armfield

DISTILLATION COLUMNS

UOP3
issue 6

Above: Computer Interfaced Distillation Column UOP3CC

Considerable advances in the instrumentation and control of distillation columns have been made in recent years, prompted by the advent of computer-linked systems supported by software packages for handling plant operating data. To reflect these advances, Armfield has developed two new state-of-the-art laboratory-based distillation columns that allow safe hands-on practical training for student engineers and plant operators:-

- *A continuous or batch operation, computer-compatible column (model reference UOP3CC) which allows a full range of demonstrations from the introductory stages of a process engineering course through to the more complex demonstrations of modern control strategies.*
- *A batch-only operated version (model reference UOP3BM) manually controlled, permits comprehensive study of the basic principles of distillation.*

Heat and Mass Transfer Unit Operations

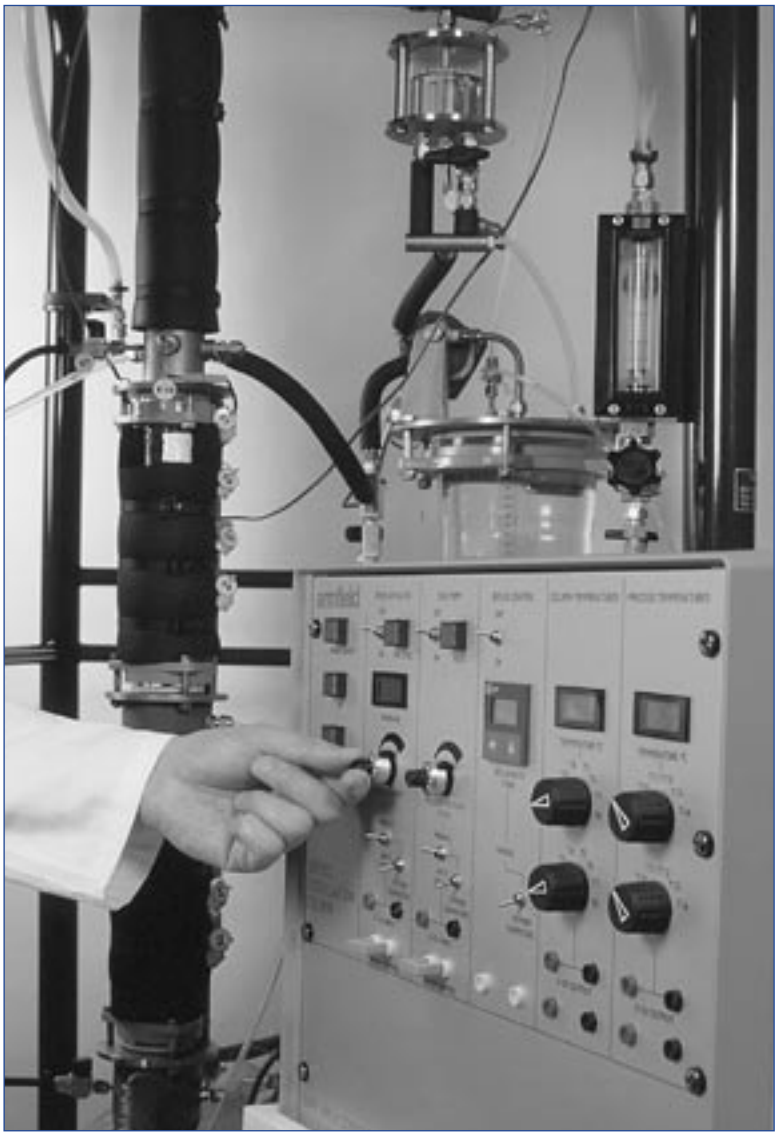
UOP

LABORATORY WORK ASSIGNMENT CAPABILITIES

For Batch Distillation Column UOP3BM - under manual control:

- *pressure drop across the column as a function of boil-up rate (Fig. 1)*
- *column efficiency as a function of boil-up rate, at total reflux (Fig. 2)*
- *plate-to-plate temperature profiles along the column*
- *McCabe-Thiele construction of operating line (Fig. 3)*
- *distillation at constant reflux ratio: variation of top product composition with time (Fig. 4)*
- *mass balance across the system*
- *manual control of reflux ratio, for example to achieve a top product of specified composition*
- *comparison of packed column with sieve plate column performance*

Note: These capabilities can also be performed with UOP3CC.



Batch Distillation Column UOP3BM under manual control

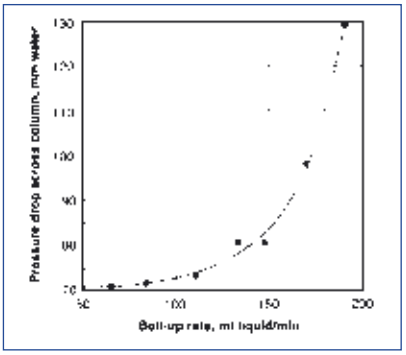


Fig. 1: Column pressure drop as a function of boil-up rate

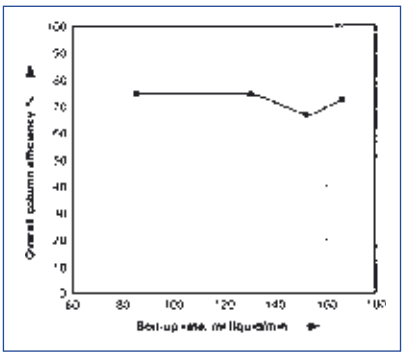


Fig. 2: Column overall efficiency as a function of boil-up rate

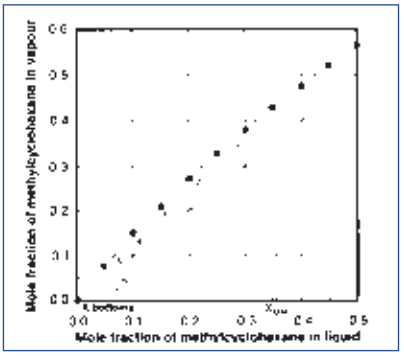


Fig. 3: McCabe-Thiele construction for batch distillation at total reflux (methylcyclohexane-toluene mixture, atmospheric pressure, boiler power 1.0kW)

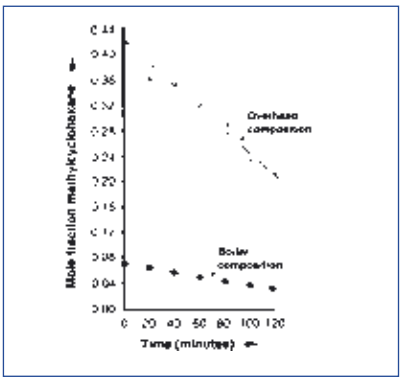


Fig. 4: Batch distillation: variation of composition with time at fixed reflux ratio of 5:1 (methylcyclohexane-toluene mixture, atmospheric pressure, boiler power 1.1kW)

Acknowledgements:
Figs 1, 2, 3 and 4, above and Table 2, page 6: Results taken from Armfield UOP3CC Distillation Column in the Process Laboratories of the Department of Chemical Engineering, University of Aston, U.K. courtesy of Dr. J. D. Jenkins

LABORATORY WORK ASSIGNMENT CAPABILITIES

For Computer-Interfaced Distillation Column UOP3CC only - continuous operation, manual or computer operation:

- *includes all demonstrations listed for UOP3BM under 'Batch Distillation Column' (opposite page)*
- *continuous, steady state distillation including temperature profiles and McCabe-Thiele analysis*
- *distillation under reduced pressure conditions (Fig. 5 - page 6)*
- *comparison of packed and plate column continuous operation (Table 1 - page 6)*
- *effect of feed pre-heat (Fig. 6 - page 6)*
- *effect of feed position (Table 2 - page 6)*
- *demonstration of azeotropic distillation (Fig. 7)*

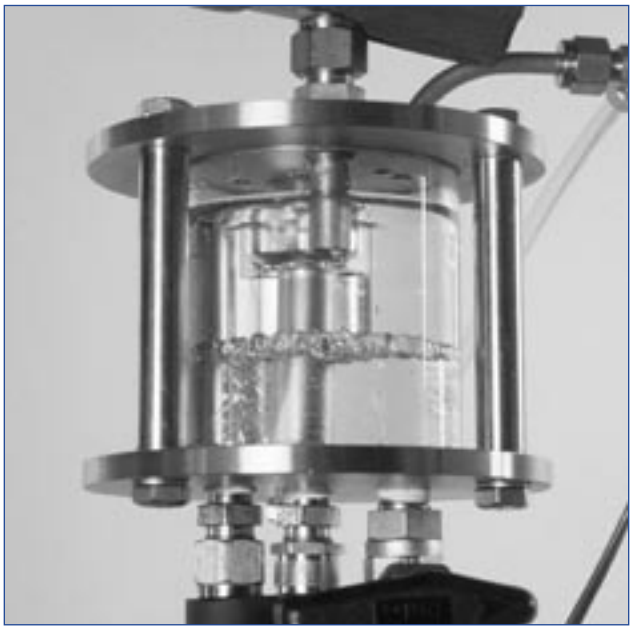


Fig. 7:
Reflux separator during azeotropic distillation of a water/organics mixture

- *computer control assignments:*
  - *the on-line use of mimic diagrams (Fig. 8 - bottom of page)*
  - *setting up data logging and subsequent analyses of captured data including use of spreadsheets (Fig. 9 - below left)*
  - *batch distillation at constant reflux ratio (Fig. 10 - page 6) or varying with time*
  - *batch distillation with reflux ratio control from a column temperature (Fig. 11 - page 6)*
  - *continuous distillation with 3-term control of reboiler heater from a column temperature*
  - *continuous distillation with top temperature controlling reflux ratio*
  - *continuous distillation with temperature control of reboiler heater and reflux ratio (two- loop control system)*
  - *optimum controller settings for changes in feed rate, composition or temperature*
  - *alternative, user-originated control algorithms*
  - *process dynamics e.g. monitoring and controlling plant start-up/shut down for continuous operation*
- *proprietary controller demonstrations:*
  - *PLC control of reboiler heater and/or reflux ratio and alarm functioning (requires Armfield PCT19BR unit incorporating an industry-standard PLC) (Figs. 13 & 14 - page 6)*
  - *demonstration of PC supervision of PLC and PID controllers - an introduction to distributed control systems*
  - *PID analog control of reboiler heater from column temperature (requires Armfield PCT20H unit incorporating an industry-standard controller*

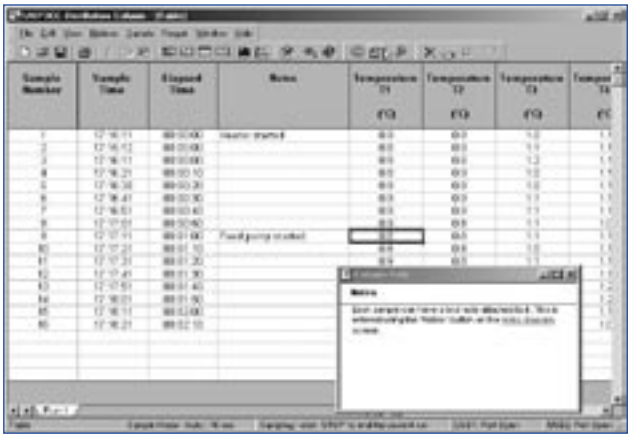


Fig. 9:
Typical results displayed in tabular format

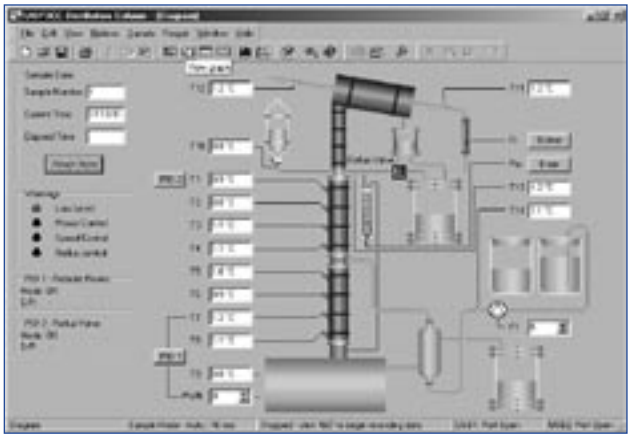


Fig. 8:
On-line mimic diagram during batch distillation at constant reflux ratio

DESCRIPTION

Batch Distillation Column (Manual) UOP3BM

The unit is a self-contained and fully instrumented distillation facility, suitable for practical laboratory work relevant to the teaching of unit operations.

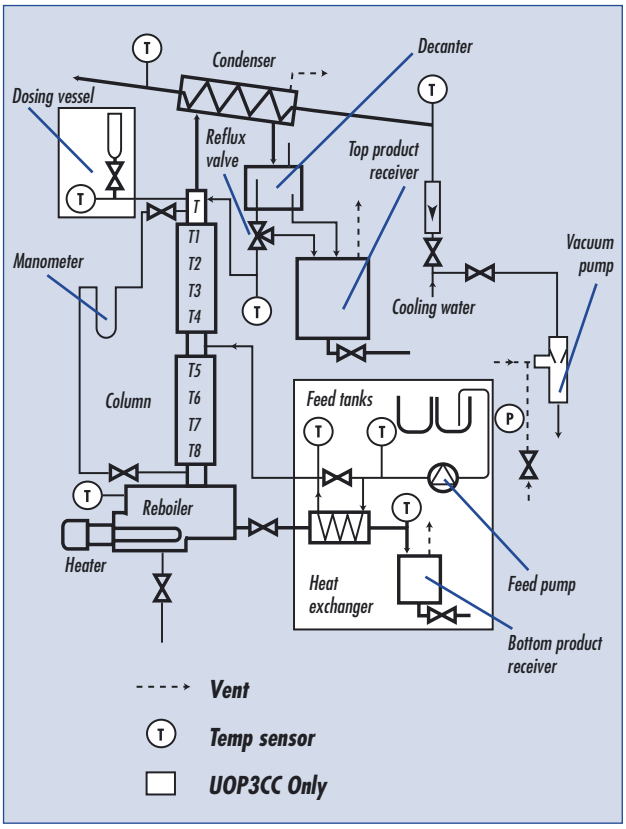
The equipment employs galvanically isolated intrinsically safe circuits and flameproof devices as appropriate, to allow safe distillation of standard test mixtures such as methylcyclohexane-toluene, methyl alcohol-water etc.

The equipment consists of two interconnected units: a floor standing process unit and a bench-mounted control console.

The following features are included:

Process Unit

- *a 50mm diameter plate distillation column containing 8 sieve plates and downcomers. Every plate includes a temperature sensor positioned to measure accurately the temperature of the liquid on each plate. The sheaths of each plate temperature sensor are not more than 1.5mm diameter, to ensure rapid dynamic response.*
- *a 50mm packed column supplied as a separate item, but readily interchangeable with the plate column by the user, for comparative studies of the two types of distillation column.*
- *electrically heated reboiler of sufficient capacity for 1-2 hours of batch operation. The reboiler heater is protected against overheating and by a low level alarm.*
- *an overhead condenser with cooling water flow measurement and adjustment.*
- *a condensate collecting vessel, equipped with double overflow weirs and exit pipes to allow separation of immiscible liquids.*
- *a reflux return valve, solenoid operated, to provide for 0%-100% reflux, adjustable by electrical signal.*
- *a differential manometer connected to the top and bottom of the column, to monitor column pressure drop.*
- *a vacuum system with gauge to allow distillation studies at reduced pressures down to 200mbar(abs).*
- *sampling points throughout the system for composition analyses.*
- *materials of construction for surfaces in contact with the process fluids are; glass, stainless steel, PTFE or similar solvent-resistant materials.*
- *overall height of the process unit does not exceed 2.5 metres (8.2ft).*
- *lagging is provided, although it is possible to see at least one plate in operation with distillation in progress.*
- *maximum operating temperature inside the column operation is at least 130˚C.*



Schematic diagram of Armfield distillation columns

Control Console

- *monitoring and selectable display of at least 13 system temperatures, including those of the liquid on each tray, the reboiler and across the condenser.*
- *monitoring, display and manual adjustment of:*
  i) the electrical power to the reboiler heater.
  ii) the reflux ratio setting.
- *front panel connections to allow the user to connect 0-5 Volt industry-standard analog or programmable logic controllers, to provide on-line control of the boil-up rate or reflux ratio from chosen column temperature measurements. The connection points also allow for the use of standard laboratory chart recorders and data-loggers. (Up to two temperature measurements simultaneously).*
- *mains power connection (single phase 3kW max. supply) protected by Residual Current Device. No-volt protection safety circuits to prevent unintentional start-up.*
- *individual circuits protected against excess current with resetable circuit breakers.*

DESCRIPTION

Computer-Interfaced Distillation Column UOP3CC

This unit incorporates all the features of the manually operated batch column described on opposite page (UOP3BM) but includes the following additional items:

Process Unit

- *two 5 litre feed vessels, with rapid changeover to permit step changes in feed composition to be made.*
- *peristaltic feed pump, range 0-0.25 litres/ minute adjustable by voltage input variation to the pump motor controller.*
- *electrically heated reboiler of sufficient capacity for 1-2 hours of batch operation, but equipped with an internal overflow when continuous operation is required.*
- *a bottoms product heat exchanger which may either be water cooled or used as a (variable) feed pre-heater.*
- *alternative column feed points and the ability to vary the inlet feed temperature to the column.*
- *dosing feed vessel, connected to the column for the continuous addition of a third iquid component, which, together with the condensate phase separator vessel, allows study of azeotropic distillation.*
- *temperature sensors in each flow stream entering and leaving the condenser and of the feed, product system and reboiler temperatures.*

Control Console

- *monitoring and selectable display of at least 14 system temperatures, including those of the liquid on each tray, the reboiler, across the condenser, and of the feed and product streams.*
- *monitoring, display and manual adjustment of:*
  i) the electrical power to the reboiler heater.
  ii) the reflux ratio setting.
  iii) the feed rate setting.
- *ribbon cable connector at rear of the console allows the use of standard laboratory chart recorders and data-loggers (all measurements simultaneously).*
- *USB connector at the rear of the unit allows connection to a user supplied PC, via the integral USB interface.*
- *remote/manual switch is provided on the front panel of the console to allow simple changeover from PC to front panel control to be made by the operator.*
- *power and motor control circuits shut down automatically with loss of computer control signals (when in computer control mode).*

Software

- *bespoke Windows based software, supplied on CD-ROM, allowing real time data acquisition via USB port, mimic diagram of process tabular and graphical display of results, and export to external spreadsheet.*
- *fully configurable, multiple loop control strategies.*

control options include:

i) manual control of feed rate, reboiler power and reflux ratio.

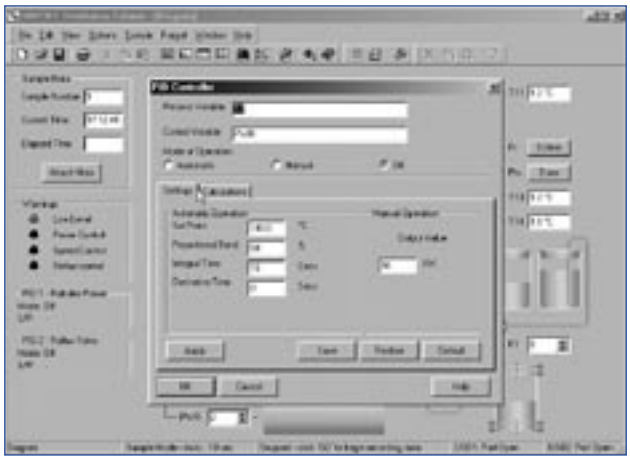
ii) alarm setting.

iii) adjustable PID control of the power to the reboiler heater from a temperature sensor.

iv) alternative algorithms for controlling the reflux ratio, in particular by programmed variation with time and from a column temperature.

v) 'two point' temperature control of reboiler power and reflux ratio simultaneously.

- *full help facilities including presentation screen to provide a brief overview of the equipment, and detailed texts giving all the information required to run the experiments.*



PID controller screen from Armfield software

PERFORMANCE RESULTS

Fig. 13: Equipment set up

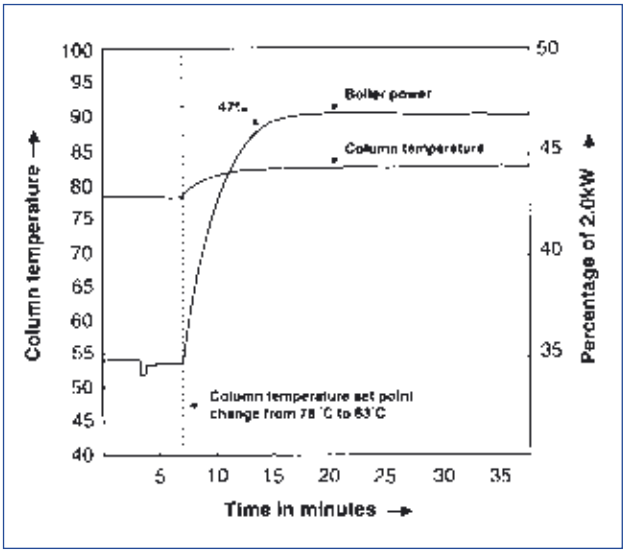


Fig. 14: Hard copy of results

Distillation column control using an Armfield PCT19BR Industrial PLC Unit

Comparison of batch distillation for different reflux ratio control strategies

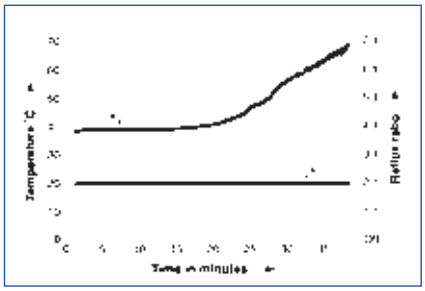


Fig. 10: Constant reflux ratio

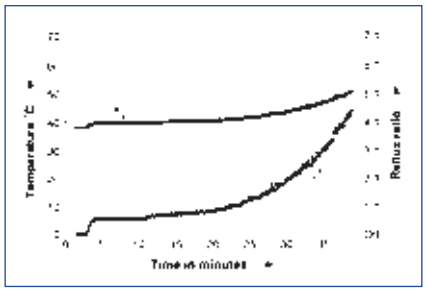


Fig. 11: Reflux ratio controlled by top plate temperature

Effect of operating parameters on column temperature profile

(Feed rate of 60ml/min, 60% trichlorethylene/40% methylene chloride, boiler power 0.75kW, reflux ratio 2:1)

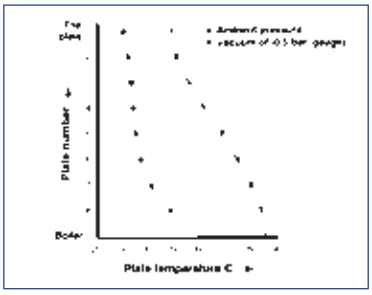


Fig. 5: Effect of reduced pressure

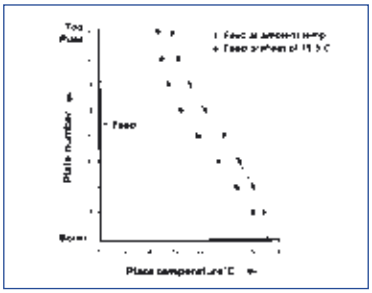


Fig. 6: Effect of feed pre-heat

Measurements in	*Temp. of top plate*	*Temp. of boiler*
Packed column	*48.4℃*	*82.5 ℃*
Plate column	*48.0℃*	*85.0 ℃*

Conditions:
Feed: *60ml/min of 60:40 trichlorethylene/methylene chloride*
Reboiler power: *0.75kW*
Reflux ratio: *2:1*
Ambient feed temperature: *17℃*
Atmospheric pressure.

Table 1: Comparison of temperatures across packed and plate columns

Feed to top of column

Time	*Compositions, m.f. MCH*			*Power*	*Reflux*	*Temperatures, ˚C*		
	Feed	*Overheads*	*Bottoms*	*Input, kW*	*Ratio*	*Reboiler*	*O/H Line*	*Top Plate*
13.40	0.293							
15.00				0.79	2:1	108.8	103.4	103.5
15.15				0.77	2:1	108.4	103.0	102.7
15.20		0.472	0.088					
15.30				0.79	2:1	107.1	102.9	103.6
15.35		0.464	0.097					
15.50		0.481	0.107	0.75	2:1	107.4	103.0	103.6

Table 2: Results for an alternative feed position

INSTALLATION REQUIREMENTS

Solvent resistant level floor.
Either a flame-proofed room or in an area where a 2 metre clear and uninterrupted space on each and every side and above the unit can be maintained and into which no potentially spark producing equipment should be allowed to enter.

Electrical supply:
UOP3BM-A: 220-240V/1ph/50Hz @ 13A
UOP3BM-B: 120V/1ph/60Hz @ 25A
UOP3BM-G: 120V/1ph/60Hz @ 13A

UOP3CC-A: 220-240V/1ph/50Hz @ 13A
UOP3CC-B: 120V/1ph/60Hz @ 25A
UOP3CC-G: 120V/1ph/60Hz @ 13A

Cold water supply:
15 litres/min at 2.0bar pressure (min.)

Venting:
exhaust line to fume cupboard or to safe discharge area outside of laboratory.

***NB:** The distillation unit is floor mounted and is supplied already connected to the bench-mounting control console by sufficient armoured cable to allow the 2m clear space to be maintained around the column.*

ESSENTIAL ACCESSORIES

Analytical equipment, suitable for composition analyses of any particular liquid mixture selected by the user (e.g. refractometer).

For UOP3CC only:-

PC (not supplied by Armfield) with the following minimum specification:

- *Windows 98 or later*
- *USB port*
- *Pentium processor*
- *16Mb RAM*
- *15Mb Hard disk space*
- *SVGA display (800x600, true colour)*

Note:
***It is not possible to upgrade a UOP3BM unit to a UOP3CC unit,** owing to the complexity of the flameproof barriers within the UOP3CC control console.*

OPTIONAL ACCESSORIES

PCT19BR:
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 analogue input/output control loops suited to the UOP3 Distillation Column unit (either BM or CC versions), but may be re-configured by users via their PC.

PCT19BR Industrial PID controller

PCT20H:
PID controller, incorporating a Honeywell UDC3300 series unit, with voltage/mA input and output for single loop control and alarm configurations. Suitable for both UOP3BM and CC versions. 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

UOP3BM:

Batch Distillation Column (manual):

- ***Self-contained sieve plate distillation column unit including reboiler, condenser and reflux tank, suitable for use with flammable solvents and fully instrumented for batch operation.***
- ***Temperatures throughout the process including those on each and every sieve plate are monitored and displayed on a bench mounted control console, via a selector switch. The console also houses controls for the power supplied to the reboiler heater and for reflux ratio settings between 0 and 100%.***
- ***The console front panel connections allow the use of standard laboratory recorders and data loggers and of industry-standard PID and PLC controllers (not supplied).***
- ***A U-tube manometer is incorporated to measure pressure drop over the distillation column.***
- ***The 50mm diameter sieve plate column may be readily interchanged with a packed column supplied as an alternative.***
- ***A vacuum system allows operation at reduced pressures down to 200mbar(abs).***
- ***The unit is supplied completely assembled including lagging, and a comprehensive instruction manual describes commissioning, maintenance and instructional assignments.***

OVERALL DIMENSIONS

Process Unit:	***Control Console:***
Height: 2.25m	*Height: 0.30m*
Width: 0.85m	*Width: 0.52m*
Depth: 0.80m	*Depth: 0.40m*

SHIPPING SPECIFICATION

Packed Volume:	*3.4m³*
Gross Weight:	*425kg*

Armfield Limited
Bridge House, West Street, Ringwood,
Hampshire BH24 1DY, England

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Jackson NJ 08527

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E mail: info@armfieldinc.com

UOP3CC:

Computer-interfaced Distillation Column:

- ***Self-contained sieve plate distillation column unit including feed vessels and pump, reboiler, condenser, reflux separator, product collecting tanks, bottoms product cooler/feed pre-heater, suitable for use with flammable solvents and fully instrumented for both batch and continuous operation.***
- ***Temperatures throughout the process including those on each and every sieve plate are monitored and displayed on a bench mounted control console, via a selector switch. The console also houses controls for the power supplied to the reboiler heater and for reflux ratio settings between 0 and 100%.***
- ***The console front panel connections allow the use of standard laboratory recorders and data loggers and of industry-standard PID and PLC controllers (not supplied).***
- ***The console is designed to be connected to a PC (not supplied), and software is provided to allow on-line data logging, real time trend monitoring and PID control loops to be set up, monitored and configured by the user via a mimic diagram.***
- ***A U-tube manometer is incorporated to measure pressure drop over the distillation column.***
- ***A vacuum system allows operation at reduced pressures down to 200mbar(abs).***
- ***A third feed vessel is supplied such that, with the reflux phase separator, azeotropic distillation may be demonstrated.***
- ***The 50mm diameter sieve plate column may be readily interchanged with a packed column supplied as an alternative.***
- ***The unit is supplied completely assembled including lagging, and a comprehensive instruction manual describes commissioning, maintenance and instructional assignments.***

OVERALL DIMENSIONS

Process Unit:	***Control Console:***
Height: 2.25m	*Height: 0.42m*
Width: 0.85m	*Width: 0.52m*
Depth: 0.80m	*Depth: 0.40m*

SHIPPING SPECIFICATION

Packed Volume:	*3.5m³*
Gross Weight:	*450kg*

Specifications may change without notice
iss6/5k/0904/B&S.