard water is used) it will be necessary to manually clean the plates of the heat exchanger to remove scale which will effect heat transfer in the exchanger. Ensure that the exchanger is reassembled in the correct order. It may be necessary to re-tighten the nuts on the heat exchanger for the first few runs after reassembling the exchanger.

5. In areas of hard water, the amount of scale in the heat exchanger can be reduced by fitting a de-ioniser in-line with the water supply to the equipment.

6. To reduce the amount of scale and algae growth in the hot water tank it is suggested that de-ionised water containing a suitable biocide is used to fill the tank. Refer to local regulations for information on suitable biocides.

7. The life of the flexible tubing used in the peristaltic pump heads can be extended by moving the tubing through the pump head to an unused section at regular intervals.

When replacement of the flexible tubing is necessary it is important to ensure that the replacement tubing is compatible as follows:

Feed Pump

<table>
<thead>
<tr>
<th>Material</th>
<th>Silicon Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall thickness</td>
<td>1.6mm</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>3.2mm</td>
</tr>
</tbody>
</table>

Water Pump

<table>
<thead>
<tr>
<th>Material</th>
<th>Silicon Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall thickness</td>
<td>1.6mm</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>4.8mm</td>
</tr>
</tbody>
</table>

General connections on Process Plant Trainer

<table>
<thead>
<tr>
<th>Material</th>
<th>Silicon Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall thickness</td>
<td>1.6mm</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>8.0mm</td>
</tr>
</tbody>
</table>

Note: Before attempting to replace the flexible tubing in either peristaltic pump head, ensure that the control console has been disconnected from the electrical supply to prevent inadvertent rotation of the rollers.
Both peristaltic pump heads have a lifting clamp on the pump head for fitting the flexible tubing.

Before installing the flexible tubing ensure that the adjusters on either side of the pump head (at the bottom) have been set to the diameter of tube in use. (The standard tubing supplied has a bore of 3.2mm in the feed pump and 4.8mm in the water pump so the indicator must align with the 3.2 mark or 4.8 mark as appropriate when the head is unclamped.) To install or replace the flexible tubing lift the clamp (on the top of the pump head) upwards and backwards to expose the rotor. Load the tubing into the slot between the rotor and pump head then close the pump head by pushing the clamp forwards and downwards. The clamp will click shut. The tube will retain its elasticity for many hours of use but there is sufficient length to allow the tube to be moved to other positions of less wear. It is essential to release the clamp when the equipment is not being used to prevent permanent deformation of the tube.

8. At regular intervals it will be necessary to clean the inline filter (7) located adjacent to the flow sensor. Remove the filter (7) from the equipment and clean by flushing with clean water flowing in the opposite direction to normal flow. The frequency of cleaning will depend on the cleanliness of the water supply.
10. FAULT FINDING

If the equipment does not function correctly it is suggested that the following checks are carried out.

NOTE: Copies of the wiring diagrams are included on pages 34 and 36 of this manual to assist in tracing any electrical fault. However, any electrical work inside the electrical console must only be carried out by a competent electrician.

The DC and signal fault simulator on the side of the control console should be checked to see that all switches are in the up position before attempting to diagnose faults in the equipment.

1) **RCCB (ELCB)**

   Ensure that the Residual Current Circuit Breaker is latched.

   If the RCCB trips in operation or fails to latch, then a fault is indicated inside the electrical console or in the electrical equipment installed on the PCT23.

   This fault condition could be dangerous to the operator and the equipment should not be operated until checked by a competent electrician.

2) **MCBs**

   Ensure that all three Miniature Circuit Breakers are latched.

   If one or more MCBs trip in operation of fails to latch, then a fault is indicated inside the electrical console or in the electrical equipment installed on the PCT23.

   The left hand MCB protects the element of the heater, the middle MCB protects the rest of the console, and the right hand MCB protects the 240Vac mains outlet socket at the rear of the electrical console.

3) **ELECTRICAL SUPPLY**

   Ensure that the Liquid Crystal Display associated with the instrumentation operates when the mains switch is switched on.

   If the display is not illuminated, check that an electrical supply of an appropriate voltage is connected to the console, and that the supply is switched on.

4) **POWER SUPPLY**

   If the above checks confirm that the console is connected to an appropriate electrical supply, then the fault is likely to be in the dc power supply located inside the console.

   NOTE: The dc power supply incorporates a fuse to protect the mains supply. This should be replaced with a fuse of appropriate rating as follows:

   Fuse type QuickBlow (F), 20mm x 5mm diameter, 2 amps.

5) **CONNECTIONS BETWEEN CONSOLE AND PROCESS UNIT**

   Ensure that connections are made in accordance with section 6 (Assembly).
6) **GENERAL CONSOLE FUNCTIONS**

If any of the console functions appears to malfunction, firstly check that the selector switch is set to the correct position.

**MANUAL**

The appropriate controlled variable is adjusted via the front panel control, eg. motor speed is varied by rotating the multi-turn potentiometer.

**INPUT SOCKET**

The appropriate controlled variable is adjusted by a 0-5Vdc signal applied to the red and black sockets on the front panel, eg. PID control of the heater element using a PCT20H.

**ON/OFF**

The appropriate controlled variable is switched on or off by a switched input connected to the yellow sockets on the front panel.

**I/O PORT**

The appropriate controlled variable is adjusted by a 0-5Vdc signal connected to the I/O port at the rear of the console, eg. control using a PC microcomputer.

7) **FOR EACH CONSOLE FUNCTION**

Ensure that the toggle switch is in the ‘ON’ position.

If using the red and black input sockets for connection to a PID controller, ensure that the selector switch is set to INPUT SOCKET, and that the input signal is within the range 0-5Vdc.

If using the yellow input On/Off sockets for connection to an On/Off controller (such as the relay output of a PCT20H) ensure that the selector switch is in the ON/OFF position and that the multi-turn potentiometer has been set to give the required level of power, flow etc. during the ON phase.

8) **HEATER**

The LOW LEVEL warning is activated by a float switch in the hot water vessel. If this switch is not covered, then the power is disconnected from this console function. Power is re-established automatically when the level is restored.

The OVER TEMP warning is activated by an adjustable thermostat mounted in the heater tank. If the temperature of the water exceeds this setting, then the power is disconnected from this console function. Power is re-established automatically when the temperature of the water falls below the setting.

9) **TEMPERATURES**

The top selector switch can be used to indicate the required temperature on the liquid crystal display.

If any temperature reading is not sensible, check that the temperature sensor is connected to the rear of the console. Connection is made using a special 2-way plug. A faulty temperature sensor can be checked by substituting an alternative. If the reading is corrected, then the original sensor is faulty. If the error continues, then the calibration of the thermocouple should be checked.
The first selector switch determines which temperature is output to the top set of red and black output sockets. The bottom set of sockets is permanently wired to temperature T1. These sockets output 0-5Vdc equating to 0-150°Celsius.

10) **OPERATION IN CONJUNCTION WITH A COMPUTER**

Ensure that the USB connection is made between the computer and the console, and that the power and active LEDs on the rear of the console are illuminated. If they are not, the connection should be broken for about 30 seconds, then re-made. If the LEDs still do not illuminate, the computer should be restarted.

Ensure that the function switches on the front of the electrical console are set to the I/O PORT position where required.

11) **POSITION OF VALVES**

The valves have the following positions when in the OFF state:

- SOL1 Divert Valve Diverting
- SOL2 Feed Selector Feed from tank A
- SOL3 Cold Water to Exchanger Off
- SOL4 Tank A Fill Off
- SOL5 Tank B Fill Off

Check that the cold water drain, diverted product drain and the finished product output are connected to suitable drains or receptacles.

In manual operation, be aware that SOL4 (tank A fill) and SOL5 (tank B fill) will continue to supply water until switched off, and that there is a risk of overflow.
11. USING NON-ARMFIELD CONTROLLERS/SOFTWARE

11.1 I/O Port Signal Connections - Non-Armfield Controllers

The I/O Port at the rear of the Electrical Console allows direct connection of appropriate control or data logging equipment (eg. PCT19BR PLC) simply by using the 50 way IDC ribbon cable supplied.

Where it is required to use the PCT23 Process Plant Trainer in conjunction with other control or data logging equipment, it will be necessary to terminate the connections in a suitable 50 way IDC connector (standard density, IDC 0.05 inch cable pitch, female socket) to suit the I/O Port at the rear of the console. The following list summarises the connections to the 50 way I/O Port on to allow such terminations to be made.

**NOTE:** The various signals may be defined as Inputs or Outputs. In all instances, the type of signal is defined at the control or data logging hardware at the free end of the ribbon cable which is connected to the I/O Port at the rear of the console.

Eg. Level L1 on channel 1 is an Analog Input (0-5Vdc for a change in level of 0-250mm) to a PLC connected to the I/O Port.

<table>
<thead>
<tr>
<th>PIN NO</th>
<th>CHANNEL NO</th>
<th>SIGNAL FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Inputs: (0-5Vdc):</td>
<td></td>
<td>AD - O - F</td>
</tr>
<tr>
<td>1</td>
<td>Ch 0 signal</td>
<td>L1   Tank A Level (0-250mm)</td>
</tr>
<tr>
<td>2</td>
<td>Ch 0 return</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ch 1 signal</td>
<td>F1   Feed Flow (0-500 ml/min)</td>
</tr>
<tr>
<td>4</td>
<td>Ch1 return</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Ch 2 signal</td>
<td>PWR  Heater Power (0-2kW)</td>
</tr>
<tr>
<td>6</td>
<td>Ch 2 return</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Ch 3 signal</td>
<td>T1   Holding Temperature (0-150°C)</td>
</tr>
<tr>
<td>8</td>
<td>Ch 3 return</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Ch 4 signal</td>
<td>T2   Hot Water Temperature (0-150°C)</td>
</tr>
<tr>
<td>10</td>
<td>Ch 4 return</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Ch 5 signal</td>
<td>T3   Product Exit Temperature (0-150°C)</td>
</tr>
<tr>
<td>12</td>
<td>Ch 5 return</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Ch 6 signal</td>
<td>T4   Heated Feed Exit Temperature (0-150°C)</td>
</tr>
<tr>
<td>14</td>
<td>Ch 6 return</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Ch 7 signal</td>
<td>C1   Product Conductivity (0-200 mS/cm)</td>
</tr>
<tr>
<td>16</td>
<td>Ch 7 return</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Not used</td>
<td></td>
</tr>
</tbody>
</table>
**Analog Outputs: (0-5Vdc):**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch 0</td>
<td>Feed Pump Speed (0-100%)</td>
</tr>
<tr>
<td>Ch 1</td>
<td>Heating Pump Speed (0-100%)</td>
</tr>
</tbody>
</table>

**Digital Inputs: (0-5Vdc):**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch 0</td>
<td>Digital Ground</td>
</tr>
<tr>
<td>Ch 1</td>
<td>Divert Valve Position</td>
</tr>
<tr>
<td>Ch 2</td>
<td>Hot Water Over Temperature</td>
</tr>
<tr>
<td>Ch 3</td>
<td>Tank B Low Level</td>
</tr>
<tr>
<td>Ch 4</td>
<td>Tank B High Level</td>
</tr>
<tr>
<td>Ch 5</td>
<td>Feed pump Switch detect</td>
</tr>
<tr>
<td>Ch 6</td>
<td>Water Pump Switch Detect</td>
</tr>
<tr>
<td>Ch 7</td>
<td>Water Heater Switch Detect</td>
</tr>
<tr>
<td>Ch 8</td>
<td>Valve Control Switch Detect</td>
</tr>
</tbody>
</table>

**Digital Outputs: (0-5Vdc):**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch 0</td>
<td>Heater Control Clock Line</td>
</tr>
<tr>
<td>Ch 1</td>
<td>Heater Control Bit Line</td>
</tr>
<tr>
<td>Ch 2</td>
<td>Heater Control Load Line</td>
</tr>
<tr>
<td>Ch 3</td>
<td>Divert Valve (Divert Normal)</td>
</tr>
<tr>
<td>Ch 4</td>
<td>Feed Select Valve (Tank A Normal)</td>
</tr>
<tr>
<td>Ch 5</td>
<td>Cold Water Valve (Closed Normal)</td>
</tr>
<tr>
<td>Ch 6</td>
<td>Tank A Fill Valve (Closed Normal)</td>
</tr>
<tr>
<td>Ch 7</td>
<td>Tank B Fill Valve (Closed Normal)</td>
</tr>
<tr>
<td>Ch 8</td>
<td>Digital Ground</td>
</tr>
<tr>
<td>Ch 9</td>
<td>Not used</td>
</tr>
<tr>
<td>Ch 10</td>
<td>Not used</td>
</tr>
<tr>
<td>Ch 11</td>
<td>Not used</td>
</tr>
<tr>
<td>Ch 12</td>
<td>Not used</td>
</tr>
</tbody>
</table>
11.2 Power to Heater

Since the two analogue outputs channels are used to control the speed of the two peristaltic pumps, the heater circuit incorporates a digital to analogue converter (DAC) which can be driven by digital signals to provide a voltage power output. Contact Armfield for details of the signals required to drive this DAC.

The console must receive logic signals of TTL compatible level.
12. FAULT INSERTION

The fault insertion unit is situated on the side of the console.

12.1 Signal Faults

Analogue Signal Fault Switches in the fault insertion unit are assigned as follows:

<table>
<thead>
<tr>
<th>Switch Name</th>
<th>Function Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWITCH CENTRAL</td>
<td>Signal broken, down scale (0Vdc permanent)</td>
</tr>
<tr>
<td>SWITCH DOWN</td>
<td>Signal broken, up scale (1.5-5Vdc permanent)</td>
</tr>
<tr>
<td>SWITCH UP</td>
<td>Signal connected (0-5Vdc from process)</td>
</tr>
</tbody>
</table>

**Switch No** | **Signal Function**
---|---
1 | L1 | Level, Tank A (0-250mm)
2 | F1 | Feed Flow (0-500ml/min)
3 | T1 | Holding Temperature (0-150°C)
4 | T2 | Hot Water Temperature (0-150°C)
5 | T3 | Product Exit Temperature
6 | T4 | Heated Feed Exit Temperature (0-150°C)
7 | T5 | User Defined Temperature (0-150°C)
8 | -  | Not used

**Analog Signals:**

**Digital Signals:**

1 | STAT | Over-temperature Thermostat, Heating Tank
2 | LVL  | Low Level Switch, Heating Tank
3 | LL   | Low Level Switch, Tank B
4 | HL   | High Level Switch, Tank B
### 12.2 DC Faults

DC Fault Switches are assigned as follows:

<table>
<thead>
<tr>
<th>Switch No</th>
<th>Signal Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N1</td>
</tr>
<tr>
<td>2</td>
<td>N2</td>
</tr>
<tr>
<td>3</td>
<td>SOL1</td>
</tr>
<tr>
<td>4</td>
<td>SOL2</td>
</tr>
<tr>
<td>5</td>
<td>SOL3</td>
</tr>
<tr>
<td>6</td>
<td>SOL4</td>
</tr>
<tr>
<td>7</td>
<td>SOL5</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
</tr>
</tbody>
</table>

Supply broken

Supply connected (24Vdc to process)
13. OPERATIONAL PROCEDURES

13.1 Initial Set-up of the PCT23-MKII

Connections

Ensure that the following connections are made between the rear of the Process Unit and the rear of the Control Console:

1. Heater lead to socket marked ‘HEATERS’ on Console
2. Process lead to socket marked ‘PROCESS’ on console
3. Thermocouple leads to appropriate sockets

Process Unit

Ensure that the hot water tank is filled with water to a level at least 10mm above the central heating element.

Ensure that the pump heads on the hot water pump and feed pump have been clamped onto the flexible tubing by pivoting the clamp on the pump head forwards and downwards.

Ensure that flexible tubing is fitted to the outlet connections for diverted product, finished product and cooling water. The flexible tubing should be directed to a suitable drain or receptacle (or returned to the appropriate feed tank if no cold water supply is available).

Connect a cold water supply to the inlet at the rear, adjacent to pressure reducing valve PRV1.

Note: Do not adjust pressure reducing valve PRV1 unless instructed to later. Only adjust valve V1 to change the flow of cold water.

Ensure that valve V2 (between the feed tanks) and drain valve V3 in tank B are closed. Fill the front tank (tank A) by opening solenoid valve SOL4 (Switch Valve Control ‘ON’ then set switch SOL4 to FILL A). If necessary adjust the flow into tank A using valve V1.

Note: In operation, the tank must not be allowed to run dry or overflow.

Most (but not all) of the training exercises can be performed if a continuous supply of clean water is not available by filling the feed tanks using a suitable container. To reduce the frequency of filling, the water exiting the process can be returned to the appropriate feed tank. Alternatively, both feed tanks can be used in parallel by opening valve V2 beneath the tanks.

Initial Settings on PCT23-MKII Console

Before adjusting the controls on the console to suit a particular training exercise of other application, set all controls to the safe default position as follows:

- RCCB and all circuit breakers ON (switches up)
- Power switch ON
- All black function switches set to MANUAL
- All control potentiometers set to zero (fully anticlockwise)
All Valve Controls set as follows:
SOL1 to ‘DIVERT’
SOL2 to ‘TANK A’
SOL3 to ‘STOP’
SOL4 to ‘TOP’
SOL5 to ‘STOP’

13.2 USE OF QUICK RELEASE FITTINGS

Quick release fittings are used on the equipment for convenience when changing the configuration or removing items for cleaning. The diagrams below show the simple operation of these fittings:

- To connect to a quick release fitting

Align the parallel section of the rigid tube with the loose collet on the quick release fitting and push firmly until the tube stops.

An 'O' ring inside the fitting provides a leak-proof seal between the tube and the fitting. The collet grips the tube and prevents it from being pulled out from the fitting.

- To disconnect from a quick release fitting

Push the loose collet against the body of the quick release fitting while pulling the tube firmly. The tube will slide out from the fitting. The tube/fitting can be assembled and disassembled repeatedly without damage.
13.3 Manual Operation of the PCT23

The PCT23 is designed to allow operation of the entire process plant using the controls on the electrical console. For manual operation of the process these controls should be used as follows:

**WATER PUMP (Hot water circulation)**

Set the WATER PUMP function selector switch to MANUAL.

Switch the water pump ON.

Adjust the speed control potentiometer to 4.00 (unless otherwise instructed) to operate the peristaltic hot water circulating pump.

**WATER HEATER (Hot water tank heating elements)**

Set the WATER HEATER function selector switch to MANUAL.

Switch the water heater ON.

Adjust the power control potentiometer to 4.00 (unless otherwise instructed) to power the heating elements in the hot water tank. The actual power (PWR) is indicated on the liquid crystal meter above the potentiometer.

**Note:** If either of the red warning LEDs is illuminated the power to the heating elements will be automatically set to zero.

**FEED PUMP (Product feed)**

Set the FEED PUMP function selector switch to MANUAL.

Switch the feed pump ON.

Adjust the speed potentiometer to 4.00 (unless otherwise instructed) to operate the peristaltic feed pump.

**Note:** Actual product flowrate is measured by flow sensor F1 (see below).

**PROCESS (Temperatures)**

Select the required temperature (T1-T4) to be measured using the selector switch. The appropriate temperature is indicated on the liquid crystal meter above the selector switch.

0-5Vdc outputs for T1 only or T1-T5 via the second selector switch may be connected to a suitable controller, recorder etc.

**Note:** For T1-T4, 5Vdc = 150°C.

**LEVEL/FLOW**

Select L1 or F1 as required using the selector switch. The level (L1) in tank A or feed flow (F1) is indicated on the liquid crystal meter above the selector switch.

0-5Vdc outputs for L1 and F1 may be connected to a suitable controller, recorder etc.

**Note:** For L1, 5Vdc = 250mm. For F1, 5Vdc = 1500 ml/min.

**VALVE CONTROL (Solenoid valves)**

Set the VALVE CONTROL function selector switch to MANUAL.
Each of the five solenoid valves can be opened or closed manually by operating the appropriate switch, e.g. Set switch SOL4 to FILL A – water will be admitted to tank A provided that a cold water supply is connected.

13.4 PCT23 With ON/OFF Control
Yellow banana sockets are provided on the following functions of the PCT23 Console to allow on/off control (or time proportioned control where appropriate) using an industrial controller with relay output, industrial PLC with relay output or simple switch:

**FEED PUMP (Product circulation)**
Connect the external switch/relay contact to the Feed Pump yellow banana sockets
Set the Feed Pump function switch to ON/OFF CONTROL
Set the Feed Pump speed control potentiometer to give the required pump speed (N1) when the external contact is made
Switch the feed pump ON

**WATER PUMP (Hot water circulation)**
Connect the external switch/relay contact to the Water Pump yellow banana sockets
Set the Water Pump function switch to ON/OFF CONTROL
Set the Water Pump speed control potentiometer to five the required pump speed (N2) when the external contact is made
Switch the water pump ON

**HEATER POWER**
Connect the external switch/relay contact to the Heater Power yellow banana sockets
Set the heater Power function switch to ON/OFF CONTROL
Set the power control potentiometer to give the required heater power (PWR) when the external contact is made
Switch the heater ON

**VALVE CONTROL SOL1 (Product divert valve)**
Connect the external switch/relay contact to the SOL1 yellow banana sockets
Set the Valve Control function switch to MANUAL
Set switch SOL1 to DIVERT
The product will stop diverting when the external switch contact is made

**VALVE CONTROL SOL2 (Feed tank select)**
Connect the external switch/relay contact to the SOL2 yellow banana sockets
Set the Valve Control function switch to MANUAL
Set switch SOL2 to FEED A
Tank B will feed the circulating pump when the external switch contact is made
VALVE CONTROL SOL3 (Cooling water flow)
Connect the external switch/relay contact to the SOL3 yellow banana sockets
Set the Valve Control function switch to MANUAL
Set switch SOL3 to STOP
Cooling water will flow through the heat exchanger when the external switch contact is made (if cold water supply is connected)

VALVE CONTROL SOL4 (Fill Tank A)
Connect the external switch/relay contact to the SOL4 yellow banana sockets
Set the Valve Control function switch to MANUAL
Set switch SOL4 to FILL A
Tank A will fill when the external switch contact is made (if cold water supply is connected)

VALVE CONTROL SOL5 (Fill Tank B)
Connect the external switch/relay contact to the SOL5 yellow banana sockets
Set the Valve Control function switch to MANUAL.
Set switch SOL5 to FILL B
Tank B will fill when the external switch contact is made (if cold water supply is connected)

If using the Armfield Industrial Controller PCT20H, ensure that the following connections are made between the PCT20H and PCT23 Console:

1. Mains lead at rear of PCT20H to mains outlet socket at rear of PCT23 Console.
2. Appropriate red and black 0-5V OUTPUT sockets (eg. T1) on PCT23 Console to red and black ANALOG INPUT 1 0-5V sockets on PCT20H (using red and black banana leads).
   Set selector switch on PCT20H INPUT 1 to 0-5V/1-5V position.
3. Yellow N/O RELAY OUTPUT sockets on PCT20H to appropriate yellow sockets on PCT23 function listed above (using yellow banana leads).

**Note:** PCT20H must be configured for on/off control with relay output or PID control with time-proportioned relay output as required. Refer to the PCT20H Instruction Manual if further information on configuration is required.

Switch on the controller by pressing the switch/beaker on front of PCT20H.
The controller will initially be in manual operation (MAN indicated).
Adjust the setpoint on PCT20H to a suitable value, e.g. 50°C, then press the Auto/Man button to select automatic operation (A indicated).
13.5 PCT23 with Industrial PID Controller or Industrial PLC

Red and black sockets are provided on the following functions of the PCT23 Console to allow proportional (PID) control using an external industrial controller or industrial PLC with 0-5Vdc output:

**Feed Pump (Product circulation)**

Connect the external 0-5Vdc OUTPUT to the Feed Pump red and black 0-5V INPUT banana sockets.

Set the Feed Pump function switch to INPUT SOCKET.

Switch the feed pump ON.

The speed of the Feed pump (N1) will vary with the signal from the external controller.

**Water Pump (Hot water circulation)**

Connect the external 0-5Vdc OUTPUT to the Water Pump red and black 0-5V INPUT banana sockets.

Set the Water Pump function switch to INPUT SOCKET.

Switch the water pump ON.

The speed of the Water pump (N2) will vary with the signal from the external controller.

**Heater Power**

Connect the external 0-5Vdc OUTPUT to the Heater Power red and black 0-5V INPUT banana sockets.

Set the Heater Power function switch to INPUT SOCKET.

Switch the heater ON.

The power to the heaters (PWR) will vary with the signal from the external controller.

If using the Armfield Industrial Controller PCT20H, ensure that the following connections are made between the PCT20H and PCT20 Console:

1. Mains lead at rear of PCT20H to mains outlet socket at rear of PCT23 Console.

2. Appropriate red and black 0-5V OUTPUT sockets (eg. T1) on PCT23 Console to red and black ANALOG INPUT 1 0-5V sockets on PCT20H (using red and black banana leads).

   Set selector switch on PCT20H INPUT 1 to 0-5V/1-5V position.

3. Red and black ANALOG OUTPUT 0-5V sockets on PCT20H to appropriate red and black 0-5V INPUT sockets on PCT23 Console (using red and black banana leads).

**Note:** PCT20H must be configured to suit the control demonstration and can be set up manually by pressing the buttons on the front of PCT20H. Alternatively it can be configured remotely using serial communications. Refer to the PCT20H Instruction Manual if further information on configuration is required.

Switch on the controller by pressing the switch/beaker on front of PCT20H.

The controller will initially be in manual operation (MAN indicated).
Adjust the setpoint on PCT20H to a suitable value, eg. 50°C, then press the Auto/Man button to select automatic operation (A indicated).

13.6 PCT23 with PC Software via USB Port

Connections

The Armfield PCT23 software must be installed on the PC.

Connect the socket marked USB at the rear of the PCT23-MKII Console to the USB port on the PC using the cable supplied.

Start with the PCT23-MKII Console set for manual operation with all function switches set to MANUAL and all potentiometers set to zero.

Using a PC to monitor the process

Run the Armfield software from the ‘Start’ menu. Choose ‘Exercise A’, which provides for PC data logging of the process variables.

Using a PC to control the process

Run the Armfield software from the ‘Start’ menu. At the initial menu select the required control loop(s) Set all function switches on the PCT23 Console to the I/O PORT position then switch the Water Pump, Water Heater and Feed Pump on as required.

The system will start with the controller in the software switched off, with all outputs to the process set to minimum.

Refer to the appropriate Practical Training Exercise (e.g. Exercise 7.1 for level control) for details on setting and using the software/controller.

13.7 PCT23 with Industrial PLC (PCT19BR) and SCADA Software

Ensure that the following connections are made between the PCT19BR, PCT23 Console and PC:

1. Mains lead at rear of PCT19BR to mains outlet socket at rear of PCT23 Console.
2. DC DIN connector at rear of PCT19BR to DC OUTPUT connector at rear of PCT23 Console using lead with DIN/DIN connectors.
3. DFI serial socket on PCT19BR (Communications module in slot 1 on PLC) to RS232 serial port connector at rear of PC using lead with female/female 9 pin ‘D’ type connectors.
4. Connect the socket marked ‘I/O PORT’ at the rear of the PCT23 Console to the socket marked ‘I/O PORT’ at the rear of the PCT19BR using the ribbon cable with 50 way IDC connectors. Ensure that the USB cable from the computer to the PCT23 console is NOT connected.
5. Connect a pair of yellow banana leads between Digital Outputs 1 on the PCT19BR and the ON/OFF Control sockets for the heater power on the PCT23 Console.
When using the PLC in conjunction with the Armfield software, ensure that the equipment/software is set up in the following sequence:

1. Switch on the PCT19BR by depressing the switch/breaker on the front panel. Ensure that the RUN LED is lit on PLC slot 0 and LED 3 alternates on PLC slot 2. (This indicates that the sequencing ladder program is running in the PLC.)

2. Run the PCT23 SCADA Software from the ‘Start’ menu.

3. Set all function switches on the PCT23 Console to the I/O PORT position then switch on the water pump, feed pump and heater (switch to ‘1’ position). Set the Heater Control to ON/OFF and ensure that the manual control dial for the heater is set to 10.

4. Configure then operate the sequence via the PC.

Refer to Practical Training Exercise 18 in this manual and/or the PCT19BR Instruction Manual for further information about using/programming the PLC.

13.8 Use of RS Logix 500 with Other Armfield Software/Hardware/Ladder

To allow serial communication when using other software/hardware:
When RSLogix has been loaded onto a PC it may prevent communication between the serial port on the PC and other hardware (E.g. PCT20H).
To restore communication with other hardware ensure that ‘RSLinx’ is not running (right-click the appropriate icon in the system tray and choose ‘shutdown server’). Also check that ‘RSI Directory’ is not running.

To allow reading and writing of data to a ladder:
Some programs (e.g. PCT23LL4.RSS supplied with PCT23SCADA) need to read and write data from/to the ladder running in PCT19BR. If the data file is protected then writing of data will not be possible. To allow writing of data to the ladder:
In the left hand window right-click on ‘Controller’ and choose ‘Properties’. Under ‘Compiler’ choose ‘None’ in the ‘Data File Protection’ box then Click ‘OK’.
Pull down the ‘Offline’ menu and choose ‘Download’. Switch the controller back to ‘Run mode’ when prompted.
14. INDEX TO PRACTICAL TRAINING EXERCISES

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EXERCISE 1.1 – PLANT MONITORING USING A PC

Objective
Gaining familiarity with computer-based mimic diagrams for monitoring process variables: level, temperatures, flows and power.

Equipment Required
PCT23 Process Plant Trainer
PC with Armfield PCT23 software installed.
Printer to suit PC (optional)

Equipment Set up
PCT23 commissioned with a supply of cold water connected.
Feed tanks A and B empty.
All controls on PCT23 Console set to manual operation and safe default positions.
USB port on console connected to that on PC (Refer to Operational Procedures 1, 2 and 5 if necessary).

Procedure
i. Run the PCT23 software (from the ‘start’ menu, look under ‘Armfield Process Control Software’) and choose Exercise A, for monitoring only.
ii. If necessary, read through the presentation and help screens to familiarise yourself with the software.
iii. View the Mimic Diagram, which shows a representation of the PCT23 process plant which includes:
   • Process components and connections.
   • Numerical values of measurement sensors, pump speed, heater power etc.
   • Animation of fluid flow through the plant and vessel contents.
   • Warnings about incorrect console/process operation.
   Using this screen the operation of the plant will be monitored.
   If a printer is connected to the PC, it is possible to print any screen in the software, using the ‘Print.’ command from the ‘File’ menu.
iv. Click on the ‘Start Sampling’ tool button [GO] to begin logging. Data is stored in tabular format within the program, and can be viewed using the ‘Table’ tool button at the top of the screen. Data is taken every 10 seconds, but this can be altered using the ‘Configure Sampling’ tool button.
v. At the control console set valve control switch SOL4 to FILL A (to open solenoid valve SOL4), as water fills the front feed tank (tank A) observe:
   The animated level in tank A rises
   The level is indicated as the value L1 in mm.
vi. When tank A has nearly filled (do not allow the tank to overflow) set valve control switch SOL4 to STOP.
Operate the Feed Pump (N1) on the console by turning the speed control potentiometer to 4.00. Observe:

The flowrate is displayed as the value F1 in ml/min
The animated level in tank A begins to fall

vii. Set the Feed Pump control to 8.00. Observe:

The flow rate F1 rises
The level in tank A falls faster

Switch off the Feed Pump (N1)

viii. Switch on the Water Heater. Set the power control potentiometer to 4.00. Observe:

Power PWR in Watts
Temperature T2 rises (°C)

Adjust the power control until a power of 1.00 kW is indicated on the schematic diagram (PWR).

ix. Set the Water Heater function switch to I/O PORT.

Observe that power is disconnected.

x. View the ‘Graph’ screen and configure the graph (click \( y = mx + c \)) to show L1, F1, T2, T3 and T4.

Here you will see a graphical representation of the process parameters listed above, updating whenever a sample is taken.

Make a change to the process and observe the effect displayed on the graph.

xi. Stop the data logging, using the [STOP] button.

Conclusions

A PC incorporating suitable interface and software can be used to monitor and log measurements from the process plant.

The information can be presented in different ways to suit the needs of the operator, eg. animated schematic diagram, real time graph, historical graph, tabular results etc.

Other software applications will be demonstrated in later training exercises to demonstrate how the PC can be used to control the process plant as well as providing the above monitoring facilities.
EXERCISE 1.2 – CALIBRATION OF SENSORS

Object
To calibrate the level sensor installed on the PCT23 Process Plant Trainer

Equipment Required
PCT23 Process Plant Trainer
PC with Armfield software installed (optional).
Chart recorder with 0-5V input (if PC is not available).

Equipment Set-up
PCT23 commissioned with cold water supply connected.
Feed tank A empty.
All controls on PCT23 console set to manual operation and safe default positions (refer to Operational Procedures 1, 2 if necessary).

Procedure
Level in tank A is measured using a pressure sensor which is connected to a tapping in the base of the tank. The pressure measurement circuit incorporates zero and span calibration potentiometers on the front panel of the control console.
Set the selector switch to LEVEL on the PCT23 console to indicate the level of water in tank A in mm.

Empty tank A.
Adjust the zero potentiometer on the console until the reading on the LCD meter is 0 mm. If using the PC, check that the reading for L1 is consistent. If there is any difference, the software calibration routine can be used to adjust the PC reading (see software help for details).
Fill tank A with water until the level is approximately 200 mm. Adjust the span potentiometer on the console to give the correct reading on the LCD display. Check, and if necessary, adjust the PC reading.
Repeat the zero and span adjustments (to drain tank A quickly, open valve V2 between tanks A and B then drain the contents by opening valve V3 in the base of tank B). Leave tank A filled ready for calibration of the flow sensor.
Any discrepancies between the power readings on the console and the PC can be removed using the software calibration routine (for details, see the software help text).
It is not possible for the student to calibrate the console reading for any of the other sensors on the PCT23. For calibration of other sensors see the routine maintenance section. However, it is possible for students to check, and if necessary, adjust the software calibration using the method detailed in the software help text.

Conclusions
The readings from electronic sensors used to monitor/control industrial processes can be checked using suitable calibration/test equipment.

The PC software can be calibrated independently using its own routine.
EXERCISE 2.1 – PROCESS DYNAMICS I – STEADY STATE OPERATION

Object
Introducing a first order system and the achievement of steady state by investigating the hot water tank characteristics (observing the effect of constant direct heating on the temperature in the hot water tank).

Equipment required
PCT23 Process Plant Trainer
PC with Armfield software installed (optional).
Chart recorder with 0-5 input (if PC is not available).

Equipment Set-up
PCT23 commissioned with cold water supply connected and all process outlet connections to drain.

All controls on PCT23 Console set to manual operation and safe default positions. Refer to OPERATIONAL PROCEDURES 1, 2 and 5 if necessary.

If using the computer to monitor the performance, check that the USB port on PCT23 Console is connected to that on the PC. Run the PCT23 software and choose Exercise A.

If using a chart recorder to monitor performance set the lower PROCESS TEMPERATURE selector switch to ‘T2’ and connect the banana sockets to the chart recorder (5Vdc = 150°C).

If neither is available, set the top PROCESS TEMPERATURE selector switch to ‘T2’ and read the temperature T2 directly from the console. (Note the reading at regular intervals of time.)

Procedure
i. Set Water Pump speed control to 5.00. (This establishes a steady flow of water through the hot water tank to promote mixing.)

ii. Set Water Heater power control to 4.00. (This establishes a constant power input into the hot water tank.)

iii. Monitor the change of the temperature inside the tank, T2, using the PC, chart recorder or direct readings as appropriate.

iv. Once T2 reaches 60°C, set the Water Heater control to 1.0 and allow the hot water tank to cool.

Note: If allowed to continue at this power input the water will continue to heat until the protection thermostat in the hot water tank trips.

v. Continue to monitor T2 as the contents of the hot water tank cools to a reduced constant temperature (achieves steady state).

Conclusions
Theoretically, the graph of T2 against time should be a straight line when the tank is heating. Compare the observed graph to that predicted and explain any differences.

The concept of steady state has been introduced.
Observe that the graph of temperature against time is an exponential decay when the tank cools to a new steady state.

Exercise 2.2 should be carried out on the completion of this exercise.
EXERCISE 2.2 – PROCESS DYNAMICS I – INDIRECT HEAT EXCHANGE

Object
Demonstrating indirect heating using a plate heat exchanger.

Equipment Required
As Exercise 2.1.

Equipment Set-up
As set on completion of Exercise 2.1.

Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

Procedure

i. Set water pump speed control to 8.00.
   Set water heater power control to 2.5.
   Set feed pump speed control to 4.00.
   (These settings establish a constant power input into the directly heated hot water tank and a constant load - cold feed heated indirectly by hot water circulated through the plate heat exchanger.

ii. Monitor T2 (temperature in the hot water tank) and T4 (temperature of feed leaving the heat exchanger) again using the PC, chart recorder or direct readings as appropriate.
   Continue to monitor T4 and T2 until the temperatures have stabilised (the system has reached steady state).

iii. When steady state is achieved, disturb the system by setting the feed pump speed control to 8.00 to double the feed flow rate. (This is a step change to the system.)

iv. Monitor T4 and T2 until the system once again reaches steady state. Observe that T4 and T2 both reduce.

   Note: If using a PC increasing the time scale of the graph and reducing the temperature scale will improve the visual impact of the step change response.

Conclusions
The concept of the step change has been introduced.

The heat exchanger allows cold feed liquid to be heated indirectly by hot water circulating through it.

The graph of temperature against time resulting from the step change should be an exponential decay (if the graph does not appear as such try changing the axes as described above).

Comment on the results obtained.

Exercise 2.3 should be carried out on the completion of this exercise.
EXERCISE 2.3 – PROCESS DYNAMICS I – DEAD TIME

Object
This exercise demonstrates the phenomenon of dead time.

In this exercise using FCT23, the dead time is the time taken for a particle of fluid to flow through the holding tube from the bottom to the top.

Equipment Required
As Exercise 2.1.

Equipment Set-up
As set on completion of Exercise 2.2.

Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

Procedure
i. Maintain the steady state conditions achieved at the end of Exercise 2.2 (i.e. water pump speed control set at 8.00, feed pump speed control set at 8.00 and water heater power control set at 2.50.

ii. Monitor temperature T4 (bottom of the holding tube) and T1 (top of the holding tube) as before. After confirming that the temperatures are constant set the feed pump speed control to 2.0 (quartering the product flow rate).

iii. From the responses obtained determine the time lag between the responses at T4 and T1 to the step change. This is the dead time causing by the holding tube. The dead time can be predicted by using the relationship:

\[
\text{Dead time} = \frac{\text{Volume of holding tube}}{\text{Feed pump flow rate, F1}}
\]

Where the volume of PCT23 holding tube is 82 cm³.

iv. Calculate the theoretical dead time from the above relationship then compare the value obtained with the previous result obtained from the graphical result.

v. Set the water heater power control to zero.

Conclusions
Any change in temperature in the fluid entering the bottom of the holding tube cannot be detected at the top of the holding tube until the fluid affected by the change appears at the top of the tube. This delay is called the dead time.

Comment on any discrepancies between the two different methods of determining the dead time.

The presence of dead time is a system can be an unwelcome complication when attempting to control the system accurately. However, in processes such as Pasteurisation dead time is vital to achieve the objectives of the process. Discuss this conflict between Process and Control requirements.

Exercise 2.4 should be carried out on the completion of this exercise.
EXERCISE 2.4 – PROCESS DYNAMICS I – STEP CHANGES

Object
Measuring the response of a system (the plate heat exchanger) to step changes.

Equipment Required
As Exercise 2.1.

Equipment Set-up
As set on completion of Exercise 2.3.
Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

Procedure

i. Following Exercise 2.3 allow the temperature in the hot water tank, T2, to return to below 50°C.

ii. Set water pump speed control to 8.00.
    Set water heater control potentiometer to 2.50.
    Set feed pump control potentiometer to 4.00.
    (These settings establish a constant power input into the hot water tank and a constant load - cold feed heated indirectly by hot water circulated through the plate heat exchanger.)

iii. Monitor temperatures T1, T2 and T4 as they climb then settle at constant values (using the PC, chart recorder or directly from the console readout). When the temperatures stabilise, the process has reached steady state.

iv. Once steady state is achieved, apply a step change to disturb the system by setting the water pump speed control to 2.00 (decreasing the flow of hot water through the exchanger).

v. Monitor the resulting changes in T1, T2 and T4.

Note: Increasing the time scale of the graph and reducing the temperature scale will improve the visual impact of the step change responses.

Conclusions
Cold feed liquid is heated indirectly by the plate heat exchanger.

Temperature of the feed at the exit from the exchanger (T4) depends on other parameters relating to the system, eg. feed flowrate, hot water temperature, hot water flowrate etc.

Exercise 2.5 will introduce measurement of heat transfer in the plate heat exchanger.
EXERCISE 2.5 – PROCESS DYNAMICS I – HEAT TRANSFER LOSSES

Object
To calculate heat transfer losses for the system.

Equipment Required
PCT23 Process Plant Trainer.
PC with Armfield software installed (optional).
Chart recorder with 0-5V input (if PC is not available).

Equipment Set-up
PCT23 commissioned with cod water supply connected and all process outlet connections to drain.
All controls on PCT23 Console set to manual operation and safe default positions.
Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).
If using the PC to monitor the performance, check that the USB port on the PCT23 Console is connected to that on the PC (Refer to Operational Procedures 1, 2 and 5 if necessary).

Procedure
i. Measure the temperature of the water in the feed tank by removing one of the thermocouples (e.g. T3) from its housing and immersing it in the fluid.
ii. Set the two pumps to 50% and set the heater power to 25%. Ensure that the system is in steady state, then record the heat input to hot water tank (PWR).
iii. Record the temperature difference across the holding tube (T1-T4).
iv. Record the temperature difference across the product side of the heat exchanger (T4-T0).
v. Record the flow of product F1.
vi. Calculate heat input to product stream
\[ Q_{product} = M_{product} \times SHC \times (T4 - T0) \text{ kW} \]
where \[ M_{product} = F1 \times \rho \] (assume \( \rho = 1000 \text{ kg/m}^3 \))
vii. Calculate heat losses in the process
\[ \text{Between hot tank and product} \quad \text{PWR} - Q_{product} \text{ kW} \]
\[ \text{In holding tube} \quad M_{product} \times SHC \times (T1 - T4) \text{ kW} \]

Conclusions
Any operation involving heat transfer is subject to heat loss. In the case of PCT23:
Heat input to the hot water tank is significantly larger than heat gained by the product stream (large losses from tank and pipework).
Heat is lost while product travels through the holding tube (small loss even though pipework is lagged).
EXERCISE 3.1 – PROCESS DYNAMICS II – INTERACTION

Object
Demonstrating the interaction between different loops in the system.
Understanding how changing one process variable (e.g. flow rate) affects all the others (e.g. temperatures).
The feed flow loop and the heating water loop will be demonstrated.

Equipment Required
PCT23 Process Plant Trainer.
PC with Armfield software installed (optional).
Chart recorder with 0-5V input (if PC is not available).

Equipment Set-up
PCT23 commissioned with cold water supply connected an all process outlet connections to drain.
All controls on PCT23 console set to manual operation.
Ensure that tank A is filled with cold water.
Set controls initially on PCT23 as follows:
- Water pump switched on and speed control set to 5.00.
- Water heater switched on and power control set to 2.00.
- Feed pump switched on and speed control set to 8.00.
- Valve control switches set to default positions.

If using the PC to monitor the performance check that the USB port on PCT23 console is connected to that on the PC.
Refer to Operational Procedures 1, 2 and 5 if necessary.

Procedure
i. Allow the process to stabilise with the settings listed above.
ii. Change the feed pump speed control to 4.00. Allow the system to return to a new steady state.
iii. Observe the direct result of this change on T1 and T4.
iv. Observe the indirect result of this change on T2.

Conclusions
T1 and T4 are both in the same ‘loop’. A change in feed pump speed (flowrate F1) has a direct effect on these temperatures - increasing flow reduces outlet temperatures.
Although the hot water flow is in a separate ‘loop’ and not directly affected by a change in feed pump speed, the heat transferred in the exchanger indirectly affects hot water temperature T2.
Are there any variables not affected by the selected step change? Discuss the reasons.
Perform a trial to prove your assumptions.
Exercise 3.2 should be carried out on the completion of this exercise.
EXERCISE 3.2 – PROCESS DYNAMICS II – HEAT REGENERATION

Object

From both environmental and economic viewpoints, recycling or regeneration of energy within the process is desirable.

The heat exchanger on PCT23 is equipped with a regeneration section where incoming cold feed is preheated by outgoing hot product.

Equipment Required

As Exercise 3.1.

Equipment Set-up

As set on completion of Exercise 4.1

Procedure

i. Maintain the steady state achieved at the end of Exercise 4.1 (i.e. water pump speed control set to 5.00, water heater power control set to 2.00, feed pump speed control set to 4.00).

ii. Note the steady state value of T2.

iii. Switch Solenoid 1 from 'Divert' to 'Normal'.

This diverts the product leaving the top of the holding tube into the preheating regeneration stage of the heat exchanger rather than going directly to drain.

iv. Observe the effect on T2.

v. Once T2 becomes steady (or before if the temperature within the hot water tank exceeds 80°C) reduce the power setting of the water heater. Attempt to return T2 to its original value by throttling back the power in this way.

Note: the power will need to be reduced by approximately half to achieve this.

Conclusions

Cold feed is raised in temperature before reaching the heating section of the heat exchanger using waste heat from the finished product. This reduces the heat input required to the process.

From this exercise it can be seen that energy can be saved by the introduction of heat regeneration into the system. (The saving is small at this scale but savings can be considerable in a full sized industrial process).

Consider the long term result of this energy saving.

Exercise 3.3 should be carried out on the completion of this exercise.
EXERCISE 3.3 – PROCESS DYNAMICS II – INDIRECT COOLING

Object
In some situations, the finished product will need to be cooled further for final storage even after giving up energy in the regeneration section of the heat exchanger.

The heat exchanger on PCT23 is equipped with a cooling section where outgoing product can be indirectly cooled using cold water (or chilled water).

Equipment Required
As Exercise 3.2

Equipment Set-up
As set on completion of Exercise 4.2

Procedure
i. Maintain steady state achieved at the end of Part 4.2 (i.e. water pump speed control set to 5.00, water heater power control set to approximately 1.00, feed pump speed control set to 4.00).

ii. Switch solenoid 3 from 'Stop' to 'Cool' then adjust valve V1, if necessary, to establish a steady flow of cold water from the mains through the cooling section of the heat exchanger then to drain.

iii. Observe the effect of this change on T3, the temperature of the outgoing product.

iv. Change the flow of cooling water by adjusting valve V1. Observe the effect on T3.

Conclusions
The cooling section in the heat exchanger allows the final product to be reduced in temperature following processing.

Compare the product temperature T3 with the temperature of the mains water supply (measure the temperature independently).

Comment on the difference and the need for a chilled water source if colder final product was required.
EXERCISE 3.4 – PROCESS DYNAMICS II – PROCESS DUTY

Object
Understanding process duty and temperature differentials in the heat exchanger.

Equipment Required
PCT23 Process Plant Trainer
PC with Armfield software installed (optional).
Chart recorder with 0-5V input (if PC is not available).

Equipment Set-up
PCT23 commissioned with cold water supply connected an all process outlet connections to drain.
All controls on PCT23 console set to manual operation and safe default positions.
Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).
If using the PC to monitor the performance check that the USB port on the PCT23 console is connected to that on the PC (refer to Operational Procedures 1, 2 and 5 if necessary).

Procedure
The following procedure assumes an understanding of the process hardware having completed Exercises 1 to 4. Your task is to achieve a specified process duty by manual adjustment of the appropriate process parameters.

i. Adjust feed pump speed (N1) to give a product flow (F1) of 200 ml/min.

ii. Adjust the heater power (PWR) and hot water flow rate (water pump N2) to achieve a steady product temperature (T1) at the top of the holding tube of 55°C.

iii. When the system has stabilised at the required temperature investigate how to achieve the same condition with minimum heat input to the process.

Conclusions
Comment on how easy it is to achieve a specified process duty by manual adjustment of the appropriate process parameters.
Discuss the requirements for minimum heat input to the process.
EXERCISE 4.1 – PID CONTROL OF LEVEL USING SOFTWARE

Object
Introduction to level control using a PC (single loop PID controller in software, level L1 controlling the speed N1 of the feed pump).

Equipment Required
PCT23 Process Plant Trainer.
PC with Armfield software installed.

Equipment Set-up
PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.
Feed tanks A & B empty.
Connect flexible tube from valved outlet at front of Tank A, via pump N1 to drain.
All controls on PCT23 console set to manual operation and safe default positions.
USB Port on PCT23 console connected to that on the PC (refer to OPERATIONAL PROCEDURES 1, 2 & 5 if necessary)

Procedure
Before proceeding with actual control of the process, the control software will be installed and introduced:

i. Run the PCT23 Software from the 'start menu'. Load Exercise B which provides PID control of level L1.

ii. View the Mimic Diagram to display an animated diagram of the process loop which is the subject of this exercise. The task is to maintain the level L1 in tank A at a required value by adjusting the speed of the feed pump N1.

Water enters the tank via solenoid valve SOL4 (the flow into the tank is manually adjusted using valve V1).

The current values of L1 and F1 are displayed

iii. Click on the PID button to edit the settings of the controller. The window shows the current settings of the PID controller resident in the software and allows these settings to be varies (values in blue boxes). The current process variable (L1) and controller output (0-100% of available pump speed) are also displayed for convenience (green boxes).

When the software is first loaded, the controller starts in MANUAL operation with the controller output set to zero for safety. The controller can be toggled between manual and automatic control by clicking the button at the top of the screen.

In manual control the speed of the feed pump can be set by the operator by entering a value in the box labelled Manual Output. In automatic control the operator enters the desired setpoint for level L2 in the box labelled SE and the speed of the feed pump is continuously varied by the controller depending on the values set for P, I and D in the controller.
Having become familiar with the layout and capabilities of the process control software, it will now be used to control and actual process:

iv. Ensure that valves V2 and V3 are closed.

Set all function switches on the PCT23 console to I/O PORT, except the switch for valve control. This should be kept in MANUAL so that tank A can be supplied with cold water.

v. Ensure that valves V2 and V3 are closed. Set switch SOL4 to the FILL A position then adjust valve V1 to give a continuous trickle into tank A.

vi. Choose a sample interval of 2 seconds, then click GO to begin logging the response of the process.

vii. Ensure that the controller output is set to manual, then set the controller output (feed pump speed) to 50%. The feed pump will pump water from tank A.

viii. Adjust valve V1 to match the flow of water into the tank to the rate at which the feed pump empties the tank, i.e. the water in tank A at a steady level (not rising or falling).

Click History to view the response of the process at any time and check that steady state has been achieved.

ix. Ensure that the process has reached steady state then enter the current value of level L1 as the Set Point.

x. Switch the controller from manual to automatic control.

xi. Ensure that the computer is maintaining L1 at the required set point for a short time then apply a step change by opening valve V1 slightly to increase the flow of water into the tank. Observe that L1 starts to rise in response to the step change then the controller adjusts the feed pump speed in an attempt to restore the required level in tank A. Choose GRAPHS to view the response graphically.

xii. Apply a step change by reducing the setpoint, e.g. reduce the set point of L1 by 2mm. Observe the response to the step change.

xiii. If time permits, the effect of changing the P, I and D values in the controller can be investigated, e.g. increase the setting of the proportional band to 20% or set I to 0 then apply a small step change to the process and observe the response.

Note: Determining the ideal controller parameters to suit a particular process loop is covered in Exercise 6.

Conclusions

A PC equipped with appropriate interface and software can be used to monitor and control a process loop at a required level.

The required process level (setpoint) can be changed easily using the PC software.

P, I and D values for the controller in PC software can be adjusted to suit the process loop being controlled.

Exercise 4.2 should be carried out on the completion of this exercise.
EXERCISE 4.2 – PID CONTROL OF FLOW USING SOFTWARE

Object
Introduction to flow control using a PC (single loop PID controller in software, flow F1 controlling the speed N1 of the feed pump).

Equipment Required
PCT23 Process Plant Trainer.
PC with Armfield software installed.

Equipment Set-up
As Exercise 4.1.
Return function switches on PCT23 console to manual operation and controls to safe default positions.

Procedure
i. Run the PCT23 software and load Exercise C which provides PID control of flow F1.

ii. View the Mimic Diagram to display an animated diagram of the process loop which is the subject of this exercise. The task is to maintain the flow of product F1 through the heat exchanger at a required value by adjusting the speed of the feed pump (N1).

The current values of L1, and F1 are displayed.

iii. Click on the PID button. The window shows the current settings of the PID controller and allows these settings to be varied (values in white boxes). The current process variable (F1) and controller output (0-100% of feed pump speed) are also displayed for convenience (green boxes).

When the software is first loaded, the controller starts in manual operation with the controller output set to zero for safety. The controller can be toggled between manual and automatic control by clicking the buttons at the top of the screen.

In manual control the speed of the feed pump can be set by the operator by entering a value in the box labelled Manual Output. In automatic control the operator enters the desired setpoint for flow F1 in the box labelled Setpoint and the pump speed is continuously varied by the controller depending on the values set for P, I and D in the controller.

Having become familiar with the layout and capabilities of the process control software, it will now be used to control an actual process:

iv. Set all function switches on the PCT23 console to I/O PORT, except the switch for valve control. This should be kept in MANUAL so that tank A can be filled as required by setting switch SOL4 to the FILL A position.

v. Choose a sample interval of 2 seconds, then click GO to begin logging the response of the process.
vi. Ensure that the controller is set to Manual then set the controller output (feed pump speed) to 50%. The feed pump will operate and the actual flow (process variable F1) will be indicated.

vii. Allow the system to settle to a steady state. Click History to view the response of the process at any time.

viii. Ensure that the process has fully primed with water and the flow has reached steady state then enter the value of flow F1 as the set point.

ix. Switch the controller from manual to automatic control.

x. Ensure that the computer is maintaining F1 at the required set point for a short time then apply a step change by opening the bypass valve (black valve rear of heat exchanger) slightly.

Observe that F1 starts to fall in response to the step change then the controller adjusts the speed of the pump in an attempt to restore the required flow.

Click History to view the response graphically.

xi. Apply a step change by reducing the setpoint, eg. reduce the set point of F1 by 50 ml/min.

Observe the response to the step change.

xii. If time permits, the effect of changing the P, I and D values in the controller can be investigated, eg. increase the setting of the proportional band to 30% or set I to 0 then apply a small step change to the process and observe the response.

Note: Determining the ideal controller parameters to suit a particular process loop is covered in Exercise 6.

Conclusions

A PC equipped with appropriate interface and software can be used to monitor and control a process loop at a required flow.

The required process flow (setpoint) can be changed easily using the PC software.

P, I and D values for the controller in PC software can be adjusted to suit the process loop being controlled.

Exercise 4.3 should be carried out on the completion of this exercise
EXERCISE 4.3 – PID CONTROL OF TEMPERATURE USING SOFTWARE

Object
Introduction to temperature control using a PC (single loop PID controller in software, hot water temperature T2 controlling the power PWR to the heaters).

Equipment Required
PCT23 Process Plant Trainer.
PC with Armfield software installed.

Equipment Set-up
As Exercise 4.2.

Return function switches on PCT23 console to manual operation and controls to safe default positions.

Procedure
Before proceeding with actual control of the process, the control software will be installed and introduced:

i. Run the PCT23 Software and choose Exercise 4 which provides PID control of temperature T2.

ii. View the Mimic Diagram to display an animated diagram of the process loop which is the subject of this exercise. The task is to maintain the temperature T2 in the hot water tank at a required value by adjusting the power to the heaters in the hot water tank. The flow of feed (F1) can be varied by changing the speed of the feed pump (N1) to change the load on the process. The current values of T2, PWR and F1 are displayed.

Using this process diagram, the speed of the feed pump can be manually set by entering the required speed in the blue box labelled N1. Similarly the speed of the water pump can be manually set by entering the required speed in the blue box labelled N2.

iii. Click the PID button. The screen shows the current settings of the PID controller resident in the software and allows these settings to be varied (values in white boxes). The current process variable (T2) and controller output (0-100% of available power) are also displayed for convenience (green boxes).

When the software is first loaded, the controller starts in manual operation with the setpoint and controller output set to zero for safety. The controller can be toggled between manual and automatic control by choosing the switch at the top of the screen.

In manual control the speed of the feed pump can be set by the operator by entering a value in the white box labelled manual output. In automatic control the operator enters the desired setpoint for flow F1 in the white box labelled setpoint and the pump speed is continuously varied by the controller depending on the values set for P, I and D in the controller.

Having become familiar with the layout and capabilities of the process control software, it will now be used to control an actual process:
iv. Set all function switches on the PCT23 console to I/O PORT, except the switch for valve control. This should be kept in MANUAL so that tank A can be filled as required by setting switch SOL4 to the FILL A position.

v. Choose a sample interval of 5 seconds, then click GO to begin logging the response of the process.

vi. View the Mimic Diagram, then set the hot water pump (N2) to 50% and the feed pump (N1) to 50%. The pumps will operate.

vii. Ensure that the controller output is set to manual then set the controller output (heater output) to 25%. The hot water tank will start to heat.

viii. Allow the system to settle to a steady state. Click History to view the response of the process at any time.

ix. Ensure that the process has reached steady state then enter the value of temperature T2 as the set point.

x. Switch the controller from manual to automatic control.

xi. Ensure that the computer is maintaining T2 at the required set point for a short time then apply a step change by increasing the speed of the feed pump (N1) to 60%.

Observe that T2 starts to fall in response to the step change then the controller adjusts the heater power in an attempt to restore the required temperature in the hot water tank.

Click History to view the response graphically.

xii. Apply a step change by reducing the setpoint, e.g. reduce the set point of T2 by two degrees.

Observe the response to the step change.

xiii. If time permits, the effect of changing the P, I and D values in the controller can be investigated, e.g. increase the setting of the proportional band to 20% or set I to 0 then apply a small step change to the process and observe the response.

Note: Determining the ideal controller parameters to suit a particular process loop is covered in Exercise 6.

Conclusions

A PC equipped with appropriate interface and software can be used to monitor and control a process loop at a required temperature.

The required process temperature (setpoint) can be changed easily using the PC software.

P, I and D values for the controller in PC software can be adjusted to suit the process loop being controlled.
EXERCISE 4.4 – PID CONTROL OF CONDUCTIVITY USING SOFTWARE

Object
To control the conductivity of the final product by adding a salt solution to the feed.

Equipment Required
PCT23 Process Plant Trainer.
PC with Armfield software installed.
Suitable salt to add to second feed tank (e.g. Potassium Chloride - KCl)

Warning: take care when handling the potassium chloride, as it can be irritating to the skin and respiratory system. If any gets in the eyes, wash with water and seek medical advice.

Equipment Set-up
Make up a batch of 4 litres of conducting solution (e.g. add 200g of potassium chloride to 4 litres of deionised water - this will give a solution with a conductivity of around 70 mS/cm).

Fill tank A the salt solution. Fill Tank B with clean water, preferably de-ionised.

Return function switches on PCT23 console to manual operation and controls to safe default positions.

Procedure
Before proceeding with actual control of the process, the control software will be installed and introduced:

i. Run the PCT23 Software and choose Exercise D which provides PID control of conductivity C1.

ii. View the Mimic Diagram to display an animated diagram of the process loop which is the subject of this exercise. The task is to maintain the conductivity C1 in the product line at a required value by mixing deionised water and salt solution using the solenoid valve SOL2.

iii. Using the process diagram, the speed of the feed pump can be manually set by entering the required speed in the box labelled N1.

iv. Click the PID button. The screen shows the current settings of the PID controller resident in the software and allows these settings to be varied. The current process variable (C1) and controller output (0-100% salt solution) are also displayed.

v. When the software is first loaded, the controller starts in manual operation with the controller output set to zero. The controller can be toggled between manual and automatic control by clicking the button at the top of the window.

vi. In manual control the output of the controller can be set by the operator by entering a value in the white box labelled manual output. In automatic control the operator enters the desired setpoint for conductivity C1 in the white box labelled setpoint and the valve position is continuously varied by the controller depending on the values set for P, I and D in the controller.
Having become familiar with the layout and capabilities of the process control software, it will now be used to control an actual process:

vii. Set all function switches on the PCT23 console to I/O PORT.
viii. Choose a sample interval of 5 seconds, then click GO to begin logging the response of the process.
ix. View the Mimic Diagram, then set the feed pump (N1) to 50%.
x. Ensure that the controller output is set to manual then set the controller output to 25%. The solenoid valve will begin adding salt solution to the flow.
xi. Allow the system to settle to a steady state. There will be a considerable time delay while the solution is pumped through the system. Click History to view the response of the process at any time.

xii. Ensure that the process has reached steady state then enter the value of conductivity C1 as the set point.

xiii. Switch the controller from manual to automatic control.

xiv. Ensure that the computer is maintaining C1 at the required set point for a short time then apply a step change by altering the setpoint by, say, 10mS. Click History to view the response graphically.

xv. If time permits, the effect of changing the P, I and D values in the controller can be investigated.

Note: Determining the ideal controller parameters to suit a particular process loop is covered in Exercise 6.
EXERCISE 5.1 – INDIRECT PID CONTROL OF TEMPERATURE

Object

To demonstrate single loop PID control, with product temperature (T4) controlling heater power (PWR)

Note: It is assumed that Exercise 7 has been carried out and you are familiar with the layout and operation software.

Equipment Required

PCT23 Process Plant Trainer.

PC with Armfield software installed.

Equipment Set-up

PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

All controls on PCT23 console set to manual operation and safe default positions.

Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow.)

USB Port on PCT23 console connected to that on the PC (refer to OPERATIONAL PROCEDURES 1, 2 & 5 if necessary).

Procedure

i. Load the PCT23 Software and choose Exercise E which provides PID control of temperature T4.

ii. View the Mimic Diagram to familiarise yourself with the process loop which is the subject of this exercise. The task is to maintain the product temperature T4 at the exit from the heating section of the exchanger at a required value by adjusting the power to the heaters in the hot water tank.

iii. Set all function switches on the PCT23 console to I/O PORT, except the switch for valve control. This should be kept in MANUAL so that tank A can be filled as required by setting switch SOL4 to the FILL A position.

iv. Choose a sample interval of 5 seconds, then click GO to begin logging the response of the process.

v. Set the hot water pump (N2) to 50% and the feed pump (N1) to 50%. The pumps will operate.

vi. Set the manual controller output (heater output) to 25%. The hot water tank will start to heat and product temperature T4 will start to rise.

vii. Ensure that the process has reached steady state then enter the value of T4 as the set point.

viii. Switch the controller from manual to automatic control.

ix. Ensure that the computer is maintaining T4 at the required set point for a short time then apply a step change by increasing the speed of the feed pump (N1) to 60%.
Observe that T4 and T2 fall in response to the step change then the controller adjusts the heater power in an attempt to restore the required temperature.

x. When the temperatures have stabilised apply a step change by reducing the setpoint, e.g. reduce the set point of T4 by two degrees.

Observe the response to the step change.

xi. If time permits, the effect of changing the P, I and D values in the controller can be investigated, e.g. increase the setting of the proportional band to 50% or set the integral time to 0 seconds, then apply a small step change to the process and observe the response.

**Note:** Determining the ideal controller parameters to suit a particular process loop is covered in Exercise 9.

**Conclusions**

A PC equipped with appropriate interface and software can be used to monitor and control a process loop at a **required** temperature.

The required process temperature (setpoint) can be changed easily using the PC software.

P, I and D values for the controller in PC software can be adjusted to suit the process loop being controlled.

The large capacity of the hot water tank and the interaction between heating and product streams in the exchanger result in slow response to changes in the system.

Exercise 5.2 should be carried out on the completion of this exercise.
EXERCISE 5.2 – PID CONTROL OF TEMPERATURE WITH DEAD TIME

Object
To demonstrate single loop PID control, with product temperature (T1) controlling heater power.

Equipment Required
As Exercise 5.1

Equipment Set-up
As Exercise 5.1.

Return function switches on PCT23 console to manual operation and controls to safe default positions.

Procedure
xii. Choose ‘Load New Exercise’ from the file menu. Choose Exercise F which provides PID control of temperature T1.

xiii. View the Mimic. The task is to maintain the product temperature T1 at the exit from the heating Diagram to familiarise yourself with the process loop which is the subject of this exercise section of the exchanger at a required value by adjusting the power to the heaters in the hot water tank.

xiv. Set all function switches on the PCT23 console to I/O PORT, except the switch for valve control. This should be kept in MANUAL so that tank A can be filled as required by setting switch SOL4 to the FILL A position.

xv. Choose a sample interval of 5 seconds, then click GO to begin logging the response of the process.

xvi. Set the hot water pump (N2) to 50% and the feed pump (N1) to 50%. The pumps will operate.

xvii. Click the PID button to edit the controller settings. Set the manual controller output (heater output) to 25%. The hot water tank will start to heat and product temperature T1 will start to rise.

xviii. Ensure that the process has reached steady state then enter the value of T1 as the set point.

Note: Click History to view the response of the process at any time.

xix. Switch the controller from manual to automatic control.

xx. Ensure that the computer is maintaining T1 at the required set point for a short time then apply a step change by increasing the speed of the feed pump (N1) to 60%.

Observe that T1, T4 and T2 fall in response to the step change then the controller adjusts the heater power in an attempt to restore the required temperature.

xxi. When the temperatures have stabilised apply a step change by reducing the setpoint, eg. reduce the set point of T1 by two degrees.

Observe the response to the step change.
xxii. If time permits, the effect of changing the P, I and D values in the controller can be investigated, e.g. increase the setting of the proportional band to 30% or set I to 0 then apply a small step change to the process and observe the response.

**Note:** Determining the ideal controller parameters to suit a particular process loop is covered in Exercise 9.

**Conclusions**

A PC equipped with appropriate interface and software can be used to monitor and control a process loop at a required temperature.

The required process temperature (setpoint) can be changed easily using the PC software.

Setpoint, P, I and D values for the controller in PC software can be adjusted to suit the process loop being controlled.

The addition of the holding tube adds dead time which further reduces the response to changes in the system.

Exercise 5.3 should be carried out on the completion of this exercise.
EXERCISE 5.3 – PID CONTROL WITH ALARM DRIVEN DISTURBANCES

Object
To demonstrate the effect on control action of including an alarm-activated diverter valve (the effect of recycling heated product back through the heat exchanger).
Also to demonstrate the action of a cooling alarm.

Equipment Required
As Exercise 5.2

Equipment Set-up
As Exercise 5.2

Procedure
Choose ‘Load New Exercise’ from the file menu. Choose Exercise G which provides the same control loop as Exercise 8.2 (PID control of temperature T1) but with the addition of alarms.

i. Set all function switches on the PCT23 Console to I/O PORT.

ii. Select a sample interval of 5 seconds, then click GO to begin logging the response of the process.

iii. Check that tank A is filled with water (choose SOL4 to open and close the solenoid valve when necessary).
Set the hot water pump (N2) to 50% and the feed pump (N1) to 50%. The pumps will operate.

iv. Check that the controller settings are as follows and adjust if necessary:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setpoint (T1)</td>
<td>50°C</td>
</tr>
<tr>
<td>Proportional Band</td>
<td>15%</td>
</tr>
<tr>
<td>Integral term</td>
<td>300</td>
</tr>
<tr>
<td>Derivative Term</td>
<td>0</td>
</tr>
<tr>
<td>Divert temp T1</td>
<td>48°C (Action alarm)</td>
</tr>
<tr>
<td>Cooling temp T3</td>
<td>30°C (Action alarm)</td>
</tr>
</tbody>
</table>

Switch the controller from manual to automatic and allow the process to stabilise.

Note: Click History to view the response of the process at any time.

i. Observe that when the product temperature T1 exceeds 48°C (divert temperature setting) the product passes through the regeneration section of the exchanger.

Observe the response of the process following the operation of divert solenoid valve SOL1.

Observe that when the finished product temperature exceeds 30°C (cooling temp T3) SOL3 is opened to allow cooling water to flow through the cooling
section of the heat exchanger (the flow of water can be adjusted using valve V1).

ii. Allow the process to stabilise at the required setpoint then apply a step change by increasing the speed of the Feed Pump (N1) to 70%. Observe the response to the step change as the product initially diverts to drain following the drop in temperature T1.

Conclusions

An alarm with control action can be incorporated in the control strategy to take immediate action if the process is outside satisfactory limits. (Product which has not reached the required processing temperature is diverted to drain.)

The operation of the divert solenoid valve SOL1 causes a considerable change to the process stability as the product starts or stops preheating in the regeneration section of the heat exchanger.

The regeneration stage of heat exchanger reduces power input to the process.

A cooling alarm can be incorporated to minimise water usage (water only flows when product temperature is excessive).
EXERCISE 6.1 – CONTROLLER OPTIMISATION

Object
Determining the ideal control parameters for a simple system (single loop, temperature T4 to heater power PWR).

A step change will be applied to the process under manual (open loop) control and the resulting reaction curve will be analysed to determine suitable controller setting (reaction curve method).

Note: It is assumed that previous exercises have been carried out and you are familiar with the layout and operation of the software mimic diagram and controller screens

Equipment Required
PCT23 Process Plant Trainer.
PC with Armfield software installed.

Equipment Set-up
PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

All controls on PCT23 console set to manual operation and safe default positions.

Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

PCT23 Console connected to PC (refer to Operational Procedures 1, 2 & 5 if necessary).

Theory
The typical response curve of a process following a step change is shown below:

From this curve, the following values can be obtained:

The time lag, L, between the step change in power and the response from T4.
The gradient, R, at the steepest part of the curve.
The value of the step change in power, M, as a percentage of the total range available.
The value R1 can be calculated as follows:

\[ R1 = \frac{R}{M} \]

Suitable controller settings can be calculated as follows:

- \( P = 0.5 \) \((R1 \text{ c L})\) to \( 0.8 \) \((R1 \times \text{ L})\) \%
- \( I - 2.0 \text{ L} \) to \( 2.5 \text{ L} \) \(\text{min}\)
- \( D - 0.3 \text{ L} \) to \( 0.5 \text{ L} \) \(\text{min}\)

**Procedure**

i. Run the PCT23 Software and choose Exercise E which provides PID control of temperature T4.

ii. Set all function switches on the PCT23 console to I/O PORT, except the switch for valve control. This should be kept in MANUAL so that tank A can be filled as required by setting switch SOL4 to the FILL A position.

iii. Start logging the response of the process.

iv. View the Mimic Diagram. Set the hot water pump (N2) to 50% and the feed pump (N1) to 50%.

v. Set the manual controller output (heater output) to 15%. Allow the system to heat up and achieve steady state.

vi. Once the system has stabilised, introduce a step change by increasing the controller output to 50%. Monitor the effect of this change on T4.

vii. Once the temperature has exceeded 70°C, set the controller output to 0% and allow the system to cool.

viii. View the Graph screen, and plot the graph of T4 and heater power against sample number or time, having adjusted the axes to concentrate on the step change and steep gradient immediately following it.

Using the theory above, determine \( L \), \( R \) and \( M \) and \( R1 \) from the graph then calculate suitable \( P \), \( I \) and \( D \) settings for the controller.

ix. Enter the calculated settings in the heater controller with an appropriate setpoint then switch the controller to automatic control.

x. Allow the process to stabilise then apply a step change.

Observe the response to the step change.

xi. Temperature T4 should show a good response, quickly settling with minimal overshoot. If you consider that improvements can be made, adjust \( P \) and/or \( I \) in small steps as appropriate then apply a step change to test the response.

**Conclusions**

Settings for a PID controller can be tailored to the system being controlled by analysis of the open loop response of the process following a step change.

Fine tuning of the parameters may be required to give optimum control of the process.
The reaction curve method demonstrated has the advantage of requiring a simple one shot measurement from which the controller settings can be calculated. The ultimate period method is an alternative technique which requires the system to be placed into regular continuous oscillation. This can take considerable time to achieve, and so has not been demonstrated here.
EXERCISE 6.2 – CONTROLLER OPTIMISATION WITH DEAD TIME

Object

Determining the ideal control parameters for a simple system with dead time (single loop, temperature T4 to heater power PWR). A step change will be applied to the process under manual (open loop) control and the resulting reaction curve will be analysed to determine suitable controller settings (reaction curve method).

Note: It is assumed that previous exercises have been carried out.

Equipment Required

As Exercise 6.1.

Equipment Set-up

As Exercise 6.1.

Theory

Refer to Exercise 6.1.

Procedure

i. Run the PCT23 Software and choose Exercise F which provides PID control of temperature T1.

ii. Set all function switches on the PCT23 console to I/O PORT, except the switch for valve control. This should be kept in MANUAL so that tank A can be filled as required by setting switch SOL4 to the FILL A position.

iii. Start logging the response of the process.

iv. View the Mimic Diagram. Set the hot water pump (N2) to 50% and the feed pump (N1) to 50%.

v. Set the manual controller output (heater output) to 15%. Allow the system to heat up and achieve steady state.

vi. Once the system has stabilised, introduce a step change by increasing the controller output to 50%. Monitor the effect of this change on T1.

vii. Once the temperature has exceeded 70°C, set the controller output to 0% and allow the system to cool.

viii. Plot the graph of T1 and heater power against time or sample number, and adjust the axes to concentrate on the step change and steep gradient immediately following it.

Using the theory from Exercise 9.1, determine L, R and M and R1 from the graph then calculate suitable P, I and D settings for the controller.

ix. Enter the calculated settings in the heater controller with an appropriate setpoint then switch the controller to automatic control.

x. Allow the process to stabilise then apply a step change.

Observe the response to the step change.

xi. Temperature T1 should show a good response, quickly settling with minimal overshoot. If you consider that improvements can be made, adjust P and/or I in small steps as appropriate then apply a step change to test the response.
Conclusions

Settings for a PID controller can be tailored to the system being controlled by analysis of the open loop response of the process following a step change.

Fine tuning of the parameters may be required to give optimum control of the process.

The dead time resulting from flow of product through the holding tube reduces the response of the process requiring different controller settings for optimum control.
EXERCISE 7 – TWO LOOP CASCADE CONTROL

Object
To demonstrate cascade control, whereby product temperature controls hot water temperature set point, which in turn controls heater power.

In previous exercises the product temperature (T1) has been maintained at the required value by varying the heater power (PWR) using a single loop feedback controller. One disadvantage of this arrangement is a slow response to changes in the process.

In this exercise, a cascade controller (remote set point) and conventional feedback controller are used in combination to improve the response. The output from the feedback controller is the set point for the cascade controller.

Equipment Required
PCT23 Process Plant Trainer
PC with Armfield software installed.

Equipment Set up
PCT23 commissioned with cold water supply connected and all process outlet connections to drain.

Feed tank A filled with cold water.

All controls on PCT23 console set to manual operation and safe default positions.

Refer to Operational Procedures 1, 2 and 5 if necessary.

Procedure
i. Run the PCT23 Software and choose Exercise H which performs cascade control.
ii. Set all function switches from ‘Manual’ to ‘I/O Port’.
iii. Choose the Process Diagram then set the feed pump and water pump (N1 and N2) both at 50%.
iv. Choose the Minor PID Loop Controller then set the Output (power to heaters) to 25%.
v. Allow the system to attain steady state.
vi. Set the divert alarm temperature at 45°C.
vii. Once the system is steady, choose the major PID loop controller then enter the steady state value of T1 as the set point and the steady state value of T2 as the manual output level.
viii. Place both the major and the minor PID loops into automatic control. The computer should now be able to maintain the system in its steady state.
ix. Increase the feed pump flow rate (N1) to 80%. Observe the effect of this step change on the system and see how efficiently it recovers.
x. Once the system is again steady, increase the T1 set point to 47°C. Achieving this set point should cause the divert alarm to trip. Observe the effect on the system response.
Conclusions
The remote set point facility on a controller allows the set point to be continuously updated to suit current requirements.
One advantage of the cascade control arrangement is an improvement in the response of the process to changes.
One disadvantage of the cascade control arrangement is the need to tune two PID controllers with suitable parameters.
Discuss other advantages and disadvantages of the cascade arrangement.
EXERCISE 8 – TWO LOOP CONTROL AND INTERACTION

Object
To demonstrate the effect on process response of two separate PID control loops which interact. Product temperature (T1) controlling hot water pump (N2) and hot water temperature (T2) controlling heater power (PWR).

Equipment Required
PCT23 Process Plant Trainer
PC with Armfield software installed.

Equipment Set up
PCT23 commissioned with cold water supply connected and all process outlet connections to drain.

Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

Procedure

i. Run the PCT23 Software and choose Exercise I which provides multiple PID loops.

ii. View the Mimic Diagram to familiarise yourself with the process loops which are the subject of this exercise. The task is to maintain the product temperature T1 at the exit from the holding tube at a required value by adjusting the flow of hot water. Hot water temperature T2 is maintained by adjusting power to the heaters.

Note: Keep tank A filled by choosing SOL4 when necessary.

iii. Set all function switches on the PCT23 console to I/O port.

iv. Start jogging the response of the process.

v. Choose PID control of PWR. Set the manual controller output (heater output) to 25%. The hot water tank will start to heat.

Choose PID control of N2. Set the manual controller output (hot water pump speed) to 50%.

Choose PID control of N1. Set the manual controller output (feed pump) to 50% (N1 will remain in manual control during this exercise).

vi. Ensure that the process has reached steady state then enter appropriate set points for T1 and T2.

vii. Switch the PID control of PWR controller from manual to automatic control.

Switch the PID control of N2 controller from manual to automatic control.

viii. Ensure that the process has stabilised then increase the feed pump speed to 60%.

ix. Compare the results obtained with those from Exercises 8.2 or 9.2 (single loop T1 to PWR).

x. Ensure that the process has stabilised then increase the set point of T1. Observe the response.
xi. Ensure the process has stabilised then apply a step change to the T2 set point.

Conclusions
The use of two separate loops can reduce the time taken for the system to respond to changes compared with the single loop approach of T1 to PWR.
Because of interaction between the loops, a change to one loop may require a compensating change to the other loop (eg. an increase in the set point of product temperature T1 may require an increase in set point of hot water temperature T2).
It is important to configure the loops to avoid instability occurring due to the interaction between the loops.
EXERCISE 9 – THREE LOOP CONTROL

Object
To demonstrate multivariable control with interacting and non-interacting loops: feed pump speed N1 controlled by feed flow F1, water pump speed N2 controlled by T1, heater output PWR controlled by hot water temperature T2.

Equipment Required
PCT23 Process Plant Trainer
PC with Armfield software installed.

Equipment Set up
PCT23 commissioned with cold water supply connected and all process outlet connections to drain.
All controls on PCT23 console set to manual operation and safe default positions.
Ensure that tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).
USB Port on PCT23 Console connected to that on the PC (refer to Operational Procedures 1, 2 and 5 if necessary).

Procedure
i. Run the PCT23 Software and choose Exercise I which provides multiple PID control loops.
ii. Set all function switches on the PCT23 console to I/O Port.
iii. View the Mimic Diagram to familiarise yourself with the process loops which are the subject of this exercise.
   Note: Keep tank A filled by choosing SOL4 when necessary.
iv. Start logging the response of the process.
v. Edit the settings for PID control of PWR and set the manual output to 25% (heater power).
vi. Edit the settings for PID control of N2 and set the manual output to 50% (feed pump speed).
vi. Edit the settings for PID control of N1 and set the manual output to 50% (feed pump speed).
viii. Allow the system to achieve steady state.
ix. Enter the steady state value of T2 as the set point of the PWR control loop. Switch the controller from manual to automatic control.
x. Enter the steady state value of T1 as the set point of the N2 control loop. Switch the controller from manual to automatic control.
xi. Enter the steady state value of the feed flow F1 as the set point of the N1 control loop. Switch the controller from manual to automatic control.
xii. Check that the control loops are able to maintain the system at steady state,
xiii. Increase the N1 control loop set point to 250 ml/min and monitor the consequences of this step change on both T1 and T2.

Note: T1 should drop because of the increased feed flow. The system will attempt to recover by increasing the hot water pump speed. T2 should drop because of the increased hot water demand. The system will attempt to recover by increasing the heater power.

xiv. As an aside, once the system is again steady, observe the effect of adjusting the proportional band of the N1 control loop from 100% down to 25%.

xv. Increase the value of the N1 control loop proportional band until the feed pump regains stability.

This is a demonstration of the effect of low proportional bands on fast-reacting systems.

Conclusions

The interactions of separate loops within a system can be complex. Explain why a change in the feed flow control loop affected both other loops in the system, whilst a change in the T2 control loop had no effect on the feed flow loop. Would changing the T1 control loop have any more effect on the feed flow?
EXERCISE 10 – FAULT FINDING AND DIAGNOSTICS

Object
Fault simulation and diagnosis by the instructor switching out selected signals.

Equipment Required
PCT23 Process Plant Trainer.
PC with Armfield software installed.

Equipment Set up
PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

USB Port on PCT23 connected to that on the PC (refer to Operational Procedures 1, 2 and 5 if necessary).

Note: The PCT23 and PC with should be set up and running as described in Exercise 9 with the complete process operational and controlled by three PID control loops with alarms.

Procedure
i. View the Mimic Diagram to confirm that the process is operating satisfactorily at steady state with no alarm conditions.

ii. The instructor will operate a switch or combination of switches on the DC and/or signal fault boxes to create a fault or combination of faults.
(The action of each switch is listed on pages 38 and 39 of the Instruction Manual to aid the instructor.)

iii. Using the process diagram, trend graphs, readings on the PCT23 console etc. analyse the fault(s) introduced by the instructor.

iv. Report your findings to the instructor who will confirm if your analysis is correct.

v. The instructor will create different faults for analysis.

Conclusions
Comment on the techniques which you used to identify each of the faults.
EXERCISE 11.1 – EXTERNAL LEVEL CONTROLLER SETUP

Object

The industrial controller incorporated in PCT20H is typical of the instrumentation used to control modern industrial processes. This exercise will serve as an introduction as to how to connect and set up such a controller for control of level. In this case the controller will be configured to monitor the level in tank A (process variable L1) in engineering units (mm). The controller will also be set up for on/off control via its relay output in preparation for the exercise that follows.

Equipment Required

PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed.

Equipment Set up

PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

All controls on PCT23 console set to manual operation and safe default positions.

Tanks A and B empty.

All controls on PCT23 console set to manual operation and safe default positions.

If using the PC to monitor the performance, check that the USB Port on PCT23 console is connected to that on the PC. Run Exercise A.

PCT20H will be configured with a default configuration using serial communications from a PC. The correct default for this exercise is ‘PCT23(3) – On/off Controller, On/off Relay Output’. Refer to the PCT20H Instruction Manual for details. The default configurations for PCT23-MKII are listed in the PCT20H Instruction Manual.

Note that the default setting will set the process variable (Input 1) and the setpoint range (SP Hi Limit) to 100% range. It will also set the value of the alarm (A1S1 Value) to 90% of the range. In this exercise these will be changed to appropriate engineering units manually (100% = 250 mm level range) using the keys on the front of the controller to demonstrate how the controller can be configured using appropriate menus.

Refer to Operational Procedures 1, 2 and 3 in this manual if necessary.

Note: If a PC is not available to configure the controller then the controller can be configured manually by applying the settings listed under the default PCT23(3) in the PCT20H Instruction Manual.

Procedure

i. Connect the ‘process variable’ (L1) 0-5V output sockets on the PCT23 console to the 0-5V analogue input 1 sockets on the PCT20H ensuring that the output switch on the PCT20H is set to the 0-5V position.

ii. Download the default configuration ‘PCT23(3) – On/off Controller, On/off Relay Output’. Refer to the PCT20H instruction manual for instructions, if necessary.
Configure the PCT20H controller to display the water level in engineering units as follows:

iii. Press the ‘Setup’ key (S) on the keypad until ‘Input 1’ is displayed.
iv. Press the ‘Function’ key (F) until ‘In 1 Hi’ is displayed.
v. Press the ‘up/down’ keys to change the value from 100 % to 250 mm.

Note: To speed up the change of a numerical value, hold down the ‘up’ or ‘down’ key as appropriate and then press the other key. This will increase the units by which the numerical value is being changed.

vi. Press ‘S’ until ‘Control’ is displayed.

vii. Press ‘F’ and ‘up/down’ keys to obtain the following values:

<table>
<thead>
<tr>
<th>SP Hi Limit</th>
<th>250.0</th>
</tr>
</thead>
</table>

viii. Press ‘S’ until ‘Alarms’ is displayed.

ix. Press ‘F’ and ‘up/down’ keys to obtain the following values:

<table>
<thead>
<tr>
<th>A1S1 Value</th>
<th>150.0</th>
</tr>
</thead>
</table>

The controller is now configured to monitor the level of water in tank A in engineering units. The setpoint can be set from 0 – 250 mm and the alarm is set to activate at 150 mm depth.

x. Press the ‘Lower Display’ key. This returns the controller from the settings menus to the monitoring display. This should read ‘Man’ indicating manual control, the level of water in tank A and a reading of ‘Out’, the output of the controller (not connected or used in this exercise).


xii. As tank A fills, observe that the process variable indicated on PCT20H is the level L1 by comparing the reading the L1 indicated on the PCT23 console.

xiii. When the level L1 exceeds 150 mm observe that the alarm indicator illuminates on the controller.

xiv. Switch off SOL4 to stop filling the tank.

Conclusions

The procedure for connecting and configuring a typical industrial controller (PCT20H) for measurement of level (L1) in engineering units has been introduced.

The configuration of the controller for different types of output suitable for level control will be demonstrated in the following exercises.

As the controller has been configured for on/off control of level, it is sensible to continue with Exercise 11.2.
EXERCISE 11.2 – EXTERNAL ON/OFF LEVEL CONTROL

Object
To demonstrate the use of an industrial controller to control liquid level (proportional input) using on/off relay output. The controller will be used to switch the feed pump on and off to maintain the level L1 in tank A.

Equipment Required
PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed (optional).

Equipment Set up
PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

All controls on PCT23 console set to manual operation and safe default positions.

Ensure tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

If using the PC to monitor the performance check that the USB Port on the PCT23 console is connected to that on the PC. Run Exercise A.

PCT20H configured with settings from Exercise 11.1.

Refer to Operational Procedures 1, 2 and 3 if necessary.

Procedure

i. Connect the relay output ‘N/C Contact’ sockets on the PCT20H to the feed pump ‘on/off control’ input sockets on the PCT23 console.

ii. Set feed pump speed control to 5.00 and allow the level in tank A to fall.

iii. Set the valve control switch SOL4 to ‘FILL A’ then adjust manual valve V1 so that the water level in tank A remains constant (i.e. inflow and outflow are balanced).

Manual Control


v. Set feed pump function switch to ‘On/Off Control’ and set feed pump speed control to 10.0. (When the pump is switched on by the controller it will drain the tank faster than SOL4 can fill it.)

vi. Attempt to maintain the level of water in tank A at 100mm +/- 5mm (i.e. between 95 and 105mm) by operating the ‘up/down’ keys on the controller to produce a controller output of 0% or 100% (off or on). Maintain manual control for a few minutes.
Automatic Control

vii. Using the ‘up/down’ keys, set ‘SP’ to 100.0 to enter the required set point at 100mm.

viii. Set PCT20H controller to automatic using the ‘manual/auto’ key.

ix. Observe how the controller maintains the level (use the software if available).

x. Apply step changes to the system and observe the response, eg. open valve V2 briefly, adjust V1 slightly, change the set point, adjust feed pump speed control etc.

Conclusions

The concept of on/off process control has been introduced using level as the process variable.

The output from the controller can only be in two states, on or off.

Discuss the advantages over manual control

Consider the need for hysteresis when using a controller of this type.
EXERCISE 11.3 – EXTERNAL TIME-PROPORTIONED LEVEL CONTROL

Object

To demonstrate the use of an industrial controller for proportional (PID) control of liquid level (proportional input) using time proportioned relay output.

The controller will be used to switch the feed pump on and off in a time proportioned cycle to maintain the level L2 in tank A - this technique would not normally be used to control level in an industrial process but clearly demonstrates the principle of time proportioning.

Equipment Required

As Exercise 11.2

Equipment Set up

As set at the end of Exercise 11.2

Manually or remotely change the configuration of the controller to the default ‘PCT23(2)’ PID Controller, Time Proportioned Relay Output. Refer to the PCT20H Instruction Manual for details.

Procedure

i. Maintain the water inlet valve position, console settings and wiring arrangements on completion of Exercise 11.2.

ii. Changes and additions to the configuration of the PCT20H controller are as follows:

<table>
<thead>
<tr>
<th>Set Up</th>
<th>Function</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning</td>
<td>Prop BD</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>Rate Min</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Rset RPM</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Manual Control

iii. Check that PCT20H controller is in manual operation (‘MAN’ indicator illuminated). If not press ‘manual/auto’ key.

iv. Note that the available output is now variable between 0 and 100%. Set the controller output to 50% and observe how a proportional output is achieved by the controller using a mark/space mode of action. (With cycle time set to 10 seconds, 50% output is achieved with the pump on for 5 seconds and off for 5 seconds.)

v. Attempt to maintain the tank A water level at 100mm by adjusting the output of the controller.

Automatic Control

vi. Set PCT20H controller to automatic using the ‘manual/auto’ key.

vii. Ensure the set point is set at 100mm.

viii. Observe how the controller maintains the level in the tank.
ix. Apply step changes to the system and observe the response, eg. open valve V2 briefly, adjust V1 slightly, change the set point, adjust the feed pump speed etc.

Conclusions

A time proportioned output allows a controller to produce a proportioned output variable from 0 to 100%. This allows PID control to be implemented using a simple relay output on the controller.

One disadvantage of time proportioned control over simple on/off control is the need to enter correct settings for P, I and D into the controller to suit the process being controlled.

Discuss applications where this technique would not be appropriate.
EXERCISE 11.4 – EXTERNAL PID LEVEL CONTROL

Object

To demonstrate the use of an industrial controller for proportional (PID) control of liquid level (proportional input) using proportional (voltage) output.

The controller will be used to vary the speed of the feed pump to maintain the level L1 in tank A.

Equipment Required

As Exercise 11.1

Equipment Set up

As set at the end of Exercise 11.3

Manually or remotely change the configuration of the controller to the default ‘PCT23(1)’ PID Controller, Proportional Output. Refer to the PCT20H Instruction Manual for details.

Procedure

i. Keeping the other console settings the same as in Exercise 11.3, change the feed pump control switch to ‘Input Socket’.

ii. Keeping the other wiring the same as in Exercise 11.3, remove the wires connecting the ‘on/off’ input sockets of the feed pump to the relay output sockets of the PCT20H and instead connect the 0-5V input sockets of the feed pump to the 0-5V analogue output of the PCT20H.

iii. Changes and additions to the settings of the PCT20H controller are as follows:

<table>
<thead>
<tr>
<th>Set up</th>
<th>Function</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning</td>
<td>Prop BD</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>Rate Min</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Rset RPM</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Manual Control


v. Set controller to 50% output using ‘up/down’ keys. Note how this output is now achieved, compared with the control in Exercise 11.3.

vi. Attempt to achieve and maintain a level of 100mm in tank A by manual control of the output.

Automatic Control

vii. Set PCT20H controller to automatic using the ‘manual/auto’ key.

viii. Keeping the set point at 100mm, observe how the controller maintains this level.

ix. Apply step changes to the system and observe the response, eg. open valve V2 briefly, adjust V1 slightly, change the set point etc.
Conclusions

Proportional output provides a superior form of process control.

One disadvantage of proportional control over simple on/off control is the need to enter correct settings for P, I and D into the controller to suit the process being controlled.
EXERCISE 12.1 - EXTERNAL FLOW CONTROLLER SETUP

Object

The industrial controller incorporated in PCT20H is typical of the instrumentation used to control modern industrial processes. This exercise will serve as an introduction as to how to connect and set up such a controller for control of flow. In this case the controller will be configured to monitor the flow of product (process variable F1) in engineering units (ml/min). The controller will also be set up for on/off control via its relay output in preparation for the exercise that follows.

Equipment Required

PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed.

Equipment Set up

PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

All controls on PCT23 console set to manual operation and safe default positions.

Tanks A and B empty.

All controls on PCT23 console set to manual operation and safe default positions.

If using the PC to monitor the performance, check that the USB Port on PCT23 console is connected to that on the PC. Run Exercise A.

PCT20H will be configured with a default configuration using serial communications from a PC. The correct default for this exercise is ‘PCT23(3) – On/off Controller, On/off Relay Output’. Refer to the PCT20H Instruction Manual for details. The default configurations for PCT23-MKII are listed in the PCT20H Instruction Manual.

Note that the default setting will set the process variable (Input 1) and the setpoint range (SP Hi Limit) to 100% range. It will also set the value of the alarm (A1S1 Value) to 90% of the range. In this exercise these will be changed to appropriate engineering units manually (100% = 1500 ml/min flow range) using the keys on the front of the controller to demonstrate how the controller can be configured using appropriate menus.

Refer to Operational Procedures 1, 2 and 3 in this manual if necessary.

Note: If a PC is not available to configure the controller then the controller can be configured manually by applying the settings listed under the default PCT23(3) in the PCT20H Instruction Manual.

Procedure

i. Connect the ‘process variable’ (F1) 0-5V output sockets on the PCT23 console to the 0-5V analogue input 1 sockets on the PCT20H ensuring that the output switch on the PCT20H is set to the 0-5V position.
ii. Download the default configuration ‘PCT23(3) – On/off Controller, On/off Relay Output’. Refer to the PCT20H instruction manual for instructions, if necessary.

Configure the PCT20H controller to display the water flow rate in engineering units as follows:

iii. Press the ‘Setup’ key (S) on the keypad until ‘Input 1’ is displayed.

iv. Press the ‘Function’ key (F) until ‘In 1 Hi’ is displayed.

v. Press the ‘up/down’ keys to change the value from 100 % to 1500 ml/min.

**Note:** To speed up the change of a numerical value, hold down the ‘up’ or ‘down’ key as appropriate and then press the other key. This will increase the units by which the numerical value is being changed.

vi. Press ‘S’ until ‘Control’ is displayed.

vii. Press ‘F’ and ‘up/down’ keys to obtain the following values:

   \[
   \text{SP Hi Limit} \quad 1500.0
   \]

viii. Press ‘S’ until ‘Alarms’ is displayed.

ix. Press ‘F’ and ‘up/down’ keys to obtain the following values:

   \[
   \text{AIS1 Value} \quad 1000.0
   \]

The controller is now configured to monitor the flow of water in engineering units. The setpoint can be set from 0 – 1500 ml/min and the alarm is set to activate at 1000 mm depth.

x. Press the ‘Lower Display’ key. This returns the controller from the settings menus to the monitoring display. This should read ‘Man’ indicating manual control, the level of water in tank A and a reading of ‘Out’, the output of the controller (not connected or used in this exercise).

xi. On the PCT23 console. Switch the feed pump on (selector switch set to Manual) then set the feed pump speed control to 5.0.

xii. As product flows through the flow sensor, observe that the process variable indicated on PCT20H is the flow F1 by comparing the reading the F1 indicated on the PCT23 console.

xiii. Gradually increase the speed of the pump. When the flow F1 exceeds 1000 ml/min observe that the alarm indicator illuminates on the controller.

xiv. Switch off the feed pump.

**Conclusions**

The procedure for connecting and configuring a typical industrial controller (PCT20H) for measurement of flow (F1) in engineering units has been introduced.

The configuration of the controller for different types of output suitable for flow control will be demonstrated in the following exercises.

As the controller has been configured for on/off control of flow, it is sensible to continue with Exercise 12.2.
EXERCISE 12.2 – EXTERNAL ON/OFF FLOW CONTROL

Object
To demonstrate that an industrial controller with on/off relay output is not suitable for the control of liquid flow (proportional input to controller).
The controller will be used to switch the feed pump on and off to maintain the flow F1 through the heat exchanger.

Equipment Required
PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed (optional).

Equipment Set up
PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.
All controls on PCT23 console set to manual operation and safe default positions.
Ensure tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).
If using the PC to monitor the performance check that the USB Port on PCT23 console is connected to that on the PC. Run Exercise A.
PCT20H configured with settings from Exercise 12.1.
Refer to Operational Procedures 1, 2 and 3 if necessary.

Note: If required PCT20H can be set up remotely using serial communications via a PC but the process variable (Input 1) will be set to 100% (=1500ml/min flow range). This can be changed to engineering units manually or remotely if required. Refer to the PCT20H instruction manual for further information. The configuration for this demonstration is PCT23(3) – On/off controller, On/off relay output.

Procedure
i. Connect the Relay Output 'N/C Contact' sockets on the PCT20H to the feed pump 'on/off control' input sockets on the PCT23 console.
ii. Set feed pump speed control to 5.00 and allow the flow F1 to stabilise.

Manual Control
iii. Check that PCT20H controller is in manual operation (‘MAN’ indicator illuminated). If not press ‘manual/auto’ key.
iv. Set feed pump function switch to 'on/off control'. When the pump is switched on by the controller flow will occur through the heat exchanger.
v. Attempt to maintain the flow F1 at 100ml/min by operating the 'up/down' keys on the controller to produce a controller output of 0% or 100% (off or on). Observe that flow is either stopped or at the feed pump setting.
Automatic Control

vi. Using the 'up/down' keys, set 'SP' to 100.0 to enter the required set point at 100 ml/min.

vii. Set PCT20H controller to automatic using the 'manual/auto' key.

viii. Observe that the controller cannot control the flow at the required set point. The pump repeatedly starts and stops.

Conclusions

The concept of on/off process control has been introduced using flow as the process variable.

The output from the controller can only be in two states - on or off.

An on/off controller with relay output is not suitable for controlling the steady flow of liquid.
EXERCISE 12.3 – EXTERNAL TIME-PROPORTIONED FLOW CONTROL

Object

To demonstrate that an industrial controller with time proportioned relay output is not suitable for the control of liquid flow (proportional input to controller).

The controller will be used to switch the feed pump on and off in a time proportioned cycle to maintain the flow FI through the heat exchanger.

Equipment Required

As Exercise 12.2

Equipment Setup

As set at the end of Exercise 12.2

Manually or remotely change the configuration of the controller to the default 'PCT23(2)' PID Controller, Time Proportioned Relay Output. Refer to the PCT20H Instruction Manual for details.

Procedure

i. Maintain the water inlet valve position, console settings, and wiring arrangements on completion of Exercise 12.2.

ii. Changes and additions to the configuration of the PCT20H controller are as follows:

<table>
<thead>
<tr>
<th>Set Up</th>
<th>Function</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning</td>
<td>Prop BD</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Rate Min</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Rset RPM</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Manual Control

iii. Check that PCT20H controller is in manual operation ('MAN' indicator illuminated). If not press 'manual/auto' key.

iv. Note that the available output is now variable between 0 and 100%. Set the controller output to 50% and observe how a proportional output is achieved by the controller using a mark/space mode of action. (With cycle time set to 10 seconds, 50% output is achieved with the pump on for 5 seconds and off for 5 seconds.)

v. Attempt to maintain the flow FI at 100ml/min by adjusting the output of the controller.

Automatic Control

vi. Set PCT20H controller to automatic using the 'manual/auto' key.

vii. Ensure the setpoint is set at 100 ml/min.

viii. Observe that the controller cannot control the flow at the required setpoint.
Conclusions

A time-proportioned output allows a controller to produce a proportioned output variable from 0 to 100%. This allows PID control to be implemented using a simple relay output on the controller.

A controller with time proportioned relay output is not suitable for controlling flow of liquid.
EXERCISE 12.4 – EXTERNAL PID FLOW CONTROL

Object

To demonstrate the use of an industrial controller for proportional (PID) control of liquid flow (proportional input) using proportional (voltage) output.

The controller will be used to vary the speed of the feed pump to maintain the flow F1 through the heat exchanger.

Equipment Required

As Exercise 12.3.

Equipment Set up

As set at the end of Exercise 12.3.

Manually or remotely change the configuration of the controller to the default ‘PCT23(1)’ PID Controller, Proportional Output. Refer to the PCT20H Instruction Manual for details.

Procedure

i. Keeping the other console settings the same as in Exercise 12.3, change the feed pump control switch to 'input socket'.

ii. Keeping the other wiring the same as in Exercise 12.3, remove the wires connecting the 'on/off' input sockets of the feed pump to the relay output sockets of the PCT20H, and instead connect the 0-5 V input sockets of the feed pump to the 0-5 V analogue output of the PCT20H.

iii. Changes and additions to the settings of the PCT20H controller are as follows:

<table>
<thead>
<tr>
<th>Set Up</th>
<th>Function</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning</td>
<td>Prop BD</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Rate Min</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Rset RPM</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Manual Control

iv. Check that PCT20H controller is in manual operation ('MAN' indicator illuminated). If not press 'manual/auto' key.

v. Set controller to 50% output using 'up/down' keys. Note how this output is achieved by running the feed pump at half speed.

vi. Attempt to achieve and maintain a flow of 100 ml/min by manual control of the output.

Automatic Control

vii. Set PCT20H controller to automatic using the 'manual/auto' key.

viii. Keeping the set point at 100ml/min, observe how the controller maintains this flow.

ix. Apply step changes to the system and observe the response, eg. open valve V2 briefly, adjust V1 slightly, change the set point etc.
Conclusions

A controller with proportional output is suitable for controlling flow of liquid in a process.
EXERCISE 13.1 – EXTERNAL TEMPERATURE CONTROLLER SETUP

Object

The industrial controller incorporated in PCT20H is typical of the instrumentation used to control modern industrial processes. This exercise will serve as an introduction as to how to connect and set up such a controller for control of temperature. In this case the controller will be configured to monitor the product temperature at the top of the holding tube (process variable T1) in engineering units (°C). The controller will also be set up for on/off control via its relay output in preparation for the exercise that follows.

Equipment Required

PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed.

Equipment Set up

PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

All controls on PCT23 console set to manual operation and safe default positions.

Ensure that tank A is filled with cold. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

If using the PC to monitor the performance, check that the USB Port on PCT23 console is connected to that on the PC. Run Exercise A.

PCT20H will be configured with a default configuration using serial communications from a PC. The correct default for this exercise is ‘PCT23(3) – On/off Controller, On/off Relay Output’. Refer to the PCT20H Instruction Manual for details. The default configurations for PCT23-MKII are listed in the PCT20H Instruction Manual.

Note that the default setting will set the process variable (Input 1) and the setpoint range (SP Hi Limit) to 100% range. It will also set the value of the alarm (A1S1 Value) to 90% of the range. In this exercise these will be changed to appropriate engineering units manually (100% =150 °C range) using the keys on the front of the controller to demonstrate how the controller can be configured using appropriate menus.

Refer to Operational Procedures 1, 2 and 3 in this manual if necessary.

Note: If a PC is not available to configure the controller then the controller can be configured manually by applying the settings listed under the default PCT23(3) in the PCT20H Instruction Manual.

Procedure

i. Connect the ‘process variable’ (T1) 0-5V output sockets on the PCT23 console to the 0-5V analogue input 1 sockets on the PCT20H ensuring that the output switch on the PCT20H is set to the 0-5V position.

ii. Download the default configuration ‘PCT23(3) – On/off Controller, On/off Relay Output’. Refer to the PCT20H instruction manual for instructions, if necessary.
Configure the PCT20H controller to display the water level in engineering units as follows:

iii. Press the 'Setup' key (S) on the keypad until 'Input 1' is displayed.

iv. Press the 'Function' key (F) until 'In 1 Hi' is displayed.

v. Press the 'up/down' keys to change the value from 100 % to 150 °C.

**Note:** To speed up the change of a numerical value, hold down the 'up' or 'down' key as appropriate and then press the other key. This will increase the units by which the numerical value is being changed.

vi. Press 'S' until 'Control' is displayed.

vii. Press 'F' and 'up/down' keys to obtain the following values:

- SP Hi Limit
- 150.0

viii. Press 'S' until 'Alarms' is displayed.

ix. Press 'F' and 'up/down' keys to obtain the following values:

- A151 Value
- 50.0

The controller is now configured to monitor the temperature of the product leaving the holding tube in engineering units. The setpoint can be set from 0 – 150 °C and the alarm is set to activate at 50 °C.

x. Press the 'Lower Display' key. This returns the controller from the settings menu to the monitoring display. This should read 'Man' indicating manual control, the level of water in tank A and a reading of 'Out', the output of the controller (not connected or used in this exercise).

xi. On the PCT23 console switch the feed pump on (selector switch set to Manual) then set the speed control to 5.0. Switch the heater on (selector switch set to manual) then set the heater control to maximum.

xii. Observe that the process variable indicated on PCT20H is the temperature T1 by comparing the reading with T1 indicated on the PCT23 console.

xiii. When the temperature T1 exceeds 50 °C observe that the alarm indicator illuminates on the controller.

xiv. Switch off the feed pump.

**Conclusions**

The procedure for connecting and configuring a typical industrial controller (PCT20H) for measurement of temperature (T1) in engineering units has been introduced.

The configuration of the controller for different types of output suitable for level control will be demonstrated in the following exercises.

As the controller has been configured for on/off control of temperature, it is sensible to continue with Exercise 13.2
EXERCISE 13.2 – EXTERNAL ON/OFF TEMPERATURE CONTROL

Object
To demonstrate the use of an industrial controller to control process temperature (proportional input) using on/off relay output.

The controller will be used to switch the heaters on and off to maintain the temperature T1 at the top of the holding tube.

Equipment Required
PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed (optional).

Equipment Set up
PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

All controls on PCT23 set to manual operation and safe default positions.

Ensure tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

If using the PC to monitor the performance check that the USB Port on the PCT23 console is connected to that on the PC. Run Exercise A.

PCT20H configured with settings from Exercise 13.1.

Refer to Operational Procedures 1, 2 and 3 if necessary.

Note: If required PCT20H can be set up remotely using serial communications via a PC but the process variable (Input 1) will be set to 100% (=150°C temperature range). This can be changed to engineering units manually or remotely if required. Refer to the PCT20H instruction manual for further information. The configuration for this demonstration is PCT23(3) – On/off controller, On/off relay output.

Procedure

i. Connect the relay output 'N/C contact' sockets on the PCT20H to the water heater 'on/off control' input sockets on the PCT23 console.

ii. Set water heater power control to 5.00.
    Set water pump speed control to 5.00.
    Set feed pump speed control to 5.00.

Manual Control

iii. Check that PCT20H controller is in manual operation ('MAN' indicator illuminated). If not press 'manual/auto' key.

iv. Set water heater function switch to 'On/Off Control'.

v. Attempt to maintain the temperature T1 at 40°C by operating the 'up/down' keys on the controller to produce a controller output of 0% or 100% (off or on). You are manually controlling the temperature by switching the heaters off when T1 is above 40°C.
Automatic Control

vi. Using the 'up/down' keys, set 'SP' to 40.0 to enter the required set point at 40.0°C.

vii. Set PCT20H controller to automatic using the 'manual/auto' key.

viii. Observe how the controller maintains the temperature (use the software if available).

ix. Apply step changes to the system and observe the response, e.g. change the set point to 45°C, increase the feed pump speed control etc.

Conclusions

The concept of on/off process control has been introduced using temperature as the process variable.

The output from the controller can only be in two states, on or off.

Discuss the advantages over manual control.

Consider the need for hysteresis when using a controller of this type.
EXERCISE 13.3 – EXTERNAL TIME-PROPORTIONED TEMPERATURE CONTROL

Object
To demonstrate the use of an industrial controller for proportional (PID) control of process temperature (proportional input) using time proportioned relay output.

The controller will be used to switch the heaters on and off in a time proportioned cycle to maintain the temperature T1 at the top of the holding tube.

Equipment Required
As Exercise 13.2.

Equipment Set up
As set at the end of Exercise 13.2.

Manually or remotely change the configuration of the controller to the default ‘PCT23(2)’ PID Controller, Time Proportioned Relay Output. Refer to the PCT20H Instruction Manual for details.

Procedure

i. Maintain the PCT23 Console settings, and wiring arrangements on completion of Exercise 13.2.

ii. Changes and additions to the configuration of the PCT20H controller are as follows:

<table>
<thead>
<tr>
<th>Set Up</th>
<th>Function</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning</td>
<td>Prop BD</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Rate Min</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Rset RPM</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Manual Control

iii. Check that PCT20H controller is in manual operation ('MAN' indicator illuminated). If not press 'manual/auto' key.

iv. Note that the available output is now variable between 0 and 100%. Set the controller output to 50% and observe how a proportional output is achieved by the controller using a mark/space mode of action (with cycle time set to 10 seconds, 50% output is achieved with the heaters on for 5 seconds and off for 5 seconds).

v. Attempt to maintain the temperature at 40°C by adjusting the output of the controller.

Automatic Control

vi. Set PCT20H controller to automatic using the 'manual/auto' key.

vii. Ensure the setpoint is set at 40°C.

viii. Observe how the controller maintains the temperature T1.
ix. Apply step changes to the system and observe the response, e.g. change the setpoint to 45°C, increase the feed pump speed control etc.

Conclusions

A time proportioned output allows a controller to produce a proportioned output variable from 0 to 100%. This allows PID control to be implemented using a simple relay output on the controller.

One disadvantage of time proportioned control over simple on/off control is the need to enter correct settings for P, I and D into the controller to suit the process being controlled.

Discuss applications where this technique would not be appropriate.
EXERCISE 13.4 - EXTERNAL PID TEMPERATURE CONTROL

Object
To demonstrate the use of an industrial controller for proportional (PID) control of process temperature (proportional input) using proportional (voltage) output.

The controller will be used to vary the power to the heaters to maintain the temperature T1 at the top of the holding tube.

Equipment Required
As Exercise 13.3

Equipment Set up
As set at the end of Exercise 13.3.

Manually or remotely change the configuration of the controller to the default ‘PCT23(1)’ PID Controller, Proportional Output. Refer to the PCT20H Instruction Manual for details.

Procedure
i. Keeping the other console settings the same as in Exercise 13.3, change the water heater function switch to 'input socket'.

ii. Keeping the other wiring the same as in Exercise 13.3, remove the wires connecting the 'on/off' input sockets of the water heater to the relay output sockets of the PCT20H, and instead connect the 0-5V input sockets of the water heater to the 0-5V analogue output of the PCT20H.

iii. Changes and additions to the settings of the PCT20H controller are as follows:

<table>
<thead>
<tr>
<th>Set Up</th>
<th>Function</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning</td>
<td>Prop BD</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Rate Min</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Rset RPM</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Manual Control
iv. Check that PCT20H controller is in manual operation ('MAN' indicator illuminated). If not press 'manual/auto' key.
v. Set controller to 50% output using 'up/down' keys. Note how this output is now achieved, compared with the control in Exercise 13.3.
vi. Attempt to achieve and maintain a temperature of 40°C at T1 by manual control of the output.

Automatic Control
vii. Set PCT20H controller to automatic using the 'manual/auto' key.
viii. Keeping the set point at 40°C observe how the controller maintains this temperature.
ix. Apply step changes to the system and observe the response, e.g. change the set point to 45°C, increase the feed pump speed control etc.
Conclusions

Proportional output provides a superior form of process control.

One disadvantage of proportional control over simple on/off control is the need to enter correct settings for P, I and D into the controller to suit the process being controlled.
EXERCISE 14 – ALARM FUNCTIONS

Object
To introduce the configuration and use of an alarm on the industrial controller (PCT20H).

An alarm allows the process to be maintained within specified maximum or minimum values by taking appropriate actions (on/off via relay output).

In this exercise the hot water supply will be switched off if the product temperature exceeds a set value.

Procedure
i. Keeping the wiring configuration the same as for Exercise 13.4, also connect the alarm output 'N/O Contact' of the PCT20H to the 'on/off control' input sockets of the water pump on the PCT23.

ii. Keeping the other PCT23 console settings the same as in Exercise 13.4, turn the water pump function switch from 'manual' to 'on/off'.

iii. Changes and additions to the settings of the PCT20H controller are as follows:

<table>
<thead>
<tr>
<th>Setting</th>
<th>Function</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1S1 Val</td>
<td></td>
<td>45.0</td>
</tr>
</tbody>
</table>

Manual Control
iv. Set output of controller to 50% so that the temperature at T1 begins to rise.

v. Observe the result of heating the product at T1 beyond the alarm value of 45°C (the hot water pump should shut off and the controller screen should indicate in the top left corner that alarm 1 has been tripped).

vi. Note the value of the alarm hysteresis (the amount the set temperature is exceeded before the alarm activates).

Automatic Control
vii. Put the controller into automatic control using the 'manual/auto' key.

viii. Set the set point to 50°C.

ix. Change the Alarm value to 51°C. This is done by changing the 'A1S1 Val' in the 'set up alarms' group of the controller settings.

x. Observe the system as it settles to the set point. Note the effect of having the alarm value so close to the set point on the achievement of steady state.

Conclusions
This exercise is a simple introduction to the use of alarms in the control of a process control.

An alarm is important in preventing system failures or danger to the operator (such as tanks overflowing or heating water boiling).

For the system to operate satisfactorily it is important to configure the alarm with a suitable hysteresis and set point to suit the process being controlled.
EXERCISE 15 – COMPARISON OF CONTROL REQUIREMENTS

Object
An Industrial Controller can be connected and configured to suit different control needs. This exercise will test your ability to change the connections and configuration to control level, flow and temperature.

A prior working knowledge of the PCT23 Process Plant Trainer and PCT20H Industrial Controller will be required to complete this exercise.

Equipment Required
PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed (optional).

Equipment Set up
PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.
Tanks A & B empty.
All controls on PCT23 Console set to manual operation and safe default positions.
If using the PC to monitor the performance check that the USB Port on the PCT23 console is connected to that on the PC. Run Exercise A.
PCT20H configured with default settings (refer to PCT20H Instruction Manual for details).
Refer to Operational Procedures 1, 2 and 3 if necessary.

Procedure
i. Inflow control of level L1 - on/off control
   Connect and configure the Industrial Controller to control the level in tank A (process variable L1 indicated in mm) with on/off control of SOL4 via the relay output on PCT20H.
   Vary the flow of water out from tank A using the feed pump to test the operation of the controller.

ii. Inflow control of level L1 - time proportioned PID
    Change the configuration of PCT20H to give time-proportioned control of the above arrangement.
    Vary the flow of water out from tank A using the feed pump to test the operation of the controller.

iii. Outflow control of level L1 - PID control
     Change the connections and configuration of PCT20H to control level L1 with proportional (PID) control of the feed pump speed (N1). Vary the inflow to tank A using manual valve V1 to test the operation of the controller.

iv. Low Alarm - Low level
Connect and configure an alarm on PCT20H to switch off the feed pump (N1) if tank A empties. Close SOL4 and test the alarm.

v. Control of flow F1 - PID control

Connect and configure the Industrial Controller to control the feed flow from tank A (process variable F1 indicated in ml/min) with proportional (PID) control of the feed pump speed (N1).

Use a bypass connected to the heat exchanger to disturb the flow of water to test the operation of the controller.

vi. Control of temperature T2 - on/off control

Connect and configure the Industrial Controller to control the temperature in the heating tank (process variable T2 indicated in °C) with on/off control of heater power PWR via the relay output on PCT20H.

Vary the flows through the heat exchanger (feed pump N1 and hot water pump N2 operating) to test the operation of the controller.

vii. Control of temperature T4 - time proportioned control of heater power

Connect and configure the Industrial Controller to control the temperature of the heated feed leaving the heat exchanger (process variable T4 indicated in °C) with time proportioned control of heater power PWR via the relay output on PCT20H.

Vary the flows through the heat exchanger (Feed pump N1 and hot water pump N2 operating) to test the operation of the controller.

viii. Control of temperature T1 - PID control of heater power

Connect and configure the Industrial Controller to control the temperature of the product after the holding tube (process variable T1 indicated in °C) with PID control of heater power PWR via the proportional output on PCT20H.

Vary the flow of through the heat exchanger (Feed pump N1 and hot water pump N2 operating) test the operation of the controller.

ix. High Alarm - Over temperature

Connect and configure an alarm to switch off the hot water pump (N2) if temperature T1 exceeds the setpoint by 5°C. If necessary manually adjust the power to the heaters to test the action of the alarm.

Conclusions

An industrial controller can be used for a wide variety of control applications but the connections and configuration must be changed to suit the needs of the individual control loop.
EXERCISE 16.1 – MANUAL TUNING OF A PID CONTROLLER

Object
To determine the ideal P, I and D settings for an Industrial Controller (PCT20H) to suit a particular process (single loop, temperature T4 to heater power PWR).

A step change will be applied to the process under manual (open loop) control and the resulting reaction curve will be analysed to determine suitable controller setting (reaction curve method).

Note: It is assumed that previous exercises have been carried out and you are familiar with the operation of the PCT20H Industrial Controller.

Equipment Required
PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed.

Equipment Set up
PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

All controls on PCT23 set to manual operation and safe default positions.

Ensure tank A is filled with cold water. If not set valve control switch SOL4 to FILL A (do not allow tank A to overflow).

USB port on the PCT23 console connected to that on the PC (refer to Operational Procedures 1, 2 and 4 if necessary).

Theory
The typical response curve of a process following a step change is shown below:

From this curve the following values can be obtained:

The time lag L between the step change in power and the response from T4.
The gradient R at the steepest part of the curve.
The value of the step change in power M as a percentage of the total range available. The value R1 can be calculated as follows:

\[ R1 = r/m \]

Suitable controller settings can be calculated as follows:

\[ P = 0.5 \times (R1 \times L) \text{ to } 0.8 \times (R1 \times L) \% \]
\[ I = 2.0L \text{ to } 2.5L \text{ min} \]
\[ D = 0.3L \text{ to } 0.5L \text{ min} \]

Procedure

i. If using the PC to monitor the response, run Exercise A and begin logging.

ii. Connect the water heater 0-5V input sockets to the 0-5V output sockets on PCT20H.

iii. Set the water heater function switch on the PCT23 console to INPUT SOCKET.

iv. Set the hot water pump power control (N2) to 50%.

v. Set the feed pump speed control (N1) to 50%.

vi. Set the manual controller output (PCT20H) to 15%.

vii. Allow the system to heat up and achieve steady state.

viii. Once the system has stabilised introduce a step change by increasing the controller output to 50%. Monitor the effect of this change on T4.

ix. Once the temperature has exceeded 70°C set the controller output to 0% and allow the system to cool.

x. Obtain a hard copy of the graph of T4 and heater power, having adjusted the axes to concentrate on the step change and steep gradient immediately following it.

Using the theory above, determine L, R and M and R1 from the graph then calculate suitable P, I and D settings for the controller.

xi. Enter the calculated settings in the Industrial Controller (PCT20H) with an appropriate set point then switch the controller to automatic control.

xii. Allow the process to stabilise then apply a step change. Observe the response to the step change.

Temperature T4 should show a good response, quickly settling with minimal overshoot. If you consider that improvements can be made, adjust P and/or I in small steps as appropriate then apply a step change to test the response.

Conclusions

Settings for a PID controller can be tailored to the system being controlled by analysis of the open loop response of the process following a step change.

Fine tuning of the parameters may be required to give optimum control of the process.

The reaction curve method demonstrated has the advantage of requiring a simple one shot measurement from which the controller settings can be calculated.
The ultimate period method is an alternative technique which requires the system to be placed into regular continuous oscillation.

This can take considerable time to achieve and so has not been demonstrated here.
EXERCISE 16.2 – AUTOMATIC TUNING OF A PID CONTROLLER

Object

The calculations introduced above can also be made automatically by the controller when it is set up to tune itself automatically. This is, naturally, a more efficient way of producing P, I and D values for a particular system.

Procedure

i. Maintain the wiring set up as in Exercise 16.1.

ii. Maintain the console settings as in Exercise 16.1.

iii. Changes and additions to the PCT20 controller settings are as follows:

<table>
<thead>
<tr>
<th>Set Up</th>
<th>Function</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning</td>
<td>Prop Bd</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>Rate Min</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Rset RPM</td>
<td>0.0</td>
</tr>
</tbody>
</table>

iv. With the PCT 20H in manual, set the output to the water heater at 20%.

v. Allow the system to stabilise at this output. Note the steady state T1 value.

vi. Place the controller in automatic using the 'manual/auto' key.

vii. Set the set point at the previous steady state T1 temperature, and allow the controller to maintain that temperature for a short time.

viii. Make a step change by changing the set point to 60°C.

The automatic tuning system of the controller should engage after a short pause, indicated by a large 'T' in the top left corner of the screen.

ix. Allow the controller to analyse the system. Observe the changes in output it makes.

x. Once the auto-tune is finished, the controller puts itself back into 'manual'. At this point, check the settings of controller. The settings 'Prop Bd', 'Rate Min', and 'Rset RPM' in the 'tuning' group correspond to the P, I, and D settings respectively. These should have been changed by the auto-tune process to the optimum values for the system.

xi. Allow the system to cool to below 35°C.

Conclusions

The industrial controller can determine values for P, I and D to suit a particular process using adaptive tuning.

Compare the values obtained in this way with those calculated manually in the previous exercise.
EXERCISE 17 – INTRODUCTION TO SCADA

Objective

To demonstrate supervision of the Industrial Controller PCT20H by PC based software - an introduction to SCADA with serial communications from a remote PC to and from the controller.

Equipment Required

PCT23 Process Plant Trainer
PCT20H Industrial Controller
PC with Armfield software installed.

Equipment Set up

PCT23 commissioned with a supply of cold water connected and all process outlet connections to drain.

Connect the RS232 communications port on the PCT20H to serial 1 port on the PC.

Maintain the wiring connections and console settings for the PCT23 achieved at the end of practical training Exercise 11, 12, 13 or 16 (the controller must remain configured to suit the appropriate exercise).

Refer to Operational Procedures 1, 2 and 4 if necessary.

Procedure

i. Load the PIE Software supplied which PCT20H which allows serial communication between a PC and the Industrial Controller PCT20H.

ii. Choose ‘PC Comm Setup’ on the PC and set Communication Type to ‘RS485’.

iii. Check that the controller is correctly configured to suit serial communication with the PC as follows:

Press ‘Set up’ (S) on the keypad repeatedly until ‘Com’ is displayed.

Press ‘Function’ (F) on the keypad to display ‘ComState’.

Use the up/down keys to change this to ‘MODBUS’.

Using the ‘F’ key to cycle through the settings, and the Up/Down keys to change them, alter the following settings to these values:

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Com Addr</td>
<td>1</td>
</tr>
<tr>
<td>ComState</td>
<td>Modbus</td>
</tr>
<tr>
<td>IR Enable</td>
<td>Enable</td>
</tr>
<tr>
<td>Baud</td>
<td>9600</td>
</tr>
<tr>
<td>Tx Delay</td>
<td>1</td>
</tr>
<tr>
<td>WS Float</td>
<td>FP B</td>
</tr>
<tr>
<td>ShedEnab</td>
<td>Enable</td>
</tr>
<tr>
<td>Shedtime</td>
<td>90</td>
</tr>
<tr>
<td>Shedmode</td>
<td>Last</td>
</tr>
<tr>
<td>ShedSP</td>
<td>To LSP</td>
</tr>
<tr>
<td>Units</td>
<td>Percent</td>
</tr>
<tr>
<td>CSP Ratio</td>
<td>1.00</td>
</tr>
<tr>
<td>CSP Bias</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Loopback

Disable

Press the 'lower display' key to leave the set up.

iv. Chose 'Online configuration'. This allows individual parameters to be changed in the controller while the controller is actively controlling a process.

Select a parameter such as the setpoint. Edit this and send the modified value to the process controller. Observe that this parameter is updated in the controller and the process responds accordingly.

Repeat this for different parameters.

v. Choose 'Maintenance Data'. This allows the operating parameters and status of the UDC3200 process controller to be monitored while it is controlling a process. This option is used primarily for diagnostics but also allows the performance of a process / process controller to be monitored.

Operate the process and observe the changing parameters in the controller such as process variable or controller output as well as the fixed parameters such as the setpoint. These can be observed on the PC using the serial communications link between the PC and the controller.

vi. Disconnect the computer from the PCT20H controller by removing the plug from the RS232 port. Observe the response of the controller and the warnings displayed by the PC software.

Conclusions

Serial communication is a widely used industrial technique which allows a process controller to be supervised by remote PC.

A break in communication between the PC and process controller does not affect the ability of the controller to control the process.

The PC is able to monitor the performance of the process through information gained from the controller. The controller settings can be changed directly from the PC. Discuss the advantages and disadvantages of this approach.
EXERCISE 18 – SEQUENCING PLANT OPERATION USING A PLC

Objective

SCADA for a PLC: Using a PC as supervisor to control the process via the PCT19BR Industrial Programmable Logic Controller.

In this exercise the process is taken through a simple sequence which is controlled by a ladder program stored in the PLC. Serial communication between the PLC and PC allows the PC to display information about the process obtained from the PLC and parameters in the ladder program of the PLC to be changed by the PC.

Note: The PLC is monitoring the sensors and controlling the process. The PC is only supervising the operation by obtaining data from the PLC and sending revised control parameters to the PLC.

Equipment Required

PCT23 Process Plant Trainer
PCT19BR Industrial Programmable Logic Controller
PC with Armfield software and Allen Bradley 'AI' software for SLC500 (PCT19BR) and Armfield PCT23 SCADA software loaded

Equipment Set up

PCT19BR loaded with sequencing ladder program. See the PCT19BR Instruction Manual for information on loading the ladder program.

PCT23 commissioned with a supply of cold water connected.

Feed tanks A and B empty.

All function switches set to MANUAL.

ALL potentiometers set to minimum.

Valve control switches set as follows:

SOL1-DIVERT,
SOL2-FEED A,
SOL3-STOP,
SOL4-STOP,
SOL5-STOP.

Refer to Operational Procedures 1 and 6 if necessary.

Ensure that the Level in Tank A (L1) is 0mm (indicated on the console display) when the tank is drained to the zero mark on the scale. Re-calibrate the display if necessary.

Procedure

i. Disconnect the USB cable from the rear of the PCT23 console and connect the adjacent I/O PORT to the I/O Port at the rear of the PCT19BR using the I/O ribbon cable with 50 way IDC connectors.

ii. Connect a pair of yellow banana leads between the digital output sockets O:1.0/0 and the yellow ON/OFF control sockets for Heater Power on the PCT23 Console.
iii. Connect the 'DF1 Port' in slot 1 of PCT19BR to the Serial Port 1 of the PC using the serial communications lead with 9 way 'D' type connectors.

iv. Set the Heater Control function switch to ON/OFF and set all other function switches on the PCT23 console to 'I/O Port'.

v. Load the PCT23 SCADA software package.

vi. View the control set up screen (PLC icon) and check that the following parameters are entered correctly:

<table>
<thead>
<tr>
<th>Stage 1 - Filling</th>
<th>Level required</th>
<th>75mm</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Stage 2 - Pre-heating</th>
<th>Speed Hot Pump</th>
<th>50.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speed Feed Pump</td>
<td>50.0%</td>
</tr>
<tr>
<td></td>
<td>Set point</td>
<td>55.0°C</td>
</tr>
<tr>
<td></td>
<td>Gain</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Intg. Term</td>
<td>0.0 MPR</td>
</tr>
</tbody>
</table>

Deriv. Term 0.00 min

<table>
<thead>
<tr>
<th>Stage 3 - Processing</th>
<th>Divert Temp</th>
<th>42°C</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Hot Water</th>
<th>Set point</th>
<th>45°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gain</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Intg. Term</td>
<td>1.0 MPR</td>
</tr>
</tbody>
</table>

Deriv. Term 0.00 min

<table>
<thead>
<tr>
<th>Feed</th>
<th>Set point</th>
<th>200 m/m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gain</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Intg. Term</td>
<td>0.4 MPR</td>
</tr>
</tbody>
</table>

Deriv. Term 0.00 min

<table>
<thead>
<tr>
<th>Stage 4 - Refilling</th>
<th>Tank A Level</th>
<th>50mm</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Stage 5 - Washing</th>
<th>Feed Pump Speed</th>
<th>50.0%</th>
</tr>
</thead>
</table>

The equipment is now set up for the demonstration of sequencing of the process via SCADA supervised PLC.

vii. Click GO to begin logging data.

viii. Choose 'start ladder' from the control set up screen to start the processing sequence.

ix. View the process diagram and observe that the screen shows the process layout and relevant measurements from the process obtained by serial communications from the PLC.

x. Observe the process as the following sequence of operations are performed (view the History window at any time to view the responses):

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Filling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tank A is filled with water (product to be processed) representing the process fluid.</td>
</tr>
<tr>
<td></td>
<td>Tank B is filled with water (used to pre-heat the system).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage 2</th>
<th>Pre-heating</th>
</tr>
</thead>
</table>
The pump and heaters in the hot water system are activated and hot water is circulated through the heat exchanger.

The product system is then pre-heated by pumping water from tank B.

**Stage 3**  
**Processing (pasteurising)**  
Once the system has reached temperature, product from tank A is run through the system to be pasteurised.

The processing ends when tank A is empty.

**Stage 4**  
**Refilling**  
Tank A is then filled with water to rinse the process fluid from the system.

**Stage 5**  
**Washing**  
The water from tank A is pumped through the process pipework, initially with SOL1 diverting and then with SOL1 allowing flow through the remainder of the pipework.

xi. While the PLC is sequencing, disconnect the serial communications lead from the 'DF1 Port' on PCT19BR.

Observe that the process continues to be controlled by the PLC despite the loss of communications.

Observe that the PC displays an alarm condition, namely loss of communications.

xii. Reconnect the serial communications lead to the 'DF1 Port' on PCT19BR. Click on 'Start Comms' in the Control screen to re-start the communications.

xiii. Allow the process to complete its cycle, then stop the logging of data.

The response of the process during any of these stages of processing can be reviewed by viewing the Graph screen.

xiv. Decide on a revised set of operating parameters then restart the sequence after entering the new parameters in the control set up screen.

Observe that the required changes are incorporated in the various stages of the processing.

**Conclusions**

This exercise has shown how a process can be taken through a sequence of different operations using a PLC to control the process which is supervised by a PC.

Serial communication between the PLC and PC allows:

1. The PC to acquire information about the process from the PLC to provide the operator with clear information about the progress and logging of the information to disc.

2. The PC to send information to the PLC to change the control parameters in the ladder program.
Loss of communication between the PC and PLC does not interrupt the operation of the process (current information is not available to the operator and control parameters in the PLC cannot be changed but the process continues to operate with the current parameters).
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