

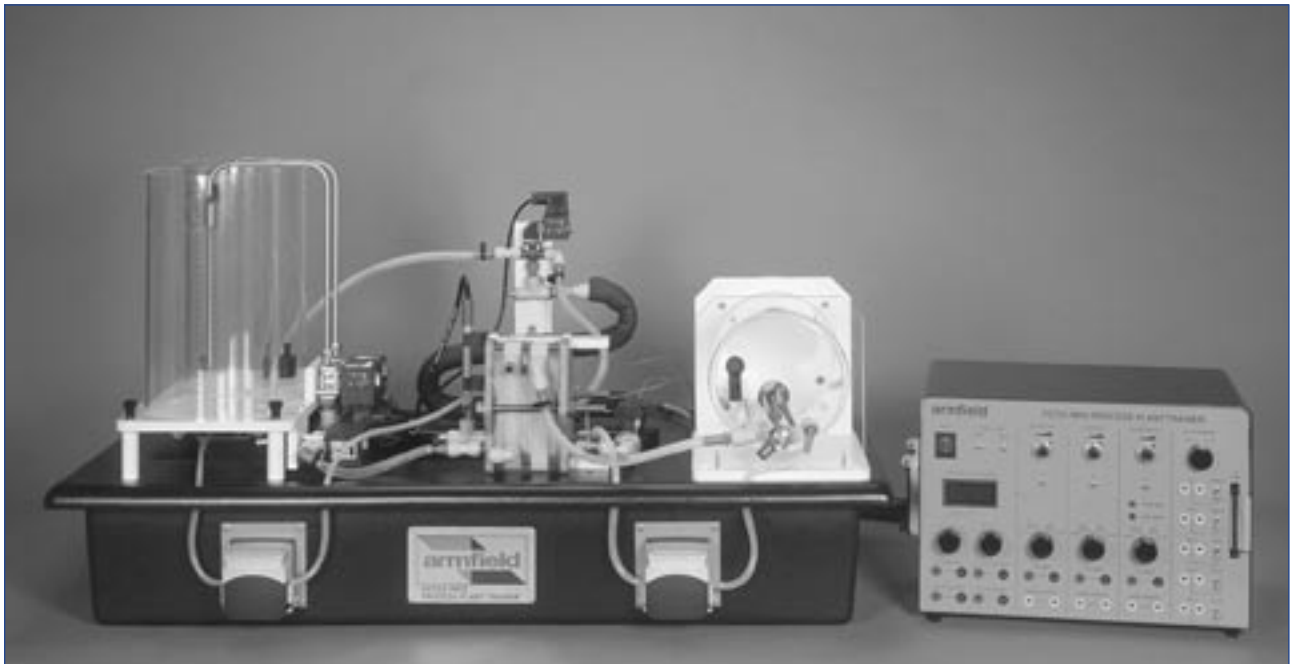


armfield

PROCESS PLANT TRAINER

PCT23MkII

issue 3



The Armfield Process Plant Trainer can be used to demonstrate a complete range of process control methods and strategies. Manual control, single feedback loops, through to sophisticated cascade loops and distributed supervisory control of the whole process by a remotely located computer can be demonstrated. The system is a miniature replication of a true production process. The student is presented with real process control problems, with realistic dynamic behaviour and instabilities.

- *multiple inputs, multiple sensors, multiple control strategies*
- *temperature, level, flow and conductivity control loops can be implemented*
- *effects of 'dead time'*
- *operational sequencing, including start up to shut down*
- *recycle implications on process control*
- *on/off, proportioning, PID, PLC, SCADA*
- *fault simulation and diagnosis*
- *includes computer interface (USB) and sophisticated educational and data logging software*

Process Control Technology

PCT



DESCRIPTION

The PCT23MkII is a bench top process control system, comprising a process unit mounted on an ABS plinth, an electrical control console, and control software which can be run on any Windows 98 or Windows 2000 PC with USB capability.

a) Process Unit:

The process is modelled on an industrial high temperature short time (HTST) pasteurisation process. In this process the product stream has to be kept at a predetermined temperature for a minimum time, usually for bacteriological purposes. This is effected by the use of a holding tube which delays the product stream, thus posing particular process control problems and introducing the concept of 'dead time'.

Other reasons why the HTST process is a particularly suitable basis for teaching process control are the use of a three stage heat exchanger (recycle, heating and cooling) and the use of a divert valve to reject inadequately treated product. Again these important industrial principles pose real process control problems and help maintain the students' interest.

Further process control problems are illustrated by the use of two feed tanks, with different level sensor types.

Solenoid driven valves control the filling and emptying of these tanks. These allow different level control strategies to be developed and provide start-up and shut-down operational sequencing capability.

The unit includes a wide range of instrumentation for temperature and flow measurement. It also includes a conductivity sensor, allowing simple process concentration experiments to be performed.

The unit comprises:

- *feed system with peristaltic pump*
- *water heating unit with peristaltic pump*
- *cooling water system*
- *plate heat exchanger with holding tube*
- *flow sensor in feed line*
- *conductivity sensor*
- *4 temperature sensors*
- *level sensor in product tank*
- *high/low level switches in washing/reagent tank*
- *2-way solenoid valves for filling feed tanks and cooling water to exchanger*
- *3-way solenoid valves for selecting feed tank and diverting waste product*
- *Connections to the electrical console*

b) Control Console:

The control console provides the electrical interface and signal conditioning for the process module. It also includes a USB interface for a Windows® computer. The process module sensor outputs can be displayed in engineering units on an integral LED display. The outputs are also available for external monitoring.

The drive signals to the process module can be selected as either manual control from the front panel, control from a PC via the USB bus, on/off control from an external source (e.g. the Armfield PCT19BR PLC), or analogue control from an external source (e.g. the Armfield PCT20H PID). The source signals for both pumps and the heater are individually selectable.

Electrical faults may be introduced into any of the low voltage measurement or control signals by a fault emulator installed in the electrical console. Faults may be inserted individually or in combination to suit the student's ability. The quick release fittings used throughout the process allow faults to be introduced into the process pipework.

The unit comprises:

- product feed pump speed control
- heating fluid pump speed control
- heater power measurement and control
- temperature (x 4), flow, level & conductivity measurement
- digital inputs/outputs (from switches/ to solenoid valves)
- simultaneous connection of all signals to PCT19BR via 50 way IDC connector or PC via USB port
- front panel sockets for connection to accessories, in particular industrial controllers and chart recorder

c) Software:

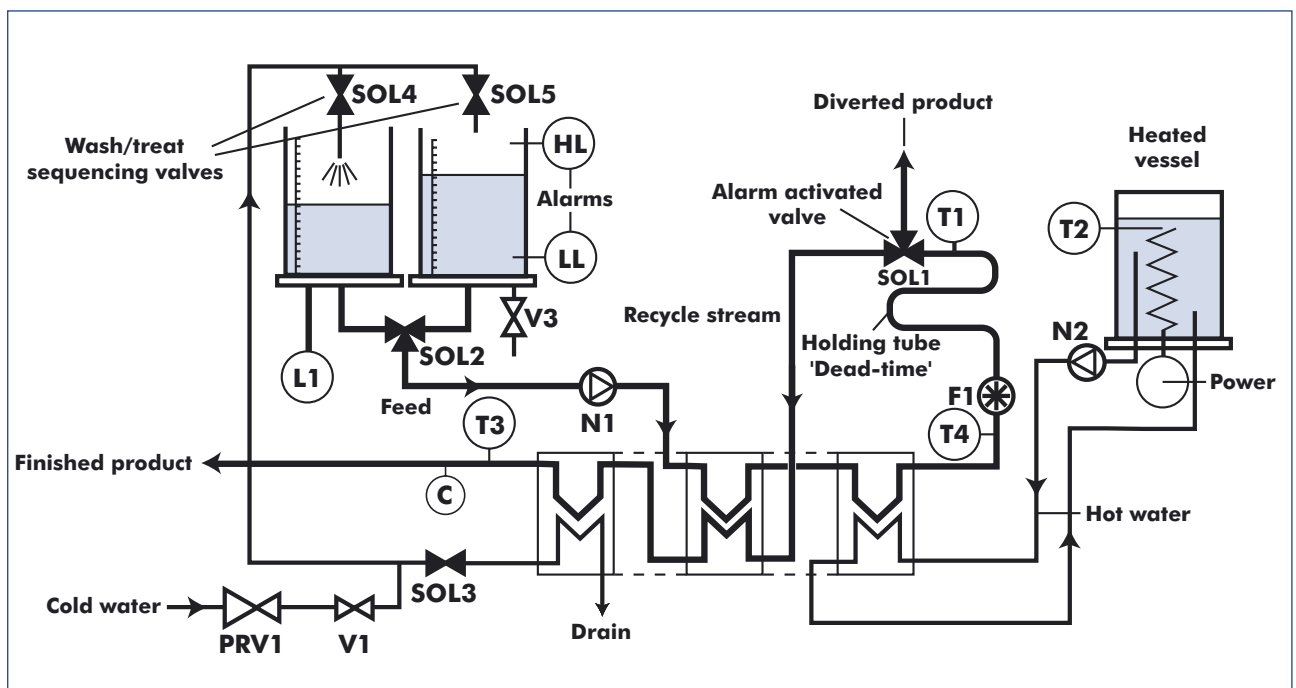
Included in the basic equipment supply is an advanced educational software package which implements the control functions. The software displays a real time process mimic diagram, and includes PID control algorithms, with user control over the key parameters. A number of predefined student exercises are implemented, such as alarm actions and acknowledgements, different single PID loops, cascade and multiple PID loops.

Included in the software is a sophisticated data logging and graphical display capability. This capability can be used even when the control signals are derived externally or manually. The data can be saved and recalled, or exported in Microsoft® Excel format.

Other facilities included in the software are a series of presentation screens to aid in the setting up, using the equipment, analysing the results, etc. This is backed up by a comprehensive Help system.

Advanced users may wish to produce their own control software using packages such as Labview, MatLab or 'C'. This is possible using the USB interface on the PCT23, as the low level software driver (DLL) is accessible and interfacing instructions are provided.

For more advanced use, an optional software package has been developed for use with the Armfield PCT19BR to demonstrate SCADA. This package (order code PCT23SCADA) allows the PLC to control the process, and extracts the data from the PLC via an RS232 connection. The PLC data is then displayed on the mimic diagram, giving the PC the supervisory role of the SCADA implementation.



Process flow diagram

PRACTICAL TRAINING EXERCISES

The Armfield PCT23MkII Process Plant trainer is designed to cover course topics ranging from a first introduction to the subject of process control through to demonstrations of the latest advanced techniques including the use of on-line mathematical models.

PCT23 TRAINING EXERCISES

- Plant monitoring using a PC
- Calibration of sensors
- Process dynamics I
 - Direct heating
 - Indirect heat exchange
 - Dead time
 - Step changes
 - Heat losses / efficiency
- Process dynamics II
 - Interactions between loops
 - Heat regeneration
 - Indirect cooling
 - Understanding process duty and its implications
- Direct Digital Control using a PC
 - PID control of level
 - PID control of flow
 - PID control of temperature
 - PID control of conductivity
 - Indirect PID control of temperature
 - Indirect PID control with dead time
 - PID control with alarm driven disturbances
 - Controller optimisation
 - Controller optimisation with dead time
 - Two loop cascade control
 - Two loop control and interactions
 - Three loop control
- Fault finding and diagnostics

TRAINING EXERCISES USING EXTERNAL CONTROLLERS

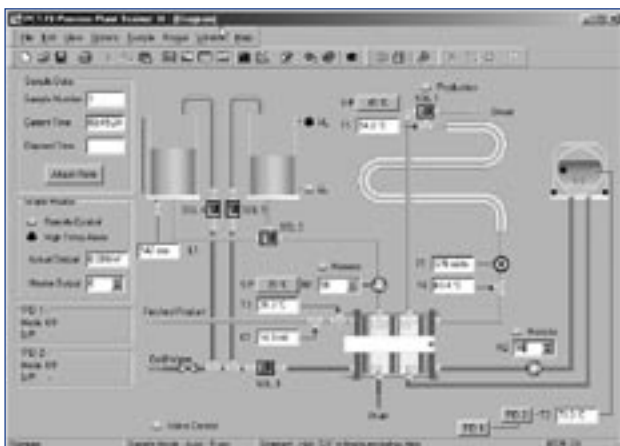
- Using an external controller*
 - Controller setup for level, flow, temperature and conductivity
 - On/off control
 - PID time-proportioned control
 - PID proportional control
 - Alarm functions
 - Comparison of control requirements
 - Manual tuning of a PID controller
 - Automatic tuning of a PID controller
 - Introduction to SCADA
- PID control using a PLC**
 - Introduction to ladder logic
 - One PID loop, two PID loops, alarms
- Sequencing plant operation using a PLC under SCADA**

* requires one Armfield PCT20H Industrial PID Controller

** requires one Armfield PCT19BR Industrial PLC Unit

ADVANCED PROCESS CONTROL:

The equipment is also ideal for more advanced process control topics, and for both project and research work.



Software mimic diagram



Graph plotting facilities

DETAILED PRACTICAL WORK ASSIGNMENTS

PCT23MkII Process Plant Trainer including Windows® software with user provided PC

1a) Manual control with software performing data-acquisition and monitoring tasks only:

- i) gaining familiarity with screen based flow sheet mimic diagrams for monitoring process variables: level, temperature, flow, conductivity and power
- ii) understanding how changing one process variable (eg flow rate) affects the others (e.g. temperature)
- iii) measuring responses to step changes: e.g. characterising the hot water tank as a 'first-order system'; the holding tube as 'dead time' and the plate heat exchanger as a combination of both types of system (Fig 1)
- iv) downloading data to a user-provided spreadsheet for subsequent analysis

1b) Automatic control with software performing control tasks; setting up and studying:

- i) single-loop PID with hot water temperature controlling the power to the heater
- ii) single-loop PID with product temperature controlling heater power
- iii) the effect of adding 'dead time' of the holding tube to the single control loop
- iv) the effect of recycling heated product through the heat exchanger on control action (Fig 2)
- v) the effect on control action of including an alarm-activated diverter valve
- vi) cascade control: whereby product temperature controls the hot water temperature set-point which in turn controls the heater power
- vii) multi-variable control: flow control of the product stream, product temperature controlling the hot water flow rate, hot water temperature controlling the heater power (Fig 3)
- viii) fault simulation and diagnosis, by the instructor switching out selected signals

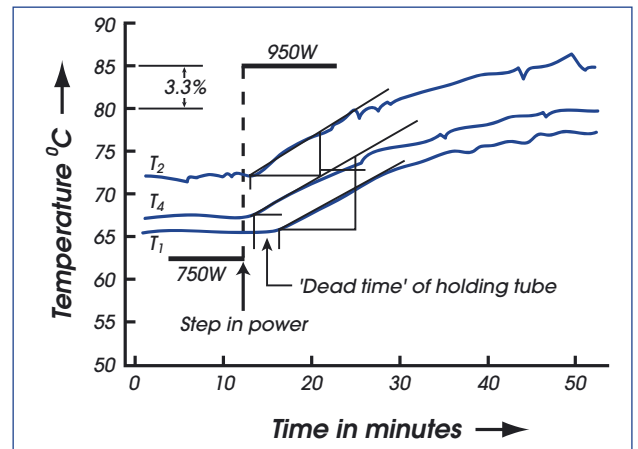


Fig 1: Open-loop temperature responses to a step in change (in power). Use of a 'reaction curve' method to obtain optimum P+I+D settings for a process temperature (T_1 , T_2 and T_4) to control the power to the heater vessel.

T_1 = Process temperature after holding tube

T_2 = Hot water circulating temperature

T_3 = Process temperature before holding tube

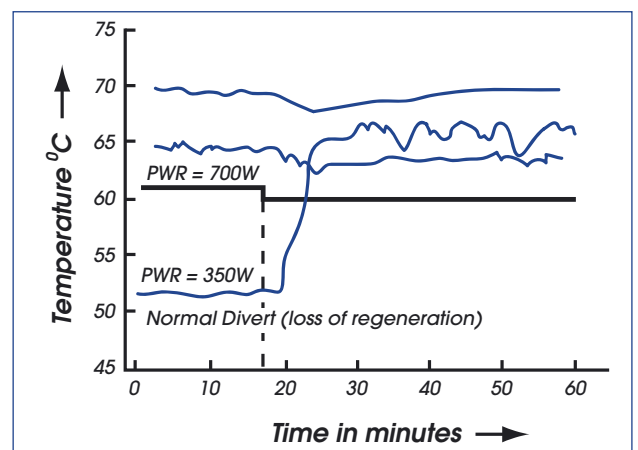


Fig 2: Controlling power consumption with and without a recycle-loop. Product temperature T_1 controlling power (PWR).

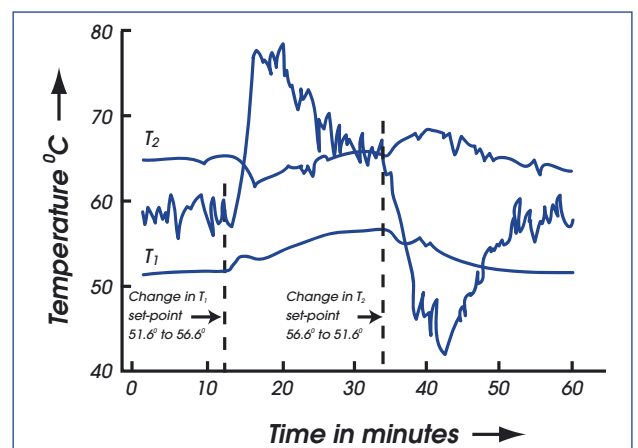


Fig 3: Dual-loop control using Windows software

- Product temperature T_1 controlling hot water circulation rate

- Hot water temperature T_2 controlling heater power (PWR)

Note reaction between T_1 , T_2 and PWR as a result of set-point change to T_1 (up to 50°C then down 50°C).

PCT23MkII Process Plant Trainer with a single PCT20H Industrial PID Controller

2a) All of the single-loop studies listed as 1b)i) to v), with the control actions being set up and performed by the PCT20H controller connected to the front panel of the PCT23 console (also on/off and time proportioned PID control).

The PCT23 software may be used to log simultaneously the plant data on-line to a PC (Fig 4)

2b) Supervision of the Industrial Controller by PC based software - ie: an introduction to SCADA with serial communications from the PC to and from the controller

2c) Alternative single-loops: including level, flow, and conductivity control, alternative temperature control loops
For each of the single control loops selected from the above, practical exercises on the following topics are possible:

- on/off control
- setting up
- P, I and D values
- tuning a controller for optimum performance
- auto/manual transfer
- stability tests

PCT23MkII Process Plant Trainer with two PC20H Industrial PID Controllers

3a) Cascade control as in 1b)vi) but using the controllers connected to the plant in place of direct PC control

3b) Two input, two output control with the product temperature controlling the feed pump and the hot water circulating temperature controlling the heater power. Demonstration of 'interacting' control is thus possible

3c) Feed forward control with product flow rate controlling the hot water circulating rate in addition to heater power being controlled by hot water temperature

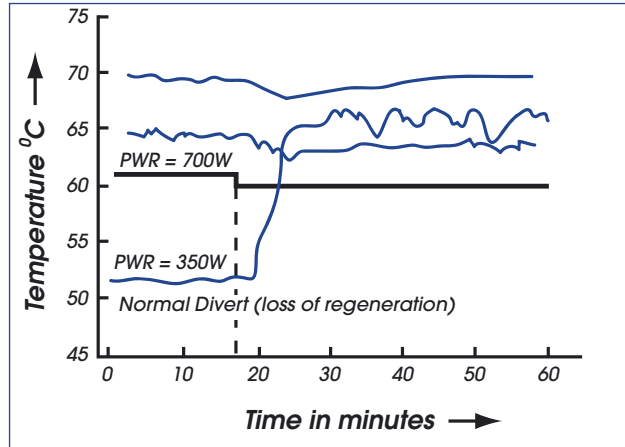


Fig 4: Single closed loop response using PCT20H Industrial PID Controller. Product temperature leaving holding tube (T_1) controlling heater power (PWR) (optimum P+I settings from Fig1:)

PCT23MkII Process Plant Trainer with a single PC19BR Industrial PLC Unit

- 4a) Connecting a PLC to a process
- 4b) Use of ladder logic to set up control and monitoring tasks (requires a PC)
- 4c) Single-loop on/off and PID control studies
- 4d) Setting of alarms in conjunction with PID control loops
- 4e) Two-loop control strategies as in 3b)
- 4f) Using digital inputs and outputs: alarms and control valve actions

Additionally a SCADA software package is available (cat ref PCT23SCADA) which in conjunction with PCT23 and PCT19BR allows studies of:

- g) 'Point to point' SCADA operation via a user provided PC
- h) Sequencing of plant operation: a 5-stage sequence may be set up
 - fill tanks
 - pre-heating
 - heat processing
 - fill wash tank
 - wash

This sequence may be carried out by the PCT19BR PLC alone or under SCADA operation from the PC with VDU mimic diagram display of the progress of the sequencing.

TECHNICAL SPECIFICATION

Flow rate ranges:
product stream: 0-480ml/min
washing reagent: 0-480ml/min
heating fluid: 0-600ml/min
Max temperature of heating fluid: 80°C
Heat exchanger: plate type
Feed and reagent vessel capacities: 5.7 litres (each)
Heating vessel capacity: 3.7 litres
Signal voltages: 0-5V
Level sensor range: 0-250mm
Flow sensor range: 0-500ml/min
Temperature sensor range: 0-100°C
(all 0-5V dc output) PCT19BR Industrial PLC Unit

Safety features:
RCD in the console, all circuits protected by MCB's, 24V dc operation of solenoid valves and pump motors

Heating vessel:

- thermostat limiting max temp
- low level switch
- vent to avoid pressurisation

ESSENTIAL ACCESSORIES

PC microcomputer:
(minimum specification)
Pentium processor or equivalent
16Mb of RAM
10Mb Hard disk space
SVGA Display
Spare USB port
CD-ROM drive
MS Windows 98 or Windows 2000

This computer is not part of the Armfield supply

OPTIONAL ACCESSORIES

Ordering Codes:

PCT19BR: Industrial PLC Unit
PLC unit incorporating Allen Bradley SLC500 complete with proprietary ladder logic set-up program (requiring user supplied PC). This program is initially configured by Armfield for two analog input/output control loops suited to the PCT23 Process Plant Trainer unit but may be reconfigured by users via their PC.



PCT19BR Industrial PLC Unit

PCT23SCADA: SCADA Software

This software contains the facilities required to demonstrate SCADA using the Armfield PCT23 and PCT19BR.

It includes:

- SLC500 ladder logic routines written specifically for the PCT23
- The communications facilities to allow the PCT23 software to display and data log the SLC500 parameters
- The additional exercises for the PCT23, allowing SCADA to be demonstrated in the same manner as the other exercises

PCT20H: Industrial PID Controller

PID controller, incorporating a Honeywell UDC3300 series unit with voltage/mA input and output for single-loop control and alarm configurations. A software package is supplied on disk to demonstrate the basic principles of SCADA whereby a user supplied PC can address the PID controller on-line.



PCT20H Industrial PID Controller

ORDERING SPECIFICATION

- *A bench mounted process plant trainer with multiple streams both interacting and non-interacting. The process plant incorporates a miniature 3-stage plate heat exchanger heated from a hot water circulator, two independent feed tanks, a holding tube with product divert valve and two variable-speed peristaltic pumps.*
- *Temperature, level, flow and conductivity control loops can be implemented.*
- *The effect of 'dead time' and heat recycle can be demonstrated.*
- *An electrical console provides measurement and control of the process plant and allows a variety of control techniques including manual operation, on/off control, control from an external signal and control from a PC or PLC.*
- *The equipment incorporates electrical fault simulation and control and data logging software, and a USB computer interface.*

SERVICES REQUIRED

Electrical supply:

PCT23MkII-A: 220-240V/1ph/50Hz

PCT23MkII-B: 120V/1ph/60Hz

PCT23MkII-G: 220V/1ph/60Hz

Cold water supply:

4 litres/min @ 2 bar

OVERALL DIMENSIONS

	<i>Process unit</i>	<i>Console</i>
<i>Height:</i>	<i>550mm</i>	<i>280mm</i>
<i>Width:</i>	<i>1000mm</i>	<i>425mm</i>
<i>Depth:</i>	<i>530mm</i>	<i>400mm</i>

SHIPPING SPECIFICATION

Volume: 1.2m³

Gross weight: 167kg

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