A&P INSTRUMENT®
科 藝 儀 器

Thermodynamic Engineering

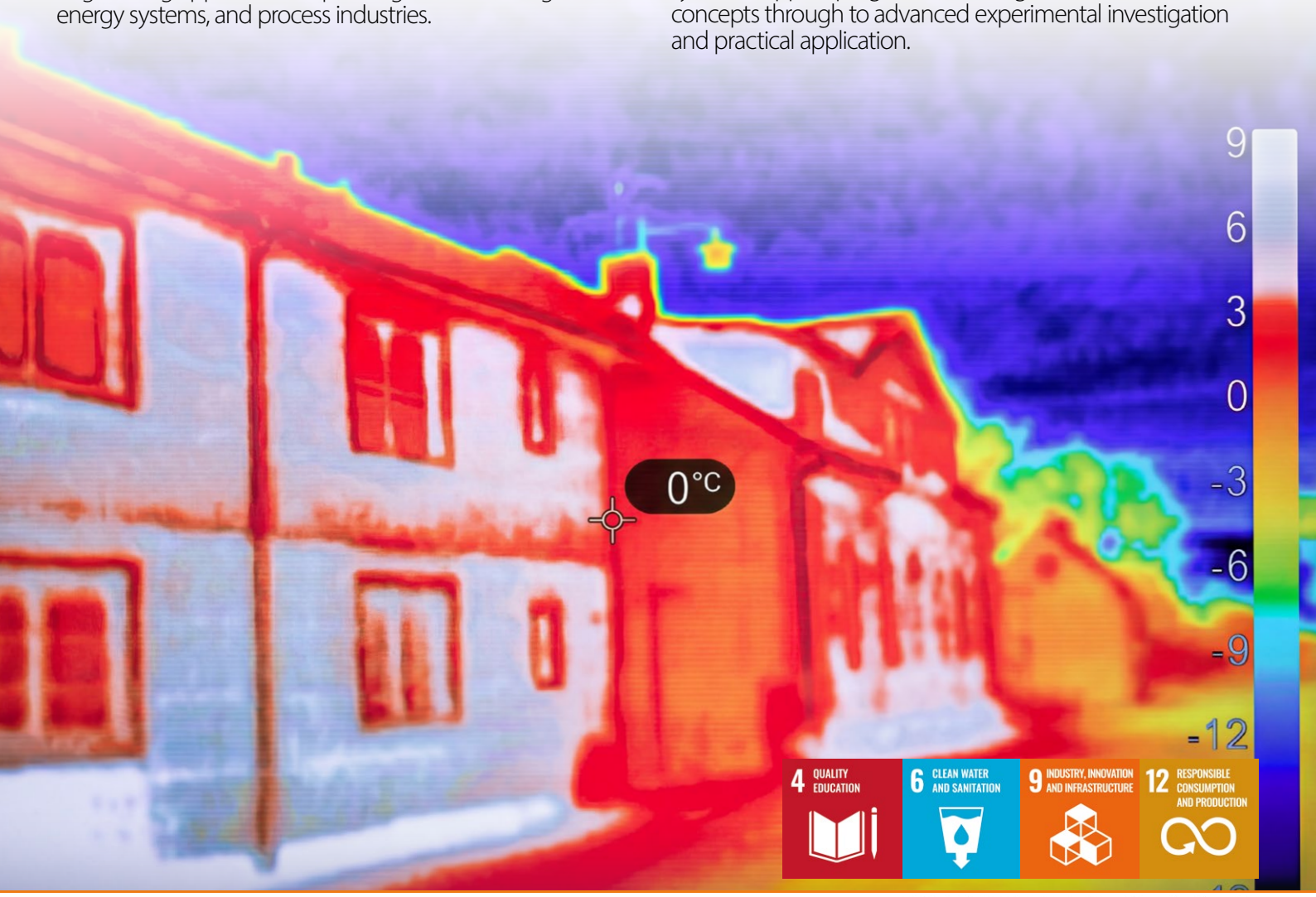
Advancing Thermodynamic Engineering

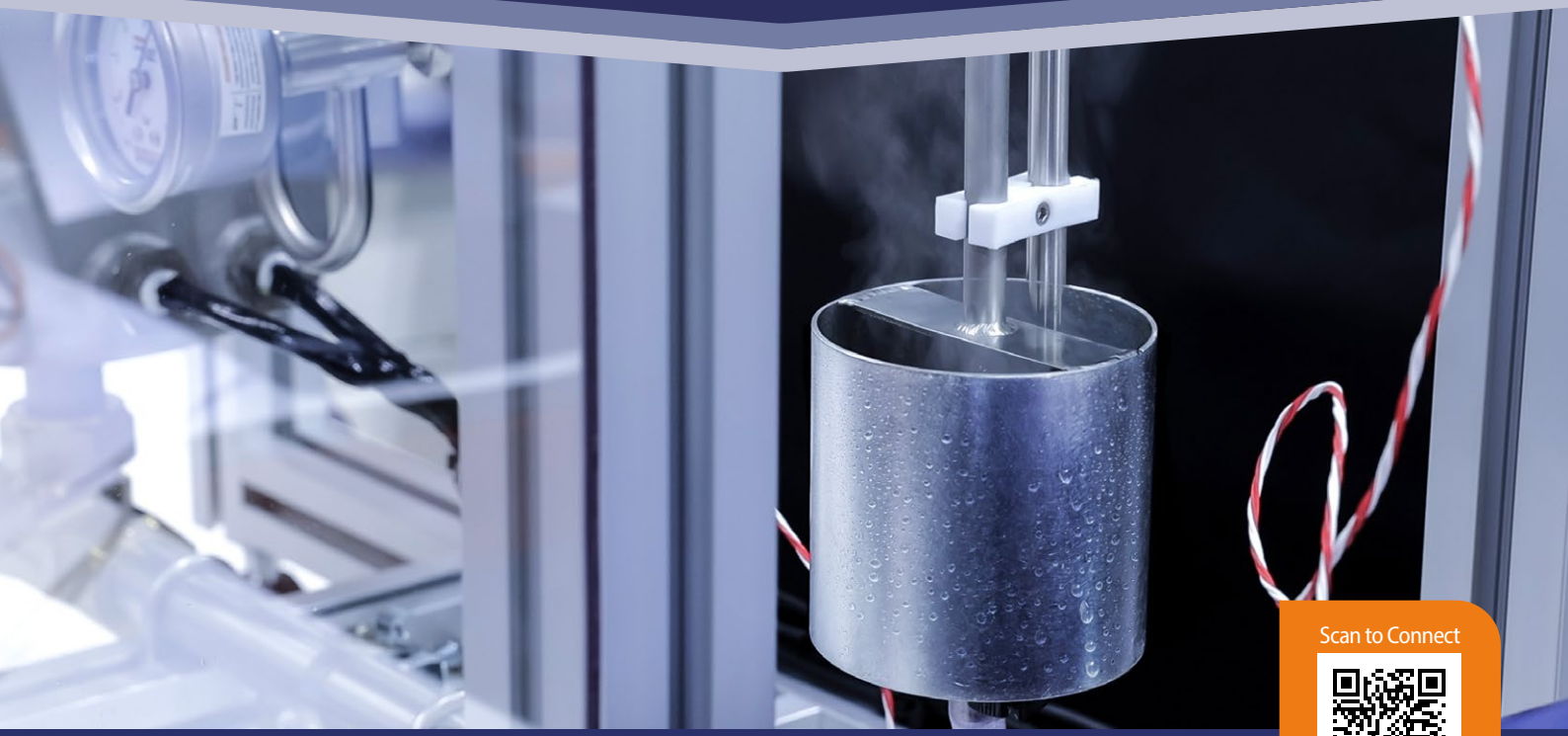
Armfield's thermodynamic studies equipment bridges the gap between theory and practice, providing students with hands-on experience of fundamental energy and heat transfer principles.

Armfield enables universities to deliver engaging, industry-relevant teaching that develops a deeper understanding of thermodynamics and prepares students for real-world engineering applications in power generation, refrigeration, energy systems, and process industries.

This brochure outlines our thermodynamic teaching solutions and their place within the engineering curriculum, including alignment with Bloom's Taxonomy, key theories, and fundamental laws.

Covering topics such as the First and Second Laws of Thermodynamics, heat transfer, steam power, refrigeration, heat engines, energy conversion, and thermal efficiency, our systems support progressive learning from fundamental concepts through to advanced experimental investigation and practical application.





Scan to Connect

ENGINEERING EDUCATION TEACHING & RESEARCH

For more than six decades, we have worked in close partnership with universities around the world to support the teaching of thermodynamics and heat transfer. Our goal has always been to transform fundamental theory into meaningful, hands-on learning experiences that align closely with course syllabuses and equip students with the practical skills required for their future careers.

Thermodynamics demands more than theoretical understanding alone. Students must observe how energy is transferred, how systems respond to changing conditions, and how the fundamental laws of thermodynamics govern real engineering processes. From heat transfer and phase change to refrigeration, steam generation, energy conversion and thermal efficiency, practical experimentation is essential to developing a deeper understanding of these principles.

At Armfield, we design educational equipment that bridges the gap between theory and practice, combining sound engineering principles with engaging, industry-relevant experimentation.

Our product development is driven by close collaboration with academic teams, ensuring that our systems support taught modules, clearly defined learning outcomes, and progressive learning pathways from introductory study to advanced investigation and independent research.

The result is a range of robust and versatile teaching platforms that allow students to visualise complex phenomena, analyse experimental data, and develop the analytical skills demanded by modern engineering practice.

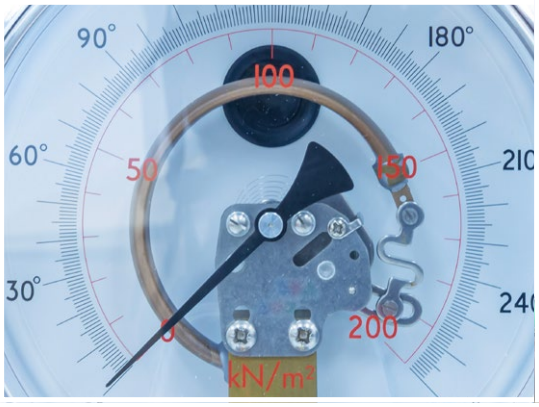
This booklet presents a comprehensive portfolio covering the core disciplines of thermodynamics and heat transfer. Each system has been designed to form part of a coherent teaching strategy, supporting multiple cohorts, learning levels, and many years of laboratory use.

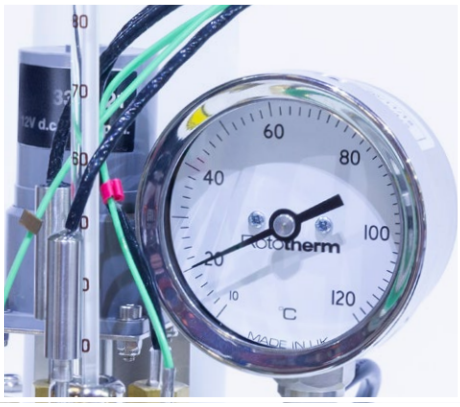
Engineering education continues to evolve, and so do we. Whether you are modernising existing laboratories, developing new programmes, or seeking bespoke solutions to support specific teaching objectives, we would be delighted to work with you.

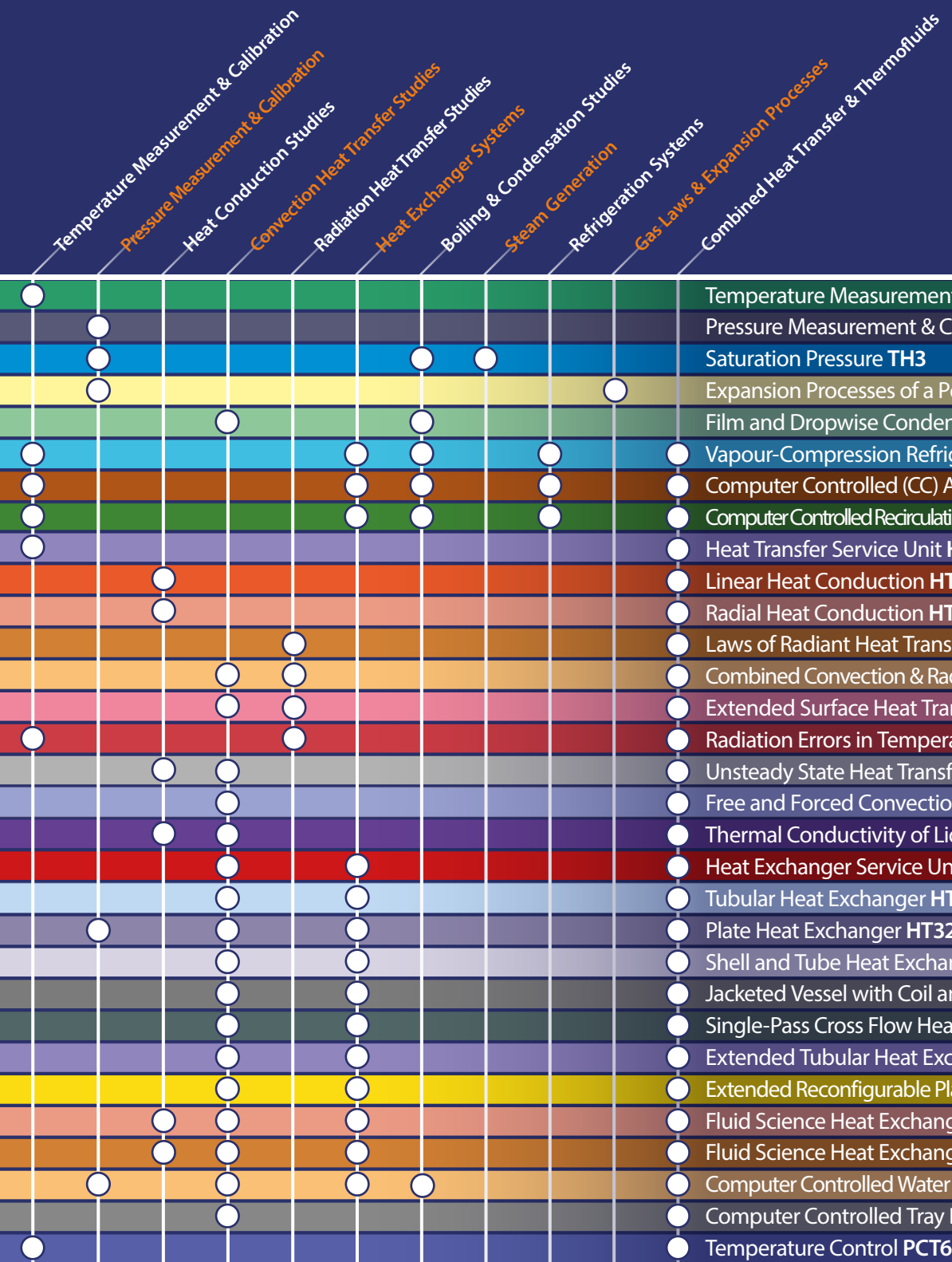
Please contact us to discuss how we can support your requirements.

Andy Macpherson
Managing Director of Armfield Ltd









Contents

Temperature Measurement & Calibration **TH1**	6
Pressure Measurement & Calibration **TH2**	7
Saturation Pressure **TH3**	8
Expansion Processes of a Perfect Gas **TH5**	9
Film and Dropwise Condensation **TH6**	10
Vapour-Compression Refrigeration Unit **RA1**	11
Computer Controlled (CC) Air Conditioning Unit **RA2**	13
Computer Controlled Recirculating Air Conditioning Unit **RA3**	14
Heat Transfer Service Unit **HT10X**	15
Linear Heat Conduction **HT11X**	16
Radial Heat Conduction **HT12X**	17
Laws of Radiant Heat Transfer **HT13X**	18
Combined Convection & Radiation **HT14X**	19
Extended Surface Heat Transfer **HT15X**	20
Radiation Errors in Temperature Measurement **HT16X**	21
Unsteady State Heat Transfer **HT17X**	22
Free and Forced Convection **HT19X**	23
Thermal Conductivity of Liquids & Gases **HT20X**	24
Heat Exchanger Service Unit **HT30X**	26
Tubular Heat Exchanger **HT31X**	27
Plate Heat Exchanger **HT32X**	28
Shell and Tube Heat Exchanger **HT33X**	29
Jacketed Vessel with Coil and Stirrer **HT34X**	30
Single-Pass Cross Flow Heat Exchanger **HT35X**	31
Extended Tubular Heat Exchanger **HT36X**	32
Extended Reconfigurable Plate Heat Exchanger **HT37X**	33
Fluid Science Heat Exchange Modules **FS3.1 - FS3.4**	34
Fluid Science Heat Exchange Modules **FS3.1 - FS3.4**	35
Computer Controlled Water Cooling Tower **UOP6-MKII**	36
Computer Controlled Tray Dryer **UOP8-MKIIe**	37
Temperature Control **PCT62**	38
Laboratory Planning & Layout Support	39
Agent / Links and Contact Us Page	40

UNIVERSITIES AND LEARNING FACILITIES

With over 150 years of experience, Armfield is a trusted global supplier of high quality equipment. Founded in 1875 in Ringwood, England, our commitment to quality, innovation and service has driven us from our roots in engineering machinery to become a world leader in two distinct fields: **Engineering Education** and **Industrial Food Technology.**

Armfield has supplied and partnered with over 3,000 universities, education centres and research hubs worldwide since 1958, providing equipment that covers all major engineering disciplines. In 1992, our Pilot-scale Food Division was launched, developing and supplying equipment for many of the world's leading corporations across the food, beverage and pharmaceutical industries. A selection of our valued customers is shown below.

TEXAS A&M UNIVERSITY
UNIVERSITY OF OXFORD
UNIVERSITY OF CAMBRIDGE
ROLLS ROYCE
VILLANOVA UNIVERSITY
IGNITE CHANGE. GO NOVA.
UNSW SYDNEY
gsk GlaxoSmithKline
UCD DUBLIN
STANFORD UNIVERSITY
المراعي Almarai
Unilever
DIAGEO
TATE & LYLE
جامعة الشارقة UNIVERSITY OF SHARJAH
RMA Royal Military Academy
UNITED STATES AIR FORCE ACADEMY
Ethiopian የኢትዮጵያ Aviation University
PIONEER OF AVIATION EXCELLENCE
Universidad de los Andes
UNIVERSIDAD DE CHILE
جامعة خليفة Khalifa University
Coca-Cola
PEPSICO
pepsi
Lay's
Tropicana
QUAKER
G



UNIVERSITY OF SHEFFIELD

"THEY UNDERSTAND."

Dr. Midiana Rosado Hau School of Engineering

From Lecture Theory to Measurable Engineering Phenomena

Dr. Midiana Rosado from the University of Sheffield works in the Fluid Mechanics Laboratory, where students from several engineering programs gain hands-on experience with aerodynamics and flow measurement.

In collaboration with Armfield, the lab recently introduced a new wing profile experiment that aerospace engineering students will use during the semester.

Using the wind tunnels and a water manometer system, students are able to measure pressure distribution around a wing & directly observe how aerodynamic forces develop.

Over the years, the University of Sheffield has worked closely with Armfield to set up a variety of practical experiments, including demonstrations of Bernoulli's principle, measurements of drag coefficients, and analysis of wake velocities behind different shapes. According to Dr. Rosado, these experiments help students move beyond theory and truly understand how fluid mechanics and aerodynamics behave in real systems.

"The students find the equipment extremely useful," she explains. "It allows them to visualise and measure the phenomena they learn about in lectures."

Looking ahead, the collaboration will continue to expand. The laboratory plans to introduce additional flow measurement equipment and develop new experimental activities together with Armfield.

For Dr. Rosado and her students, the partnership is about more than equipment, it's about creating engaging learning experiences that help future engineers understand the real behaviour of fluids and aerodynamic systems

UNIVERSITY OF NOTTINGHAM

"EXCELLENT EDUCATIONAL PARTNER!"

Professor John Turner Director of Education & Student Experience

Engineering Education Designed Around Real Learning

I have been contracted by Armfield Engineering Limited for the past year, and throughout this time I've been consistently impressed by their willingness to engage deeply with the realities of modern chemical engineering education. Rather than simply producing equipment and hoping it fits somewhere within a curriculum, Armfield has shown a genuine commitment to understanding how their rigs are used in practice and how they can better support student learning across multiple academic levels.

One clear example is the distillation column: originally suited mainly to higher-year teaching, Armfield embraced the idea of making small procedural and physical adjustments that will now allow the same rig to be used from first-year fundamentals through to final-year research projects. This shift has transformed a single-purpose piece of equipment into a multi-stage learning platform with far broader relevance.

Throughout our collaboration, Armfield has shown a strong interest in aligning their equipment with the structure and expectations of modern curricula. By exploring how different rigs map to learning outcomes, sustainability themes (UNSDGs), and practical teaching needs, they have demonstrated a thoughtful and forward-looking approach. Their willingness to develop supporting academic materials and ensure clear links between theory and practice has been particularly valuable for educators and students alike.

Working with Armfield has shown me a company that listens, adapts, and genuinely wants to enhance engineering education. Their focus on versatility, curriculum alignment, and practical relevance has made the collaboration both productive and rewarding.

Temperature Measurement & Calibration TH1

The Armfield **TH1** Temperature Measurement and Calibration unit is designed to introduce students to different temperature measuring techniques and explore the differing properties and characteristics of these devices. The devices can be calibrated using precisely generated fixed points and an accurate reference thermometer.



Relevant Curriculum Modules

- Thermodynamics *(Temperature scales, fixed points, and calibration)*
- Instrumentation & Measurement
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Thermoelectric Effect -** Basis of thermocouple operation (Seebeck Effect)
- **Resistance–Temperature Relationship -** Platinum Resistance Thermometer (PT100, Callendar–Van Dusen equation)
- **Thermistor Behaviour -** Negative Temperature Coefficient (NTC) semiconducting resistance
- **Thermal Expansion -** Principle of liquid-in-glass and bi-metal thermometers
- **Bimetallic Strip Theory -** Differential expansion of dissimilar metals
- **International Temperature Scale (ITS-90) -** Definition of fixed points and interpolation equations
- **First-Order Sensor Response -** Time constant and 63.2% rule for dynamic response
- **Conduction Error Theory -** Effect of sheath geometry and thermal bridging on measurement accuracy
- **Stefan–Boltzmann Law -** Radiant heat exchange and the role of radiation shields
- **Clausius–Clapeyron Equation -** Relationship between saturation temperature and barometric pressure at the condensation point

Learning Outcomes

Remember & Understand

Students identify and explain the operating principles of PRTs, thermocouples, thermistors, liquid-in-glass, and bi-metal thermometers. They define ITS-90 fixed reference points and relate raw sensor outputs to the physical basis of each device.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students apply calibration procedures and correction equations to convert sensor outputs into engineering units, construct calibration curves, determine time constants from step-change experiments, and analyse error sources including conduction, self-heating, and cold-junction compensation.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the suitability of different sensors for industrial measurement scenarios, design calibration protocols for alternative devices, and propose strategies to minimise measurement uncertainty. They apply ITS-90 methodology and barometric correction to generate traceable calibration data.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

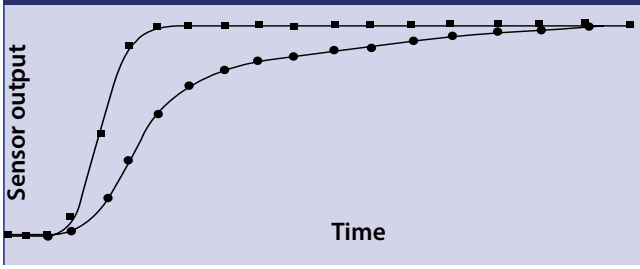
Ordering codes

- **TH1-A :** 220-240V/1ph/50Hz, 10A
- **TH1-B :** 120V/1ph/60Hz, 20A
- **TH1-G :** 220-240V/1ph/60Hz, 10A

Recommended instruments

- **Barometer:** to determine absolute pressure
- **Stop clock:** when not using the optional interface device/educational software
- **DC calibrator/thermocouple simulator:** to demonstrate calibration of instrumentation
- **Resistance box/PRT simulator:** to demonstrate calibration of instrumentation/lead errors

TH1: Response curves for different temperature sensors



Optional Software

TH-DTA-ALITE:
Educational software for TH1-TH5 on a USB key complete with data logger (a PC running Windows 7 or later, with a USB port is required)

Requirements	Dimensions		Scale
1Ph, COLD	Length	0.700	
	Width	0.325	
	Height	0.680	

Electrical Supply: **Single phase** (see Ordering codes)
Fill with distilled/deionised water:
- **Hypsometer:** 1 litre
- **Water bath:** 4 litres

Source of ice shavings made from pure water

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Pressure Measurement & Calibration TH2

The Armfield TH2 Pressure Measurement and Calibration unit is designed to introduce students to pressure and how different techniques can be employed to measure this variable. A dead-weight pressure calibrator generates precise reference pressures for calibrating a Bourdon gauge and a pressure sensor.

The unit also demonstrates Boyle's Law using a syringe and manifold assembly.

Relevant Curriculum Modules

- Thermodynamics *(Pressure scales, absolute and gauge pressure)*
- Instrumentation & Measurement
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Boyle's Law -** Inverse relationship between absolute pressure and volume at constant temperature (PV = k)
- **Hydrostatic Pressure -** Pressure generated by the dead-weight calibrator (P = F/A)
- **Bourdon Tube Principle -** Conversion of pressure to mechanical displacement via elastic deformation
- **Semiconductor Diaphragm Theory -** Piezoelectric deflection generating a voltage proportional to applied pressure
- **Relative and Absolute Pressure -** Gauge pressure, absolute pressure, and atmospheric reference
- **Sensor Calibration Theory -** Zero and span adjustment; two-point calibration method
- **Error Analysis -** Avoidable, random, and systematic errors; accuracy, mean deviation, and standard deviation
- **Damping Theory -** Effect of flow restriction on dynamic pressure sensor response
- **Ideal Gas Law -** Foundation for Boyle's Law and behaviour of gases at moderate pressures

Learning Outcomes

Remember & Understand

Students explain the operating principles of Bourdon gauges and semiconductor pressure sensors, distinguish between gauge and absolute pressure, and describe how a dead-weight calibrator generates traceable reference pressures.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students apply calibration procedures to convert arbitrary sensor outputs into engineering units of pressure, construct calibration curves for both the Bourdon gauge and semiconductor sensor, and analyse sources of error including friction, zero error, parallax, and damping effects. They verify Boyle's Law experimentally using a syringe connected to the manifold.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

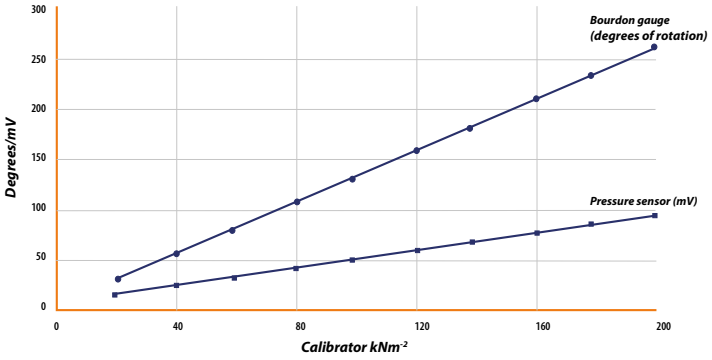
Evaluate & Create

Students evaluate the accuracy and linearity of alternative pressure sensing technologies, design calibration protocols for externally connected sensors, and quantify measurement uncertainty using standard error analysis methods. They propose strategies to minimise systematic and random errors in industrial pressure measurement.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



TH2: Calibration of gauge and sensor



Optional Software

TH-DTA-ALITE:
Educational software for TH1-TH5 on a USB key complete with data logger (a PC running Windows 7 or later, with a USB port is required)

Recommended instruments

Accurate weight balance: (0 - 5 kg)
Barometer: (to determine the atmospheric pressure)
DC calibrator: (to demonstrate calibration of instrumentation)

Requirements	Dimensions/Console		Scale
1Ph, COLD	Length	0.400	0.290	
	Width	0.275	0.225	
	Height	0.290	0.215	
Fill with clean cold water (0.1 litres)			

Ordering codes

- **TH2-A :**220-240V/1ph/50Hz, 2A
- **TH2-B :** 120V/1ph/60Hz, 4A
- **TH2-G :** 220-240V/1ph/60Hz, 2A

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Saturation Pressure TH3

The Armfield TH3 Saturation Pressure unit is designed to introduce students to how the temperature of water behaves at its boiling point with variation in absolute pressure.
Equivalent to a Marcet Boiler, the TH3 adds a throttling calorimeter and a return pipe loop, enabling the quality of the saturated steam produced to be determined and giving students a fuller understanding of two-phase thermodynamic behaviour.



Relevant Curriculum Modules

- Thermodynamics *(Saturation pressure, two-phase behaviour, and steam quality)*
- Instrumentation & Measurement
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Two-Phase Fluid Behaviour -** Boiling regimes from free convection through nucleate boiling to bulk vaporisation at constant volume
- **Saturation Line -** The pressure–temperature relationship along which liquid and vapour phases of water coexist
- **Describing Equation for Saturation Pressure -** Linearisation of the exponential pressure–temperature relationship (ln Pabs vs. 1/T) to obtain best-fit coefficients
- **Relative and Absolute Pressure -** Conversion of gauge sensor readings to absolute pressure using barometric pressure
- **Resistance–Temperature Relationship -** Platinum Resistance Thermometer (PT100) bridge-circuit correction and reference calibration charts
- **Steady Flow Energy Equation -** Energy balance applied to the throttling process, giving h1 = h2 under adiabatic, no-work conditions
- **Steam Quality (Dryness Fraction) -** x = (h2 – hf)/hfg, used to characterise a two-phase liquid–vapour mixture
- **Two Property Rule -** Defining the thermodynamic state of a fluid from two independent measured properties
- **Thermal Lag -** Effect of sensor response time on the accuracy of transient temperature and pressure measurements

Learning Outcomes

Remember & Understand

Students identify the stages of boiling behaviour in a two-phase fluid, define the concept of a saturation line, and explain the operating principles of the platinum resistance thermometers, electronic pressure sensor, and Bourdon gauge used to characterise the saturated steam.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

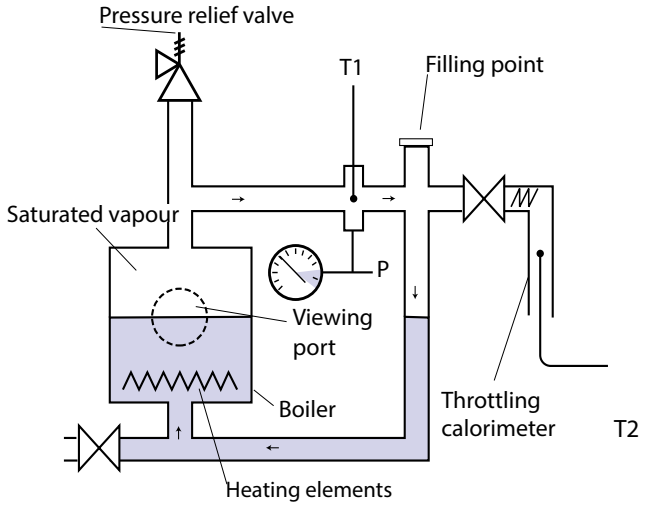
Students apply resistance and pressure correction charts to convert sensor readings into temperature and absolute pressure, plot the experimental saturation curve over the 0–7 bar operating range, linearise the describing equation to obtain best-fit coefficients, and apply the Steady Flow Energy Equation to data from the throttling calorimeter to determine the quality of the steam produced.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the accuracy of their experimental saturation curve against published steam tables, assess the effect of thermal lag on measurement accuracy at different heating and cooling rates, and propose improved sensor configurations or measurement protocols for monitoring liquid–vapour transitions in an industrial setting.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



Optional Software

TH-DTA-ALITE:
Educational software for TH1-TH5 on a USB key complete with data logger (a PC running Windows 7 or later, with a USB port is required)

Recommended instruments

Accurate barometer: (to determine the absolute pressure)

Requirements	Dimensions/Console		Scale
1Ph, COLD, DRAIN	Length	0.670	0.290
	Width	0.290	0.225
	Height	0.580	0.215

Fill with clean cold water (0.1 litres)

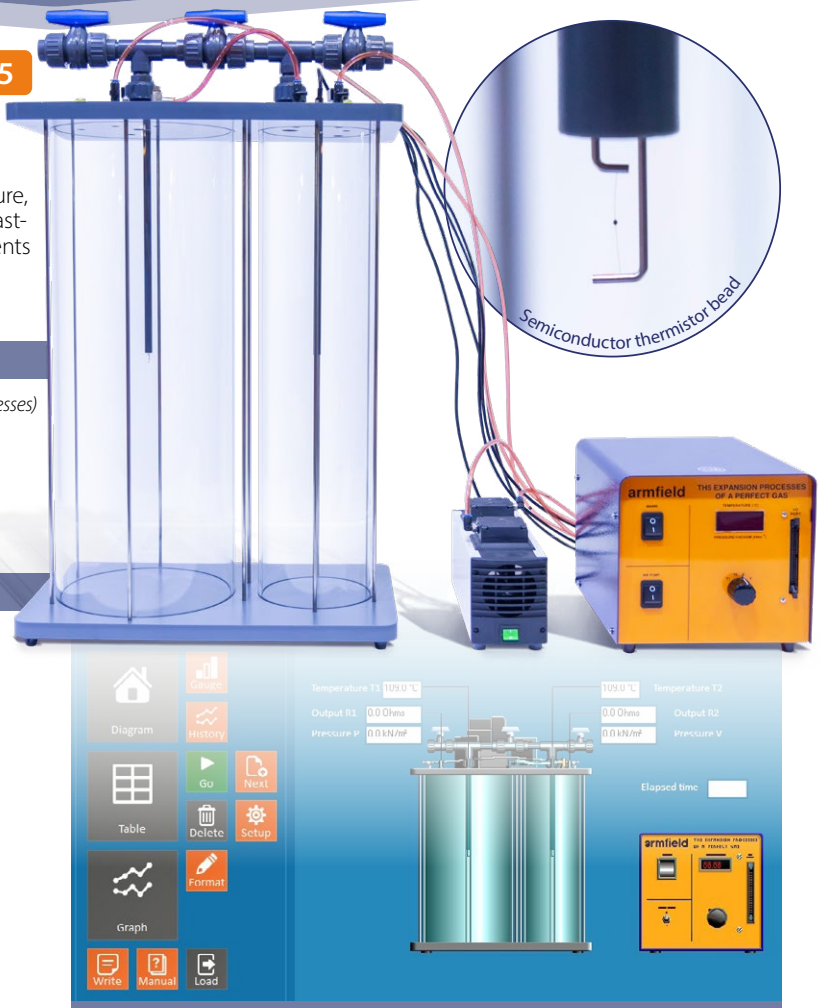
Ordering codes

- **TH3-A :**220-240V/1ph/50Hz, 6A
- **TH3-B :** 120V/1ph/60Hz, 13A
- **TH3-G :** 220-240V/1ph/60Hz, 6A

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Expansion Processes of a Perfect Gas TH5

The Armfield TH5 Expansion Processes of a Perfect Gas unit is designed to introduce students to the behaviour of a perfect gas under changing pressure and temperature. Two interconnected vessels — one for pressure, one for vacuum — are fitted with piezo-resistive pressure sensors and fast-response thermistors. By operating a set of ball and needle valves, students create rapid (adiabatic) or gradual (isothermal) changes in pressure and observe the resulting transient temperature response directly.



Relevant Curriculum Modules

- Thermodynamics *(First Law, ideal gas behaviour, adiabatic and isothermal processes)*
- Instrumentation & Measurement
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Ideal Gas Law -** Relates pressure, volume, and temperature for a perfect gas (PV = nRT)
- **First Law of Thermodynamics -** Energy balance underlying the expansion and equalisation processes (dU = dQ + dW)
- **Adiabatic Process Theory -** Rapid pressure change with no heat transfer to or from the surroundings
- **Isothermal Process Theory -** Slow process that remains in thermal equilibrium with the surroundings
- **Heat Capacity Ratio (γ = Cp/Cv) -** Determined experimentally using the Clément–Desormes method
- **Reversible and Irreversible Processes -** Entropy change associated with real versus idealised gas processes
- **Isentropic Process Theory -** The idealised, constant-entropy case of a reversible adiabatic process
- **Gauge and Absolute Pressure -** Relationship between measured (gauge) pressure and absolute pressure
- **Thermistor Response Theory -** Non-linear resistance/temperature relationship of the temperature probes

Optional Software

TH-DTA-ALITE:
Educational software for TH1-TH5 on a USB key complete with data logger (a PC running Windows 7 or later, with a USB port is required)

Learning Outcomes

Remember & Understand

Students explain the principles of adiabatic, isothermal, isentropic, and reversible/irreversible processes, distinguish gauge pressure from absolute pressure, and describe how the piezo-resistive pressure sensors and thermistor probes generate their readings.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students apply the ideal gas law and first law of thermodynamics to calculate the heat capacity ratio of air via the Clément–Desormes method, determine the volume ratio of the two vessels from isothermal pressure data, and analyse transient pressure and temperature responses following rapid valve operations to assess whether the adiabatic or isothermal assumptions hold.

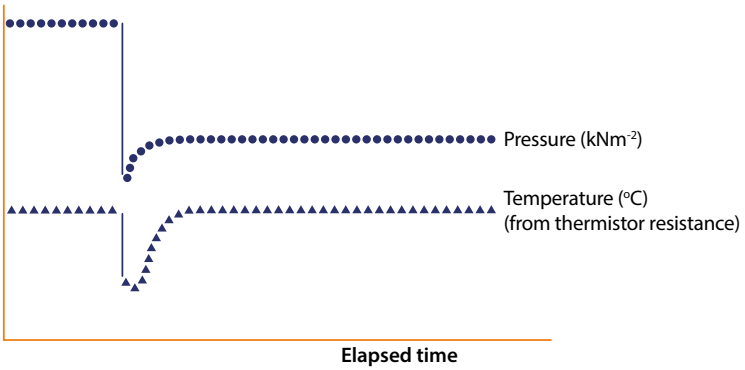
- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the accuracy of their experimentally determined heat capacity ratios and volume ratios against theoretical expectations, identify sources of error such as heat transfer during a nominally adiabatic step or a vessel leak, and design extended project-work investigations using alternative vessel configurations and adiabatic mixing between the vessels.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Response of the pressurised vessel following a brief depressurisation



Requirements	Dimensions/Console		Scale
1Ph, COLD, DRAIN	Length	0.460	0.300
	Width	0.280	0.220
	Height	0.800	0.220

Fill with clean cold water (0.1 litres)

Ordering codes

- **TH5-A :**220-240V/1ph/50Hz, 6A
- **TH5-B :** 120V/1ph/60Hz, 13A
- **TH5-G :** 220-240V/1ph/60Hz, 6A

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Film and Dropwise Condensation TH6

The TH6 Film and Dropwise Condensation unit is a self-contained, bench-top apparatus designed to provide visual and quantitative results relating to heat transfer during condensation.

Steam generation and both types of condensation take place within a single thick-walled glass chamber: the lower cover houses a variable-power electric heating element, while the upper cover carries two specially developed water-cooled copper condensers, one gold plated to promote dropwise condensation, the other in its natural state to give filmwise condensation.

The condensers present an almost isothermal surface to the steam and are instrumented so that the mean surface temperature is obtained without disturbing the surface. Cooling water flow rates are measured by flow meters with control valves, a multi-point electronic thermometer indicates all important temperatures, and a water jet vacuum pump provides air extraction, allowing the effect of air in condensers to be demonstrated at pressures up to atmospheric.



Relevant Theories and Laws

- **Filmwise Condensation -** Formation of a continuous liquid film on a plain copper surface, with the film acting as the controlling resistance to heat transfer
- **Dropwise Condensation -** Formation of discrete droplets on a non-wetting (gold plated) surface, giving substantially higher surface heat transfer coefficients
- **Surface Heat Transfer Coefficient -** Determination of the condensing coefficient from the measured heat flux and the difference between saturation and surface temperatures
- **Heat Flux -** Rate of heat transfer per unit area, with fluxes approaching 10^6 W/m^2 achievable on the dropwise condenser
- **First Law of Thermodynamics -** Energy balance on the cooling water, with the rate of heat transfer calculated from the measured water flow rate and temperature rise ($Q = \dot{m}C_p\Delta T$)
- **Latent Heat of Vaporisation -** Energy released by the condensing steam and absorbed by the cooling water
- **Saturation Pressure–Temperature Relationship -** Investigation of the saturation curve for water between approximately 20°C and 100°C
- **Dalton's Law of Partial Pressures -** Effect of air and other non-condensable gases on chamber pressure and condenser performance
- **Nucleate Boiling -** Visual observation of nucleate boiling at the submerged heating element

Learning Outcomes

Remember & Understand

Students describe the mechanisms of filmwise and dropwise condensation and explain why a non-wetting surface promotes droplet formation, define heat flux, surface heat transfer coefficient and saturation temperature, and identify the functions of the steam generator, condensers, pressure instrumentation and air extraction system.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure cooling water flow rates and temperature rises to determine heat flux and surface heat transfer coefficients for both condensation modes at pressures up to atmospheric, construct the saturation pressure–temperature curve for water between about 20°C and 100°C, and investigate the effect of air in the chamber on condenser performance as a demonstration of Dalton's Law.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the relative performance of dropwise and filmwise condensation and their measured coefficients against published correlations, assess the practical difficulty of sustaining dropwise condensation on industrial plant, and justify design and operating measures, such as venting of non-condensables for steam condensers in power and process applications.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Relevant Curriculum Modules

- Thermodynamics *(Phase change, saturation conditions and condensation)*
- Heat Transfer *(Condensation and boiling heat transfer)*
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Requirements	Dimensions		Scale
1Ph, COLD, DRAIN	Length	0.710	
	Width	0.240	
	Height	0.710	

- **Electrical supply:** 220/240 V, single phase, 50/60 Hz, 13 A (or two phases of a 220/240 V line-to-line supply; 110/130 V variant available). Suitable for a 3 kW load
- **Cold water supply:** tap for 13 mm bore hose, up to 0.6 l min^{-1} at 30 m head (3 bar), and an open drain capable of receiving this flow
- **Initial fill:** of approximately 0.5 litre of distilled/deionised water, replenished as consumed
- **Level surface**

Ordering codes

TH6-A: 3kW 220/240 Volts, Single Phase, 50 HZ

TH6-G: 3kW 110/120 Volts, Single Phase, 60 HZ

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Vapour-Compression Refrigeration Unit RA1



The Armfield RA1-MKII is a self-contained, computer-controlled vapour-compression refrigeration system demonstrating the most common refrigeration cycle in use today.

All-important process variables are automatically recorded via an integral USB interface, with real-time display of superheat conditions and Coefficient of Performance. Separate refrigerant and water circuits enable full energy balances to be carried out across the complete system.

Relevant Curriculum Modules

- Thermodynamics *(Vapour-compression cycle, refrigeration and heat pumps)*
- Heat Transfer & Energy Balances
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **First Law of Thermodynamics -** Conservation of energy applied to energy balances across the condenser and evaporator
- **Second Law of Thermodynamics -** Reversed heat engine principle underpinning refrigeration and heat pump operation
- **Vapour-Compression Refrigeration Cycle -** Compression, condensation, expansion and evaporation stages represented on the temperature –entropy (T-s) diagram
- **Coefficient of Performance (COP) -** Ratio of heat exchanged in the evaporator to compressor work input
- **Pressure–Saturation Temperature Relationship -** R134a refrigerant property behaviour and use of thermodynamic property tables
- **Superheat and Subcooling -** Departure of refrigerant temperature from saturation conditions and its role in stable system operation
- **Enthalpy and Latent Heat -** Sensible and latent heat changes during condensation and evaporation at constant pressure
- **Throttling Process -** Isenthalpic expansion of refrigerant through the thermostatic expansion valve (TXV)
- **Heat Exchanger Theory -** Heat transfer between separated fluid streams in brazed plate heat exchangers ($Q = \dot{m}C_p\Delta T$)
- **Compressor Work & Efficiency -** Relationship between electrical power input and thermodynamic work done on the refrigerant.

Learning Outcomes

Remember & Understand

Students identify the components of the vapour-compression refrigeration system, compressor, condenser, receiver, filter, sight glass, thermostatic expansion valve and evaporator, and explain the function of each within the refrigeration cycle. They define saturation temperature, superheat and Coefficient of Performance, and relate measured temperatures and pressures to the stages of the cycle on a T-s diagram.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students operate the fully instrumented system, varying condenser and evaporator water flowrates, compressor speed and expansion valve setting while logging the system response. They perform energy balances across both heat exchangers, apply R134a property tables to calculate mass flow rate, compressor work and component efficiencies, and analyse the effect of each operating variable on COP.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate overall and component-level performance to determine optimum water flowrates, refrigerant flow and expansion valve superheat setting for a given load. They diagnose off-optimal operating conditions using the sight glass and software warnings, undertake thermodynamic system modelling, and propose operating strategies that balance cooling duty against compressor energy input.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

TH-DTA-ALITE:
Computer-controlled system with automatic data acquisition, tabular and graphical display.

- Real-time schematic showing live sensor data and instantaneous Coefficient of Performance (COP).
- Variable-speed control of the compressor, condenser cooling water pump, and evaporator heating water pump.
- Integrated misuse protection with automatic alarm system.

Technical specifications

Refrigeration system	Vapour-compression type
Refrigerant	R134a
Condenser	Brazed plate heat exchanger using water as heat transfer medium
Evaporator	Brazed plate heat exchanger using water as heat transfer medium
Water reservoir	Working capacity 400 litres
Temperature sensors	NTC Thermistor
Refrigerant flowmeter	Variable area flowmeter

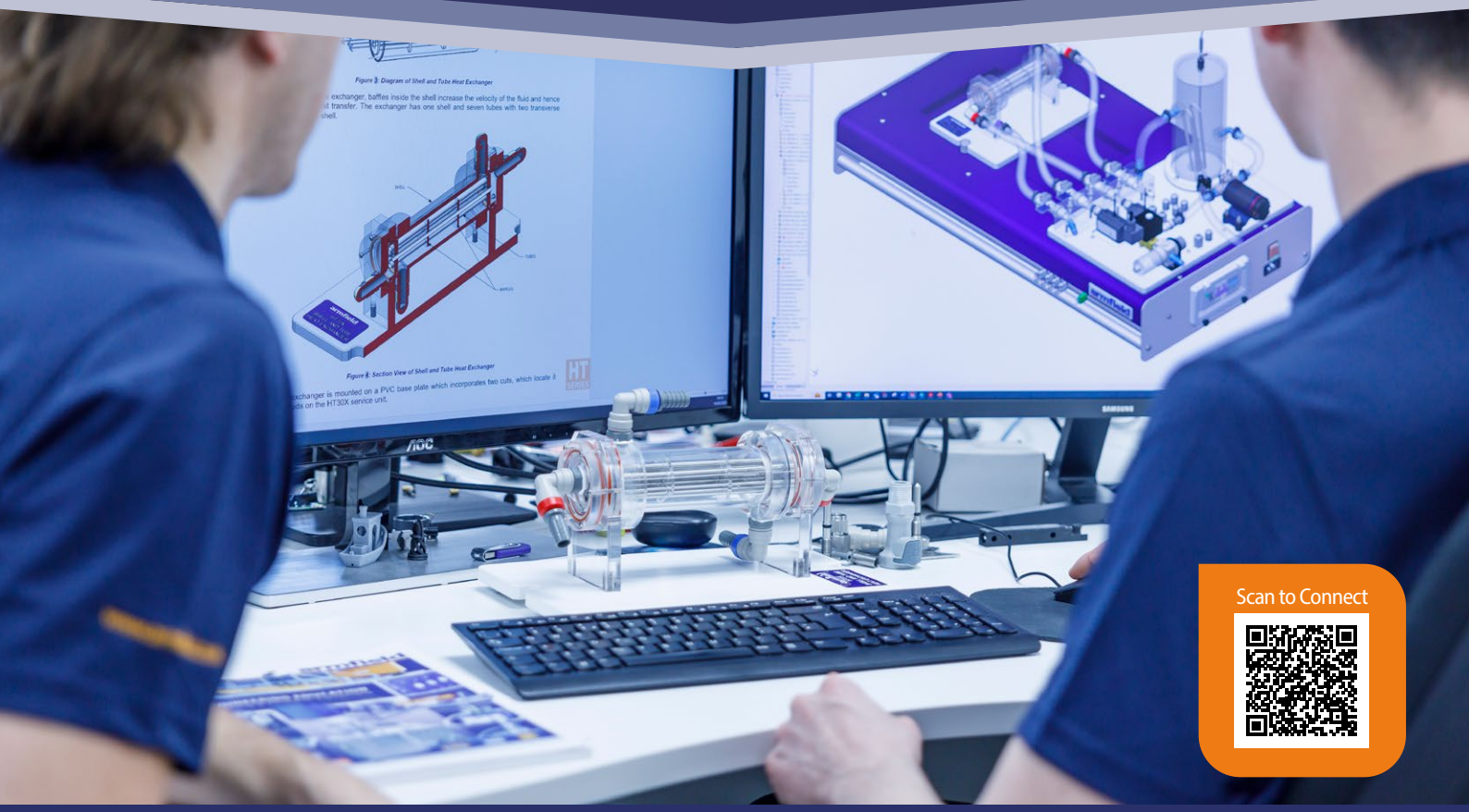
Requirements	Dimensions	Scale
1Ph, COLD, PC, USB	Length 1.090 Width 0.710 Height 1.290	

- **Electrical Supply: Single phase** (see Ordering codes)
- **Computer:** Requires a Windows PC (Windows 7 or later) with USB for data logging software

Ordering codes

- **RA1-MKII-A :** 220-240V/1ph/50Hz, 5A
- **RA1-MKII-B :** 120V/1ph/60Hz, 10A
- **RA1-MKII-C :** 220-240V/1ph/60Hz, 5A

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved



EXPERT INSTALLATION **COMMISSIONING** TRAINING

Supporting You from Day One

Armfield ensures your systems are fully operational from day one. Training is typically delivered during installation, with additional sessions available at Armfield's UK headquarters.

THANK YOU **FOR CHOOSING** ARMFIELD LTD

Time to Service Your Armfield Equipment

Keep your equipment running at peak performance with our professional maintenance services, call or scan to arrange a quote.

Why Schedule Maintenance?

Extend the lifespan of your equipment.

Prevent costly repairs.

Ensure optimal efficiency and safety.

Creative Ideas Bespoke Design

Do you need new accessories, or bespoke designs? We specialise in creating tailored solutions worldwide.

Ask for details.

Refurb: Update / Renew

We refurbish old equipment, replacing pipes, consumables, and seals to restore optimal performance.

Contact Us Customer Service Team

Our Customer Service team is ready to help with product information, technical support, and training enquiries.

sales@armfield.com

www.armfield.com
info@armfieldinc.com
Call Now +44 (0)1425 478781

Computer Controlled Air Conditioning Unit RA2

The Armfield RA2 is a fully instrumented, computer controlled bench-top duct demonstrating the four essential air conditioning processes: heating, cooling, humidification and dehumidification.
The transparent duct gives full visibility of the fan, pre-heater, steam humidifier, chiller/dehumidifier and re-heater, with temperature and relative humidity measured at every stage. Real-time USB data logging and PID control allow stable conditions to be established for complete psychrometric analysis.



Relevant Curriculum Modules

- Thermodynamics *(Psychrometrics, air conditioning and HVAC systems)*
- Heat & Mass Transfer and Energy Balances
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Psychrometrics & the Psychrometric Chart -** Graphical 'equation of state' relating dry bulb temperature, humidity ratio, relative humidity, enthalpy and specific volume of moist air
- **First Law of Thermodynamics -** Conservation of energy applied to energy balances across the heaters, humidifier and chiller
- **Relative Humidity & Saturation Vapour Pressure -** Ratio of actual to saturation water vapour pressure and its variation with temperature
- **Humidity Ratio -** Mass of water vapour per unit mass of dry air during heating, humidification and dehumidification
- **Dew Point & Dehumidification by Cooling -** Condensation of moisture when air is cooled below its saturation temperature
- **Enthalpy of Moist Air -** Combined sensible and latent heat content of the air–vapour mixture
- **Sensible and Latent Heat -** Heating without phase change versus heat absorbed or released during evaporation and condensation
- **Ideal Gas Law & Specific Volume -** Moist air density calculated from temperature, pressure and humidity ratio
- **Continuity Equation & Mass Flow Rate -** Air mass flow determined from measured velocity, duct area and specific volume
- **Vapour-Compression Refrigeration Cycle -** R134a system providing the cooling and dehumidifying duty via a direct-expansion evaporator

Learning Outcomes

Remember & Understand

Students identify the components of the air conditioning system — axial fan, pre-heater, steam humidifier, evaporator/chiller, re-heater and the temperature/relative humidity sensors at each stage — and explain the function of each within the air handling process. They define dry bulb temperature, relative humidity, humidity ratio, dew point and enthalpy, and locate the state of the air at each measurement point on the psychrometric chart.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students operate the fully instrumented duct, varying fan speed, heater power, boiler setting and chiller operation while logging the system response. They plot sensible heating, humidification and cooling with dehumidification on the psychrometric chart, calculate humidity ratio, enthalpy, specific volume and air mass flow rate, and perform mass and energy balances across each stage, including estimating the rate of dehumidification from collected condensate.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate energy balances and heating efficiency across the duct, assess the energy implications of dehumidifying by cooling followed by reheat, and tune PID control loops to establish stable target conditions. They propose conditioning strategies to achieve a specified air state from varying ambient conditions, and can extend the work into independent investigation of latent heat effects.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

TH-DTA-ALITE:
An optional automatic data acquisition system delivers real-time tabular and graphical data visualisation. Live sensor data and instantaneous Coefficient of Performance (COP) are displayed within an interactive system schematic, enabling immediate performance analysis.

Students can investigate trends, compare operating conditions, and gain deeper insights through data-driven learning, both within the laboratory and remotely beyond scheduled practical sessions.

Technical specifications

Transparent duct:	200mm x 200mm
Pre-heater:	400w
Re-heater:	200w
Humidifier total volume:	5ltr
Humidifier unit:	500w @20°c
Air velocity sensor hot film anemometer:	0-10m/s
Temperature / Relative humidity sensor x 4: (10 to 100% relative humidity)	Duct inlet
	Before the evaporator
	After the evaporator
	Duct outlet

Requirements	Dimensions		Scale
1Ph | PC | USB	Length	1.720	
	Width	0.400	
	Height	0.620	

- **Electrical Supply: Single phase** (see Ordering codes)
- **Distilled water required**
- **Computer:** Requires a Windows PC (Windows 7 or later) with USB for data logging software

Ordering codes

- **RA2-MKII-A :** 220-240V/1ph/50Hz, 13A
- **RA2-MKII-B :** 120V/1ph/60Hz, 25A
- **RA2-MKII-C :** 220-240V/1ph/60Hz, 13A

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Computer Controlled Air Conditioning Unit RA3



The Armfield RA3 is a fully instrumented, computer controlled floor-standing air conditioning system with all the features of the RA2 plus an enclosed climate chamber and adjustable recirculation of air back into the conditioning duct.

The transparent duct gives full visibility of the fan, pre-heater, steam humidifier, chiller/dehumidifier and re-heater, with temperature and relative humidity measured at six stages and air flow measured in both ducts. Real-time USB data logging and PID control allow stable conditions to be established for complete psychrometric and refrigeration cycle analysis.

Relevant Theories and Laws

- **Psychrometrics & the Psychrometric Chart -** Graphical 'equation of state' relating dry bulb temperature, humidity ratio, relative humidity, enthalpy and specific volume of moist air
- **First Law of Thermodynamics -** Conservation of energy applied to energy balances across the heaters, humidifier, chiller and recirculating system
- **Relative Humidity & Saturation Vapour Pressure -** Ratio of actual to saturation water vapour pressure and its variation with temperature
- **Humidity Ratio -** Mass of water vapour per unit mass of dry air during heating, humidification and dehumidification
- **Dew Point & Dehumidification by Cooling -** Condensation of moisture when air is cooled below its saturation temperature
- **Enthalpy of Moist Air -** Combined sensible and latent heat content of the air–vapour mixture
- **Adiabatic Mixing of Air Streams -** Mass and energy balances on the mixing of recirculated and fresh air at the duct inlet
- **Ideal Gas Law & Specific Volume -** Moist air density calculated from temperature, pressure and humidity ratio
- **Continuity Equation & Mass Flow Rate -** Air mass flow in each duct determined from measured velocity, duct area and specific volume
- **Vapour-Compression Refrigeration Cycle -** R134a system studied via the T-s diagram, with refrigerant pressures, temperatures and flow rate measured around the cycle

Learning Outcomes

Remember & Understand

Students identify the components of the recirculating air conditioning system, axial fan, pre-heater, steam humidifier, evaporator/chiller, re-heater, climate chamber and the inlet, internal and outlet louvres - and explain the function of each within the air handling process. They define dry bulb temperature, relative humidity, humidity ratio, dew point and enthalpy, and locate the state of the air at each of the six measurement points on the psychrometric chart.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students operate the fully instrumented duct, varying fan speed, heater power, boiler setting, chiller operation and louvre positions while logging the system response. They plot heating, humidification and dehumidification processes on the psychrometric chart, calculate humidity ratio, enthalpy, specific volume and air mass flow rate in both ducts, and perform mass and energy balances across each stage and across the mixing of recirculated and fresh air, tracing the vapour-compression cycle from measured refrigerant conditions.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate energy balances and heating efficiency across the duct, assess how the degree of recirculation affects heater duty and overall system efficiency, and tune PID control loops to establish stable target conditions in the climate chamber. They propose conditioning and recirculation strategies to achieve a specified room air state from varying ambient conditions, and can extend the work into independent investigation of latent heat and refrigeration cycle performance.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

TH-DTA-ALITE:
An optional automatic data acquisition system delivers real-time tabular and graphical data visualisation. Live sensor data and instantaneous Coefficient of Performance (COP) are displayed within an interactive system schematic, enabling immediate performance analysis.

Students can investigate trends, compare operating conditions, and gain deeper insights through data-driven learning, both within the laboratory and remotely beyond scheduled practical sessions.

Relevant Curriculum Modules

- Thermodynamics *(Psychrometrics, air conditioning, HVAC and refrigeration systems)*
- Heat & Mass Transfer and Energy Balances
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods



Requirements	Dimensions		Scale
1Ph | PC | USB	Length	2.450	
	Width	0.710	
	Height	1.200	

- **Electrical Supply: Single phase** (see Ordering codes)
- **Distilled water required**
- **Minimum space for ventilation of 50m³**
- **Computer:** Requires a Windows PC (Windows 7 or later) with USB for data logging software

Ordering codes

- **RA3-MKII-A :** 220-240V/1ph/50Hz, 13A
- **RA3-MKII-B :** 120V/1ph/60Hz, 25A
- **RA3-MKII-C :** 220-240V/1ph/60Hz, 13A

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Heat Transfer Service Unit HT10X

The Armfield HT10X Computer Compatible Heat Transfer Service Unit is the common bench-top platform for the HT11X–HT20X range of small-scale heat transfer accessories, which together demonstrate the basic modes of heat transfer: conduction, convection and radiation.

The service unit provides the regulated electrical supplies, sensor conditioning, temperature and power measurement, and the integral USB interface through which each accessory is operated and logged from a Windows-compatible PC.



HT10X with accessories

Relevant Curriculum Modules

- Heat Transfer *(Conduction, convection and radiation fundamentals)*
- Instrumentation & Measurement
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Modes of Heat Transfer -** Conduction, convection and radiation as the three fundamental mechanisms demonstrated across the accessory range
- **Thermoelectric Effect -** Thermocouple temperature measurement (Seebeck Effect) used throughout the accessory range
- **Electrical Power Measurement -** Heater power determined from measured DC voltage and current (Q = VI)
- **Sensor Calibration & Signal Conditioning -** Conversion of raw sensor outputs into engineering units of temperature, velocity and flow
- **Data Acquisition Theory -** Sampling, continuous logging and real-time display of process variables via the USB interface
- **Experimental Error Analysis -** Identification of systematic and random errors in electrically heated laboratory measurements

Learning Outcomes

Remember & Understand

Students identify the functions of the service unit, accessory power supplies, temperature and power measurement channels and the USB data acquisition interface and explain how a common measurement platform supports investigation and comparison of the different heat transfer mechanisms across the accessory range.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students connect individual accessories to the service unit, configure the measurement channels, and use logged voltage, current and temperature data to determine heat flows and heat transfer characteristics, applying consistent instrumentation practice across conduction, convection and radiation experiments.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the accuracy and limitations of the shared instrumentation, assess sources of measurement uncertainty common to the accessory range, and design extended investigations that exploit continuous computer-based data logging.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



armBUS NetCan: connects up-to 20 users to one piece of equipment

HT10X Input Board



Requirements	Dimensions		Scale
1Ph PC USB	Length	0.510	
	Width	0.950	
	Height	0.330	

- **Electrical Supply:** Three phase (see Ordering codes)
- **Water supply:** Cold water supply and drain: 1.5 Litres/minute at 1bar gauge (min)
- **At least one heat transfer module is required**

Software requires the user to have a PC running Windows 7 or above with a USB port.

Ordering codes

- **HT10X:** Service Unit - 90-240V 5.5A 50/60Hz or 277V 5.5A 50/60Hz
- **ArmBUS NetCan:** Network Interface
- **ACU-10 :** Armfield Control Unit 10in

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Linear Heat Conduction HT11X

The Armfield HT11X Linear Heat Conduction accessory is designed to demonstrate the application of the Fourier Rate Equation to simple steady-state conduction in one dimension.

The unit can be configured as a simple plane wall of uniform material and constant cross-sectional area, or as composite plane walls with different materials or changes in cross-sectional area, allowing the principles of heat flow by linear conduction to be investigated.

Measurement of the heat flow and temperature gradient allows the thermal conductivity of the material to be calculated, and the design also allows the conductivity of thin samples of insulating material to be determined. The HT11X is used in conjunction with the HT10X Heat Transfer Service Unit and is operated from a PC via the integral USB interface.



Relevant Curriculum Modules

- Heat Transfer (Steady-state and unsteady-state conduction)
- Thermodynamics
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fourier Rate Equation -** Rate of one-dimensional steady-state heat conduction proportional to area and temperature gradient (Q = -kA dT/dx)
- **Thermal Conductivity -** The constant of proportionality k, determined experimentally for good conductors and insulators
- **Composite Plane Walls -** Thermal resistances in series for different materials and the resulting temperature distribution
- **Overall Heat Transfer Coefficient -** Combined coefficient U for heat flow through a combination of different materials in series
- **Effect of Cross-Sectional Area -** Temperature gradient inversely proportional to cross-sectional area for constant heat flow
- **Thermal Contact Resistance -** Effect of imperfect joints, clamping pressure and conducting paste on conduction between adjacent materials
- **Insulation Theory -** thin insulating samples
- Unsteady-State Conduction - Transient temperature response along a bar following a step change in heat flow
- **Electrical Power Measurement -** Heat flow into the specimen determined from heater voltage and current (Q = VI)

Learning Outcomes

Remember & Understand

Students describe the mechanism of conduction in solids, state the Fourier Rate Equation and define thermal conductivity, thermal resistance and the Overall Heat Transfer Coefficient. They explain how the heated, specimen and cooled sections of the apparatus create a measurable one-dimensional temperature gradient.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure temperature distributions through uniform and composite plane walls at different rates of heat flow, apply the Fourier Rate Equation to calculate the thermal conductivity of conductor and insulator specimens, determine the Overall Heat Transfer Coefficient for materials in series, and demonstrate the effects of cross-sectional area and contact resistance on the temperature gradients.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

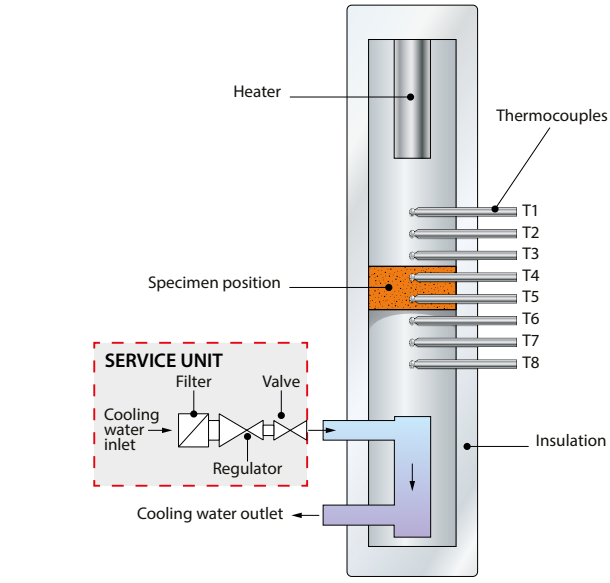
Evaluate & Create

Students evaluate experimental conductivities against published values, assess the influence of contact resistance, heat losses and sensor position on accuracy, and design extended investigations of alternative specimen materials and unsteady-state conduction using continuous computer-based data logging.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Schematic diagram showing construction of HT11X

Requirements	Dimensions		Scale
HT 10X	Length	0.430	
	Width	0.210	
	Height	0.290	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT11X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Radial Heat Conduction HT12X

The Armfield HT12X Radial Heat Conduction accessory is designed to demonstrate the application of the Fourier Rate Equation to simple steady-state conduction radially through the wall of a tube.

The arrangement uses a solid metal disk, heated at the centre and cooled at the periphery, with temperature measurements at different radii, allowing the temperature distribution and flow of heat by radial conduction to be investigated.

The HT12X is used in conjunction with the HT10X Heat Transfer Service Unit and is operated from a PC via the integral USB interface.



Relevant Curriculum Modules

- Heat Transfer (Steady-state and unsteady-state radial conduction)
- Thermodynamics
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fourier Rate Equation in Cylindrical Coordinates -** Radial steady-state conduction through the wall of a cylinder ($Q = 2\pi kL(T1 - T2)/\ln(r2/r1)$)
- **Logarithmic Temperature Distribution -** Variation of temperature with the natural logarithm of radius for radial energy flow
- **Thermal Conductivity -** Determination of the constant of proportionality k of the disk material from measured heat flow and radial temperature difference
- **Thermal Resistance of a Cylindrical Wall -** Concept of resistance to radial heat flow and its dependence on geometry
- **Unsteady-State Conduction -** Transient temperature response through the disk following a step change in heat flow
- **Electrical Power Measurement -** Heat flow into the disk determined from heater voltage and current ($Q = VI$)

Learning Outcomes

Remember & Understand

Students describe radial conduction of heat through the wall of a cylinder, state the Fourier Rate Equation in cylindrical form, and explain why the steady-state temperature distribution varies logarithmically with radius from the heated centre to the cooled periphery of the disk.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure the radial temperature distribution at different rates of heat flow, plot temperature against the logarithm of radius to confirm the theoretical profile, and apply the cylindrical form of the Fourier Rate Equation to determine the thermal conductivity of the disk material. Using computer control they also observe transient temperature changes following a step change in heat flow.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

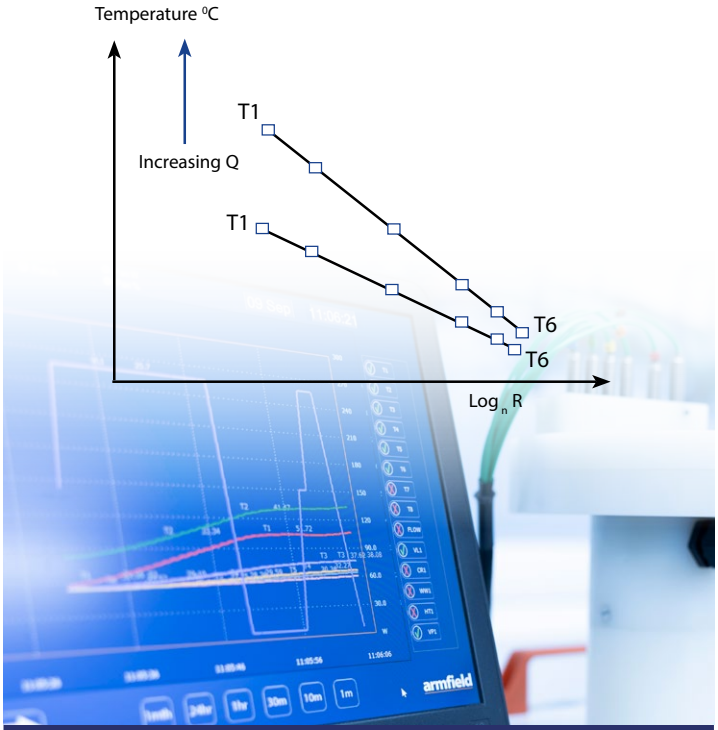
Evaluate & Create

Students evaluate their experimentally determined conductivity against published values, assess the effect of heat losses and sensor placement on accuracy, and compare radial with linear conduction to justify the appropriate analysis for cylindrical geometries such as pipes and pressure vessels.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Requirements	Dimensions		Scale
HT 10X	Length	0.430	
	Width	0.210	
	Height	0.290	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT11X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Laws of Radiant Heat Transfer HT13X

The Armfield HT13X Laws of Radiant Heat Transfer and Radiant Heat Exchange accessory is designed to demonstrate the laws of radiant heat transfer and radiant heat exchange, using light radiation to complement the heat demonstrations where the use of thermal radiation would be impractical.

The equipment comprises an arrangement of energy sources, measuring instruments, aperture plates, filter plates and target plates, mounted on a linear track in different combinations to suit the chosen exercise. The HT13X is used in conjunction with the HT10X Heat Transfer Service Unit and is operated from a PC via the integral USB interface.



Relevant Curriculum Modules

- Heat Transfer (Thermal radiation and radiant heat exchange)
- Thermodynamics
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Inverse Square Law -** Intensity of radiation on a surface inversely proportional to the square of its distance from the source, demonstrated for both heat and light
- **Stefan–Boltzmann Law -** Intensity of radiation varying as the fourth power of the absolute source temperature
- **View (Shape) Factor -** Dependence of radiation received on the interconnecting geometry between source and receiver
- **Emissivity of Surfaces -** Comparison of polished, grey and matt black surface finishes and their effect on emitted radiation and surface temperature
- **Kirchhoff's Law -** Equality of emissivity and absorptivity of a grey surface in thermal equilibrium
- **Radiant Energy Exchange between Surfaces -** Exchange of radiation as a function of the geometry and visibility between surfaces
- **Lambert Cosine Law -** Radiation in a direction at an angle to a surface equal to the normal radiation multiplied by the cosine of that angle
- **Lambert's Law of Absorption -** Reduction in intensity of light passing through non-opaque material in proportion to thickness and absorptivity

Learning Outcomes

Remember & Understand

Students state the fundamental laws of thermal and light radiation — the Inverse Square Law, the Stefan–Boltzmann Law, Kirchhoff's Law and the Lambert laws — define emissivity, absorptivity and view factor, and explain the operation of the radiometer and light meter used to measure radiation.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure radiation received at different distances, source temperatures, geometries and surface finishes, verify the Inverse Square and Stefan–Boltzmann Laws, determine view factors and surface emissivities, test Kirchhoff's Law under thermal equilibrium, and demonstrate the Lambert Cosine Law and Lambert's Law of Absorption using the light source, apertures and filter plates.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

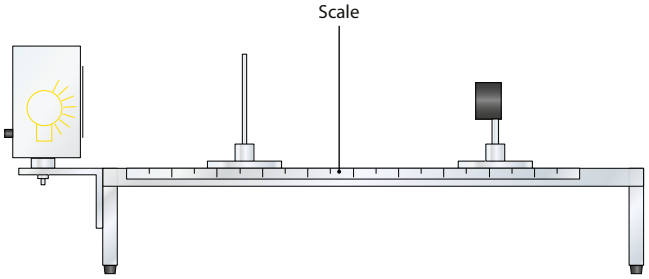
Evaluate & Create

Students evaluate the agreement between measured radiation and theoretical predictions, assess sources of error such as stray radiation and sensor response, and apply radiation theory to practical situations including surface finish selection, radiation shielding and radiant heat exchange between engineering surfaces.

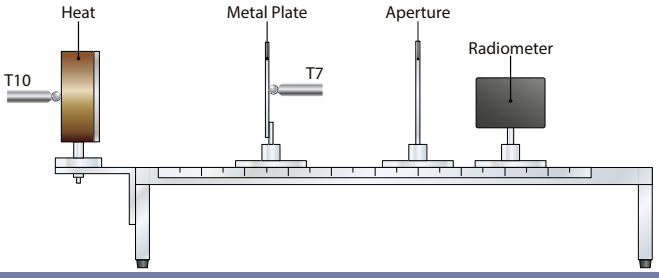
- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Schematic diagram showing HT13X set up for exercises using light



Schematic diagram showing HT13X set up for exercises using heat

Requirements	Dimensions		Scale
HT 10X	Length	1.230	
	Width	0.300	
	Height	0.440	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT13X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Combined Convection & Radiation HT14X

The Armfield HT14X Combined Convection and Radiation accessory is designed to demonstrate heat transfer from a solid surface to its surroundings.

A hot surface loses heat by the combined modes of convection and radiation; in practice these are difficult to isolate, so analysis of the combined effects at varying surface temperature and air velocity provides a meaningful teaching exercise.

The heated surface studied is a horizontal cylinder that can be operated in free convection or, when located in a stream of moving air, in forced convection. Measurement of the surface temperature and the electrical power supplied allows the combined effects to be compared with theory, demonstrating the dominance of convection at low surface temperatures and radiation at high surface temperatures. The HT14X is used in conjunction with the HT10X Heat Transfer Service Unit.

Relevant Curriculum Modules

- Heat Transfer *(Free and forced convection, thermal radiation)*
- Thermodynamics
- Fluid Mechanics
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Newton's Law of Cooling -** Convective heat transfer proportional to surface area and the temperature difference between surface and fluid (Q = hA(Ts - Ta))
- **Stefan–Boltzmann Law -** Radiative heat exchange between the cylinder surface and its surroundings, incorporating surface emissivity
- **Combined Heat Transfer Coefficients -** Contributions of the convective coefficient Hc and radiative coefficient Hr to total heat loss, and their relative dominance at low and high surface temperatures
- **Free (Natural) Convection -** Buoyancy-driven flow from a heated horizontal cylinder and empirical correlations for the natural convective coefficient
- **Forced Convection -** Effect of imposed air velocity on heat transfer from the cylinder surface and empirical correlations for flow across a cylinder
- **Local Heat Transfer Coefficient -** Variation of the local coefficient around the circumference of a cylinder in cross flow
- **Dimensionless Groups -** Reynolds and Nusselt numbers used to correlate forced convection from a cylinder
- **Energy Balance -** Electrical power input (Q = VI) equated to combined convective and radiative heat loss at steady state

Learning Outcomes

Remember & Understand

Students describe the mechanisms of free convection, forced convection and thermal radiation from a heated surface, define the convective and radiative heat transfer coefficients, and explain why the two modes cannot easily be isolated on a real surface.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

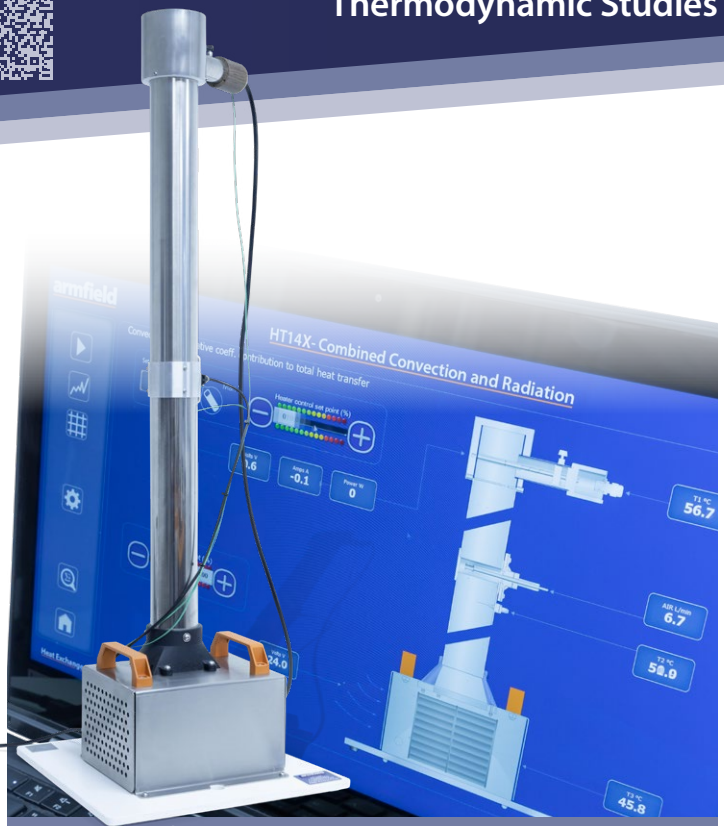
Students measure surface temperature and power input for a horizontal cylinder over a range of power settings and air velocities, calculate the convective and radiative components of heat loss, compare the dominance of Hc and Hr at low and high surface temperatures, demonstrate the enhancement of heat transfer by forced convection, and map the variation of the local heat transfer coefficient around the cylinder circumference.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

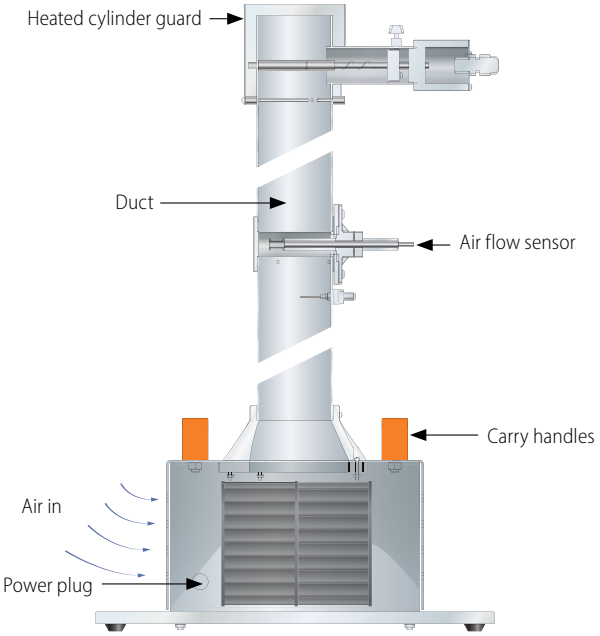
Students evaluate measured combined heat transfer against theoretical correlations, assess the assumptions and limitations of empirical convection correlations, and apply the results to practical design questions such as sizing heated elements, predicting safe surface temperatures and selecting surface finishes.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Requirements	Dimensions		Scale
HT 10X	Length	0.350	
	Width	0.300	
	Height	1.200	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT14X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Extended Surface Heat Transfer HT15X

The Armfield HT15X Extended Surface Heat Transfer accessory is designed to demonstrate the temperature profiles and heat transfer characteristics of an extended surface (a cylindrical pin), where heat flows along the rod by conduction and is lost from the rod surface by combined convection and radiation to the surroundings.

One end of the solid rod is heated and the temperature distribution along its surface is measured, allowing comparison with a theoretical analysis. The HT15X is used in conjunction with the HT10X Heat Transfer Service Unit and is operated from a PC via the integral USB interface.

Relevant Curriculum Modules

- Heat Transfer *(Extended surfaces, fins and combined mode heat transfer)*
- Thermodynamics
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Extended Surface (Fin) Theory -** One-dimensional analysis of a pin fin combining conduction along the rod with surface heat loss, and the resulting differential equation for temperature distribution
- **Fourier Rate Equation -** Conduction of heat along the rod and determination of the thermal conductivity of the rod material
- **Newton's Law of Cooling -** Convective heat loss from the rod surface proportional to the local temperature difference with the surrounding air
- **Stefan–Boltzmann Law -** Radiative heat loss from the rod surface to the surroundings, incorporating surface emissivity
- **Combined Convection and Radiation -** Combined surface heat transfer coefficient governing total heat loss from the extended surface
- **Temperature Distribution along a Fin -** Theoretical profile of temperature with distance from the heated end and its dependence on rod geometry, conductivity and surface coefficient
- **Fin Effectiveness -** Use of extended surfaces to increase heat transfer from a primary surface

Learning Outcomes

Remember & Understand

Students describe how an extended surface transfers heat by conduction along its length and loses heat from its surface by convection and radiation, and explain the practical use of fins and pins to enhance heat transfer from a primary surface.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure the temperature distribution along a heated cylindrical rod, compare the measured profile with the theoretical fin analysis, calculate the total heat transfer from the extended surface by combined free convection and radiation, and determine the thermal conductivity of the rod material from the measured distribution.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

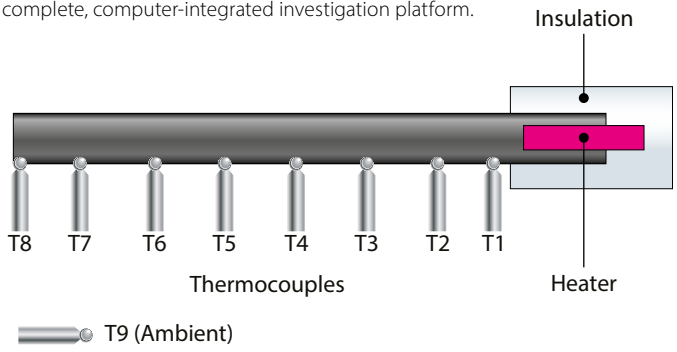
Students evaluate the agreement between measured and predicted fin temperature profiles, assess the sensitivity of the analysis to the assumed surface heat transfer coefficient and emissivity, and apply extended surface theory to the design and selection of finned surfaces in practical heat transfer equipment.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



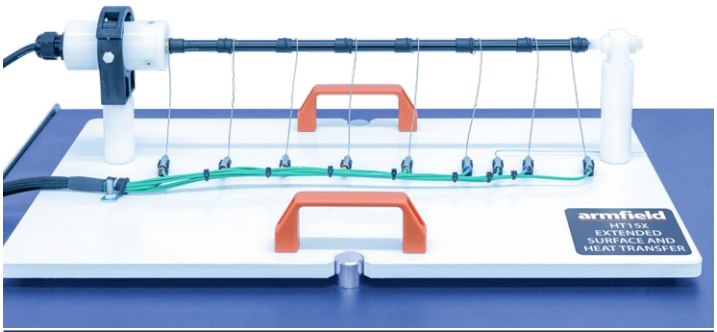
Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Schematic diagram of HT15X construction

HT15X Accessory On The Service Unit



Requirements	Dimensions		Scale
HT 10X	Length	0.500	
	Width	0.150	
	Height	0.150	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT15X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Radiation Errors in Temperature Measurement HT16X

The Armfield HT16X Radiation Errors in Temperature Measurement accessory is designed to demonstrate how temperature measurements can be influenced by sources of thermal radiation.

A group of thermocouples measures the temperature of a stream of ambient air passing through a duct whose wall is heated, subjecting the sensors to thermal radiation. Each thermocouple gains heat by radiation from the heated wall and loses heat by convection to the air stream and conduction along the wire, producing a measurable error that depends on air velocity, sensor size and sensor emissivity.

Methods of reducing the error, including radiation shields, are also demonstrated. The HT16X is used in conjunction with the HT10X Heat Transfer Service Unit.

Relevant Curriculum Modules

- Heat Transfer *(Radiation, convection and measurement error)*
- Instrumentation & Measurement
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Radiation Error Theory -** Elevation of a sensor reading above the true gas temperature caused by radiative exchange with surrounding surfaces at a different temperature
- **Sensor Energy Balance -** Steady-state balance between radiative heat gain, convective heat loss and conduction along the sensor leads
- **Stefan–Boltzmann Law -** Radiative exchange between the heated duct wall and the thermocouple surface, incorporating emissivity
- **Newton's Law of Cooling -** Convective heat loss from the sensor to the air stream and its dependence on air velocity
- **Effect of Sensor Size and Emissivity -** Influence of sensor diameter and surface finish on the magnitude of the radiation error
- **Radiation Shield Theory -** Use of a shield between sensor and radiation source, and the design of a radiation-resistant thermometer, to reduce measurement error
- **Thermoelectric Effect -** Thermocouple operation (Seebeck Effect) as the basis of the temperature measurement under study

Learning Outcomes

Remember & Understand

Students explain how radiative heat transfer between a temperature sensor and its surroundings produces measurement errors, and identify the factors, temperature difference, air velocity, sensor size and sensor emissivity, that determine the magnitude of the error.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure the readings of thermocouples of different size and emissivity in an air stream while the duct wall is heated, quantify the resulting radiation errors as air velocity and wall temperature are varied, and apply an energy balance on the sensor to explain the observed behaviour. They then demonstrate the effectiveness of a radiation shield and a radiation-resistant thermometer design in reducing the error.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

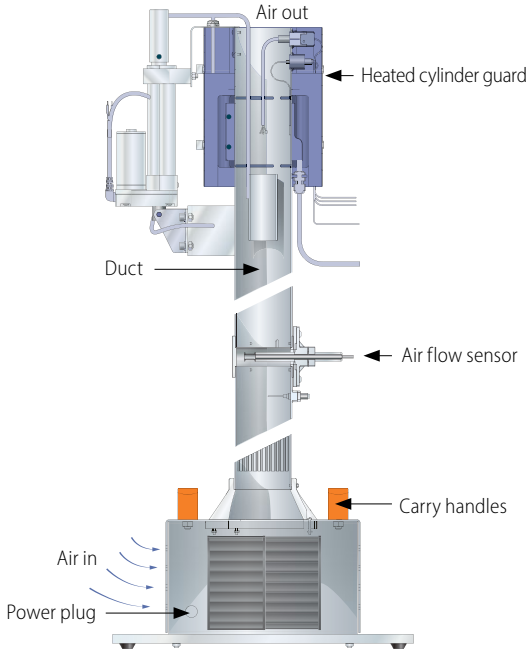
Students evaluate competing methods for reducing radiation errors, propose appropriate sensor selection and installation practice for accurate gas temperature measurement in industrial situations, and design measurement arrangements that minimise systematic error where hot surfaces are visible to the sensor.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Requirements	Dimensions		Scale
HT 10X	Length	0.350	
	Width	0.300	
	Height	1.220	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT16X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Unsteady State Heat Transfer HT17X

The HT17X Unsteady State Heat Transfer accessory is designed to allow exercises in unsteady-state heat conduction, in which simple solid shapes are suddenly subjected to convection with a fluid at constant temperature.

A set of solid shapes of different form, size and material is supplied, each instrumented with a thermocouple at its centre. Each shape is allowed to stabilise at room temperature and then suddenly immersed in a bath of hot water; the changing centre temperature is continuously logged, allowing the transient heat flow to be analysed using the appropriate transient-temperature/heat flow charts.

The HT17X is used in conjunction with the HT10X Heat Transfer Service Unit and a connected PC.



HT17X Sphere shape

Relevant Curriculum Modules

- Heat Transfer *(Transient conduction and convective boundary conditions)*
- Thermodynamics
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Unsteady-State Conduction -** Transient temperature response at the centre of a solid following a step change in surface conditions
- **Convective Boundary Condition -** Heat transfer between the immersed shape and the surrounding water governed by the surface heat transfer coefficient
- **Biot Number -** Ratio of internal conductive resistance to external convective resistance, determining the applicability of the lumped analysis
- **Fourier Number -** Dimensionless time characterising the progress of transient conduction
- **Transient-Temperature/Heat Flow Charts -** Use of analytical (Heisler-type) charts to analyse transient conduction in slabs, cylinders and spheres
- **Thermal Diffusivity -** Combined influence of conductivity, density and specific heat on the rate of temperature change
- **Determination of Thermal Conductivity -** Comparative transient method using cylinders of identical size but different materials
- **Effect of Shape, Size and Material -** Influence of geometry and thermophysical properties on unsteady heat flow

Learning Outcomes

Remember & Understand

Students explain how radiative heat transfer between a temperature sensor and its surroundings produces measurement errors, and identify the factors, temperature difference, air velocity, sensor size and sensor emissivity, that determine the magnitude of the error.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students log the transient centre temperature of solid shapes suddenly immersed in hot water, analyse the responses using transient-temperature/heat flow charts, determine the thermal conductivity of a cylinder by comparison with a similar cylinder of known conductivity, and investigate the effects of shape, size and material properties on unsteady heat flow.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

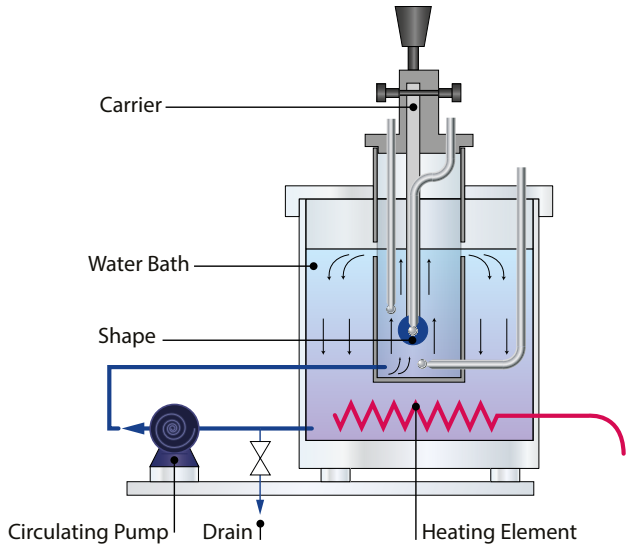
Evaluate & Create

Students evaluate the assumptions underlying the chart-based analysis, assess the influence of the surface heat transfer coefficient and sensor response on the results, and design extended project work applying transient conduction analysis to alternative shapes, materials and quenching or heating scenarios.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Requirements	Dimensions		Scale
HT 10X	Length	0.600	
	Width	0.400	
	Height	0.670	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT17X

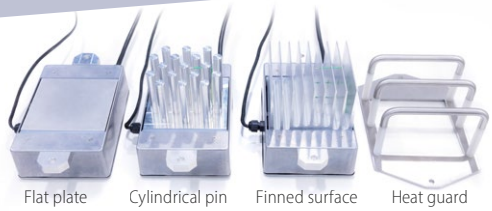
We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Free and Forced Convection HT19X

The Armfield HT19X Free and Forced Convection unit studies heat transfer by simultaneous conduction and convection, which forms the basis of most industrial heaters and related equipment.

Heat transfer coefficients are measured and predicted by studying temperature profiles and heat flux in a vertical air duct with associated flat and extended transfer surfaces. Interchangeable plug-in modules include a flat plate, a pinned heat sink and a finned heat sink and are presented to the air stream.

A variable-speed fan providing forced convection, an air velocity sensor and a continuously variable 0–240 W power supply. The HT19X is used in conjunction with the HT10X Heat Transfer Service Unit.



Flat plate surface Heat Exchanger | Cylindrical pin surface Heat Exchanger | Finned surface Heat Exchanger | Heat guard

Relevant Curriculum Modules

- Heat Transfer *(Free and forced convection, extended surfaces)*
- Fluid Mechanics
- Thermodynamics
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Newton's Law of Cooling -** Convective heat transfer from a heated surface proportional to area and surface-to-air temperature difference
- **Free (Natural) Convection -** Buoyancy-driven heat transfer from heated plates in still air and the effect of surface orientation (horizontal versus vertical)
- **Forced Convection -** Enhancement of heat transfer with imposed air velocity through the duct
- **Extended Surface Theory -** Use of pinned and finned surfaces to increase heat transfer, and the temperature distribution along an extended surface
- **Dimensionless Groups -** Reynolds, Grashof, Rayleigh and Nusselt numbers, and the characteristic velocity used to characterise free and forced convection
- **Average Heat Transfer Coefficient -** Determination of the mean coefficient for forced convection over a pinned heater (bank of tubes)
- **Energy Balance -** Relationship between electrical power input, air temperature rise through the duct and surface temperatures
- **Boundary Layer Concepts -** Development of thermal and velocity boundary layers over flat and extended surfaces

Learning Outcomes

Remember & Understand

Students distinguish free from forced convection, describe the role of buoyancy and imposed flow in each, explain the use of extended surfaces to improve heat transfer, and define the Reynolds, Grashof, Rayleigh and Nusselt numbers used to characterise convective behaviour

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure the relationship between power input and surface temperature in free and forced convection, compare flat, pinned and finned heaters at varying air velocities, determine temperature distributions along extended surfaces, calculate the characteristic velocity and the Reynolds, Grashof and Rayleigh numbers for free convection on a flat plate, and determine the average heat transfer coefficient for forced convection over the pinned heater.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the relative performance of flat and extended surfaces in different orientations and flow conditions, compare experimental heat transfer coefficients with theoretical correlations, and apply their findings to the selection and orientation of heat sinks and heated surfaces in practical thermal design.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Real-time graphing of heat transfer data

Requirements	Dimensions		Scale
HT 10X	Length	0.350	
	Width	0.300	
	Height	0.950	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT19X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Thermal Conductivity of Liquids & Gases HT20X

The Armfield HT20X is specifically designed to enable students to measure and compare the thermal conductivities of various liquids and gases.

The test section comprises an electrically heated cylindrical aluminium core surrounded by a water-cooled cylindrical aluminium jacket, arranged concentrically so that a small uniform radial gap is created between the two parts, which is filled by the fluid under test.

Measurement of the temperature difference across the fluid layer, together with the electrical power supplied to the heater, allows the thermal conductivity of the fluid to be calculated. Construction is kept simple to facilitate quick, effective cleaning and to minimise thermal losses. The HT20X is used in conjunction with the HT10X Heat Transfer Service Unit.

Relevant Curriculum Modules

- Heat Transfer *(Conduction in fluids)*
- Thermodynamics
- Fluid Mechanics
- Instrumentation & Measurement
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fourier Rate Equation -** Conduction across a thin fluid layer of constant area and thickness, allowing thermal conductivity to be calculated from heat flow and temperature gradient
- **Thermal Conductivity of Fluids -** Comparison of conductivities of different liquids and gases, and their dependence on molecular structure and temperature
- **Suppression of Convection -** Use of a small radial gap so that heat transfer through the fluid layer is by conduction alone
- **Radial Conduction Geometry -** Heat flow across the thin annular gap between concentric heated and cooled cylinders
- **Incidental Heat Losses -** Identification and allowance for heat transferred by paths other than conduction through the test fluid
- **Electrical Power Measurement -** Heat input determined from measured DC voltage and current (Q = VI)

Learning Outcomes

Remember & Understand

Students explain how a temperature gradient across a thin fluid layer of known geometry allows thermal conductivity to be determined, and why a small gap is used to suppress convection so that conduction is the only significant transfer mechanism through the sample

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students establish a temperature gradient across thin layers of test liquids and gases, measure the heat flow and temperature difference, apply the Fourier Rate Equation to calculate fluid thermal conductivity, and account for incidental heat losses in their analysis.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

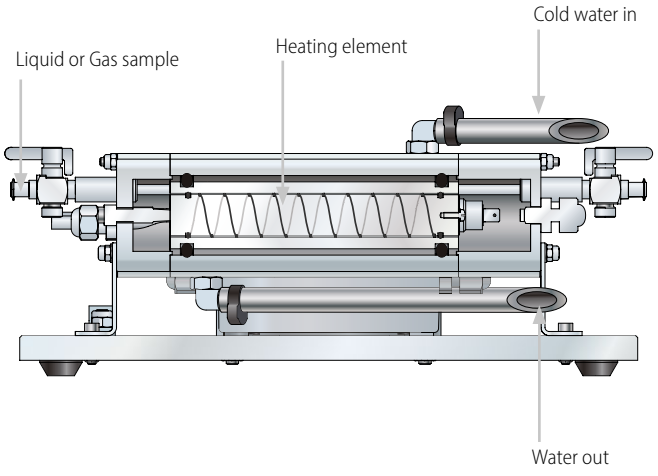
Students evaluate measured conductivities against published data for common fluids, assess the significance of convection, losses and measurement uncertainty in the method, and propose procedures for characterising alternative fluids of engineering interest.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



Optional Software

HT10X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



Requirements	Dimensions		Scale
HT 10X	Length	0.300	
	Width	0.250	
	Height	0.160	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT20X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

armfield Academy

At Armfield, we are committed to delivering innovative solutions that drive success for all our customers!

The Armfield academy is a testament to our dedication to excellence, the state-of-the-art facility is designed to provide an immersive and interactive experience for our valued customers and agents, allowing us to showcase our products/services.

Scheduling a visit to our Customer Demonstration Suite is easy.

Simply reach out to our dedicated team at sales@armfield.co.uk to book a convenient time slot.

We look forward to hosting you.



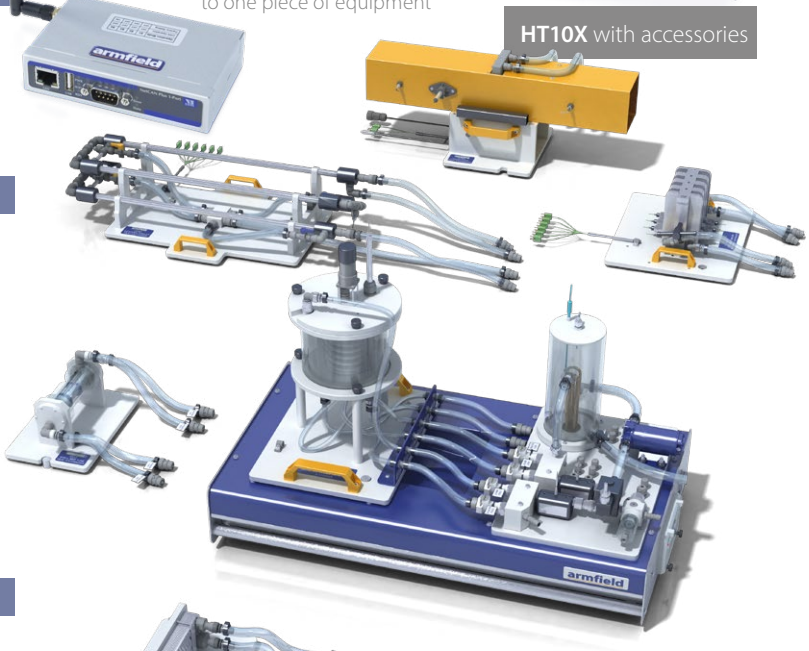
Heat Exchanger Service Unit HT30X

The Armfield HT30X Heat Exchanger Service Unit is the common bench-top platform for the HT31X–HT37X range of interchangeable small-scale heat exchangers.

The service unit provides variable flow rate streams of hot and cold water for the mounted exchanger, together with flow and temperature measurement and control and the facility for computerised data logging of the results, allowing the performance of the different heat exchanger designs to be investigated and compared on a consistent basis.



armBUS NetCan: connects up-to 20 users to one piece of equipment



HT10X with accessories



Relevant Curriculum Modules

- Heat Transfer *(Heat exchanger fundamentals)*
- Thermodynamics
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Heat Exchanger Theory -** Transfer of heat between separated hot and cold fluid streams as the common principle across the exchanger range
- **Energy Balance ($Q = \dot{m}C_p\Delta T$) -** Heat duty of each stream determined from measured flow rate and temperature change
- **Flow Measurement and Control -** Regulation and measurement of hot and cold water flow rates supplied to the exchanger
- **Temperature Measurement -** Multi-point temperature instrumentation of the inlet, outlet and intermediate stream conditions
- **Data Acquisition Theory -** Computerised logging of flow and temperature data for steady-state and transient analysis
- **Experimental Error Analysis -** Sources of systematic and random error in flow and temperature measurement affecting energy balance closure

Learning Outcomes

Remember & Understand

Students identify the functions of the service unit: the hot and cold water supply circuits, flow and temperature instrumentation, and the data logging facility and explain how a common platform supports systematic comparison of tubular, plate, shell and tube, jacketed vessel, cross flow and extended exchanger designs.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students set and measure hot and cold stream flow rates and temperatures for a mounted exchanger, log steady-state data, and perform energy balances on both streams to characterise exchanger duty, efficiency and heat transfer performance.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate energy balance closure and measurement uncertainty across the instrumentation, and design comparative experimental programmes that use the interchangeable exchangers to select the most appropriate design for a specified duty.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Requirements

1Ph | PC | USB | DRAIN

Dimensions

Length	0.510
Width	0.950
Height	0.330

Scale



- **Electrical Supply:** Three phase (see Ordering codes)
- **Water supply:** Cold water supply and drain: 1.5 Litres/minute at 1bar gauge (min)
- **At least one heat transfer module is required**

Software requires the user to have a PC running Windows 7 or above with a USB port.

Ordering codes

- **HT30X:** Service Unit - 90-240V 5.5A 50/60Hz or 277V 5.5A 50/60Hz
- **ArmBUS NetCan:** Network Interface
- **ACU-10 :** Armfield Control Unit 10in

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Tubular Heat Exchanger HT31X



The Armfield HT31X Tubular Heat Exchanger demonstrates the basic principles of heat exchanger theory using a concentric (double pipe) design, in which heat is transferred between hot water flowing through the inner tube and cold water flowing through the outer annulus.

The exchanger can be configured for co-current or countercurrent operation, and temperature measurements along the streams allow temperature profiles, efficiencies and heat transfer coefficients to be determined.

The HT31X is used in conjunction with the HT30X Heat Exchanger Service Unit, which provides the hot and cold water streams, flow and temperature measurement and data logging.

Relevant Curriculum Modules

- Heat Transfer *(Heat exchanger design and performance)*
- Thermodynamics
- Fluid Mechanics
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fluid to Fluid Heat Transfer -** Indirect heating or cooling by transfer of heat between fluid streams separated by a solid wall
- **First Law of Thermodynamics -** Energy balance across the exchanger relating heat emitted by the hot stream to heat absorbed by the cold stream ($Q = \dot{m}C_p\Delta T$)
- **Overall Efficiency and Temperature Efficiency -** Measures of exchanger performance derived from the stream temperature changes
- **Exchanger Effectiveness -** Ratio of actual heat transfer to the maximum possible heat transfer
- **Co-current and Countercurrent Flow -** Effect of relative flow direction on heat transferred, temperature efficiencies and temperature profiles
- **Logarithmic Mean Temperature Difference (LMTD) -** Appropriate mean driving force for heat transfer calculations in each flow configuration
- **Overall Heat Transfer Coefficient (U) -** Determination of U from measured duty, area and LMTD, and its variation with fluid flow rate
- **Driving Force -** Effect of hot fluid inlet temperature on efficiencies and heat transfer coefficient

Learning Outcomes

Remember & Understand

Students describe the construction and operation of a concentric tube heat exchanger, define overall efficiency, temperature efficiency, effectiveness, LMTD and the overall heat transfer coefficient, and distinguish co-current from countercurrent flow arrangements.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure the temperature changes of the hot and cold streams, perform energy balances to determine overall efficiency and effectiveness, compare co-current and countercurrent operation, calculate the overall heat transfer coefficient using the LMTD, and investigate the effects of flow rate and driving force on performance.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the relative merits of co-current and countercurrent operation, assess energy balance closure and experimental uncertainty, and apply their measured coefficients to the rating and selection of tubular exchangers for specified duties.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT30X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.

Launch experiments directly from the software start screen



Requirements	Dimensions		Scale
HT 30X	Length	0.160	
	Width	0.630	
	Height	0.390	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT30X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT31X

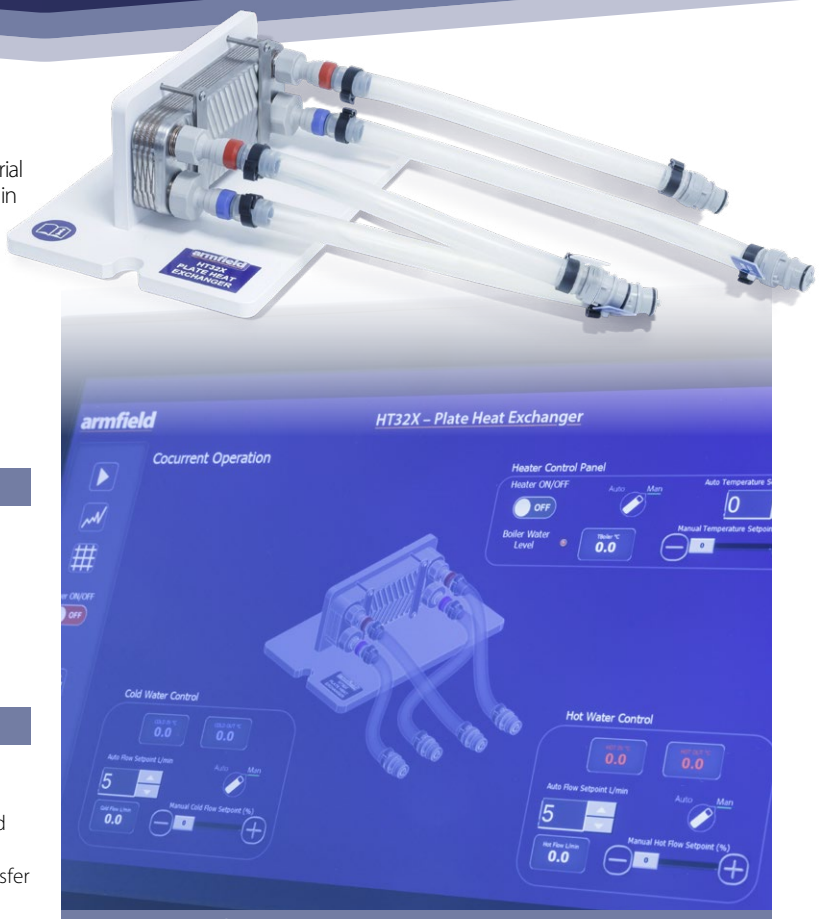
We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Plate Heat Exchanger HT32X

The HT32X Plate Heat Exchanger is a miniature scale version of a typical industrial plate heat exchanger, a design that is extremely versatile and commonly used in the food and chemical processing industries, where different combinations of plates and gaskets can be arranged to suit a particular application.

Hot and cold water streams flow through channels between alternate sides of the plates, and the exchanger can be operated in co-current or countercurrent configuration.

The HT32X is used in conjunction with the HT30X Heat Exchanger Service Unit, which provides the variable flow rate hot and cold water streams, instrumentation and data logging.



Relevant Curriculum Modules

- Heat Transfer *(Heat exchanger design and performance)*
- Thermodynamics
- Fluid Mechanics
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fluid to Fluid Heat Transfer -** Indirect heating or cooling by heat transfer between streams flowing in channels on alternate sides of the plates
- **First Law of Thermodynamics -** Energy balance across the exchanger and calculation of Overall Efficiency at different flow rates ($Q = \dot{m}C_p\Delta T$)
- **Exchanger Effectiveness -** Ratio of actual to maximum possible heat transfer for the plate configuration
- **Co-current and Countercurrent Flow -** Effect of relative flow direction on heat transferred and temperature efficiencies
- **Logarithmic Mean Temperature Difference (LMTD) -** Mean driving force, applied with an appropriate correction factor for the plate geometry
- **Overall Heat Transfer Coefficient (U) -** Determination of U from measured duty, plate area and corrected LMTD
- **Effect of Flow Rate and Driving Force -** Influence of stream flow rates and hot inlet temperature on efficiencies and heat transfer coefficient
- **Compact Heat Exchanger Concepts -** High surface-area-to-volume ratio and turbulence promotion characteristic of corrugated plate designs

Learning Outcomes

Remember & Understand

Students describe the construction of a gasketed plate heat exchanger and its widespread industrial application, define efficiency, effectiveness, LMTD (with correction factor) and the overall heat transfer coefficient, and distinguish co-current from countercurrent operation.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure stream temperatures and flow rates, perform energy balances to determine Overall Efficiency and effectiveness, compare co-current and countercurrent configurations, calculate the overall heat transfer coefficient using the corrected LMTD, and investigate the effects of flow rate and driving force on performance.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the compactness and performance of the plate design against tubular alternatives, assess energy losses and measurement uncertainty, and justify the selection of plate exchangers for duties typical of the food and chemical processing industries.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT30X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



HT32X Plate Heat Exchanger module installed on the HT30X Service Unit.

Requirements	Dimensions		Scale
HT 30X	Length	0.160	
	Width	0.630	
	Height	0.390	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT30X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT32X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Shell and Tube Heat Exchanger HT33X

The Armfield HT33X Shell and Tube Heat Exchanger demonstrates the principles of the most widely used industrial heat exchanger design.

Heat is transferred between hot water flowing through the inner tube bundle and cold water flowing through the outer shell, and the unit can be operated in co-current or countercurrent configuration.

The HT33X is used in conjunction with the HT30X Heat Exchanger Service Unit, which provides the hot and cold water streams together with flow and temperature measurement, control and computerised data logging.



Relevant Curriculum Modules

- Heat Transfer *(Shell and tube heat exchanger design and performance)*
- Thermodynamics
- Fluid Mechanics
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fluid to Fluid Heat Transfer -** Indirect heating or cooling by transfer of heat between the tube-side and shell-side streams separated by the tube walls
- **First Law of Thermodynamics -** Energy balance across the exchanger and calculation of Overall Efficiency at different flow rates ($Q = \dot{m}C_p\Delta T$)
- **Shell and Tube Construction -** Tube bundle, shell and baffle arrangement promoting cross flow over the tubes and increasing shell-side heat transfer
- **Co-current and Countercurrent Flow -** Effect of relative flow direction on heat transferred and temperature efficiencies
- **Overall Heat Transfer Coefficient (U) -** Determination of U from measured duty, transfer area and LMTD, and its variation with fluid flow rate
- **Driving Force -** Effect of hot fluid inlet temperature on temperature efficiencies and overall heat transfer coefficient

Learning Outcomes

Remember & Understand

Students describe the construction and industrial importance of the shell and tube heat exchanger, including the role of the tube bundle and baffles, define efficiency, LMTD and the overall heat transfer coefficient, and distinguish co-current from countercurrent operation.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure the temperature changes of the tube-side and shell-side streams, perform energy balances to calculate Overall Efficiency, compare co-current and countercurrent operation, determine the overall heat transfer coefficient using the LMTD, and investigate the effects of flow rate and driving force on performance

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

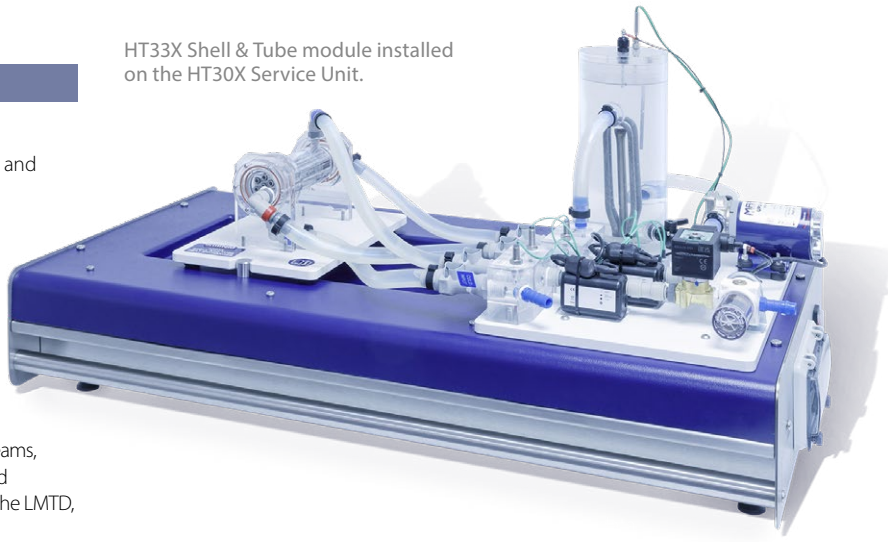
Students evaluate the performance of the shell and tube design against tubular and plate alternatives, assess energy balance closure and experimental uncertainty, and apply their results to the rating and selection of shell and tube exchangers for industrial duties.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT30X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.

HT33X Shell & Tube module installed on the HT30X Service Unit.



Requirements	Dimensions		Scale
HT 30X	Length	0.190	
	Width	0.430	
	Height	0.390	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT30X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT33X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Jacketed Vessel with Coil and Stirrer HT34X

The Armfield HT34X Jacketed Vessel with Coil and Stirrer demonstrates the heating of a liquid in a vessel, a configuration fundamental to batch processing in the chemical, pharmaceutical and food industries.

The vessel may be heated by hot water circulating either through a submerged coil or through a jacket surrounding the vessel, in batch or continuous flow operation, with a variable speed stirrer to investigate the effect of agitation.

The HT34X is used in conjunction with the HT30X Heat Exchanger Service Unit, which provides the hot and cold water streams together with flow and temperature measurement, control and data logging.



Relevant Curriculum Modules

- Heat Transfer *(Jacketed vessels, coils and agitated heat transfer)*
- Thermodynamics
- Batch and Continuous Processing
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fluid to Fluid Heat Transfer -** Indirect heating or cooling of the vessel contents by hot water in the jacket or submerged coil
- **First Law of Thermodynamics -** Energy balances for batch and continuous flow heating of the vessel contents ($Q = \dot{m}C_p\Delta T$)
- **Transient Batch Heating -** Time-dependent temperature response of a fixed batch of liquid heated via coil or jacket
- **Logarithmic Mean Temperature Difference (LMTD) -** Mean driving force used to determine the overall heat transfer coefficient, including its change as the batch temperature rises
- **Overall Heat Transfer Coefficient (U) -** Comparison of U for coil and jacket heating in batch and continuous operation
- **Overall Efficiency -** Energy balance based measure of performance for the continuous flow stirred vessel
- **Effect of Agitation -** Influence of stirrer speed on the vessel-side heat transfer coefficient and heating characteristics
- **Continuous Stirred Vessel Operation -** Steady-state heat transfer with continuous feed and discharge, and the effect of fluid volume

Learning Outcomes

Remember & Understand

Students describe the construction and operation of a stirred vessel heated by a submerged coil or an external jacket, explain the difference between batch and continuous flow heating, and define the overall heat transfer coefficient and LMTD as applied to vessel heating.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students monitor the transient temperature of a batch of liquid heated via the coil and via the jacket, determine how the overall heat transfer coefficient changes as the batch heats, perform energy balances and calculate Overall Efficiency and U for continuous flow operation with each heating surface, and investigate the effect of stirrer speed on heat transfer.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the relative merits of coil and jacket heating and of batch versus continuous operation, assess the influence of agitation and fluid volume on performance, and recommend heating configurations and operating conditions for practical batch processing duties.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT30X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



HT34X Jacketed Vessel module installed on the HT30X Service Unit.

Requirements	Dimensions		Scale
HT 30X	Length	0.400	
	Width	0.180	
	Height	0.390	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT30X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT34X

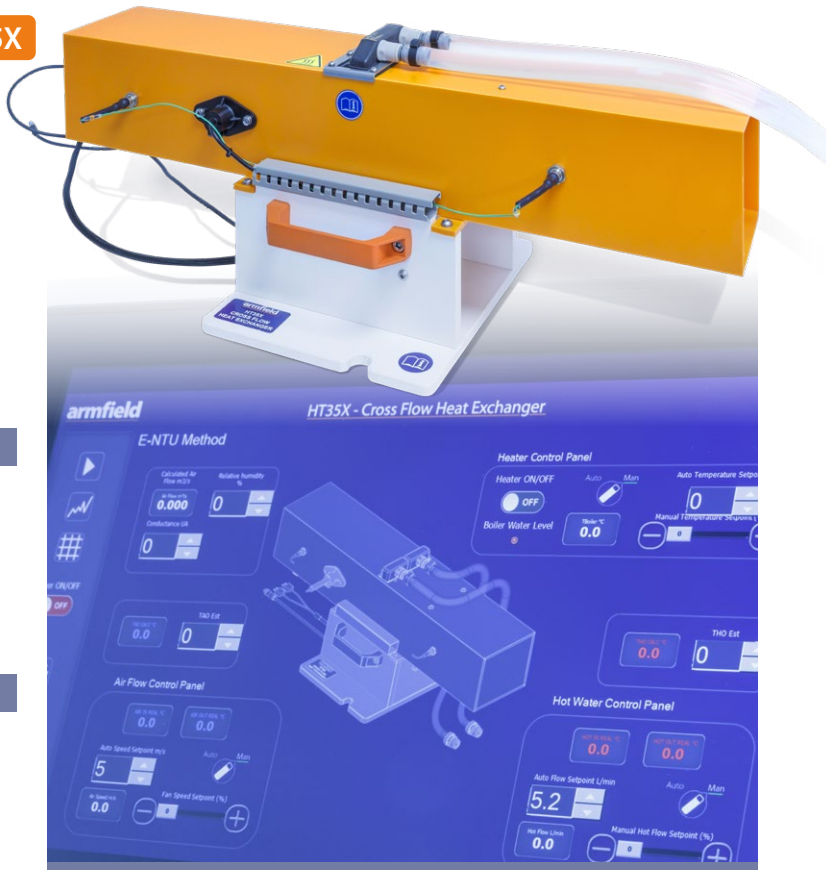
We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Single-Pass Cross Flow Heat Exchanger HT35X

The Armfield HT35X Single-Pass Cross Flow Heat Exchanger demonstrates heat transfer from hot water to air, with the direction of the air flow perpendicular to that of the hot water, a configuration typical of radiators, air coolers and air-heating coils.

Temperature measurements of both streams allow energy balances, the influence of humidity through the humid heat of the air, and the overall heat transfer coefficient to be determined, with performance also analysed by the effectiveness–NTU method.

The HT35X is used in conjunction with the HT30X Heat Exchanger Service Unit, which provides the hot water stream together with instrumentation and data logging.



Relevant Curriculum Modules

- Heat Transfer *(Cross flow and liquid-to-gas heat exchange)*
- Thermodynamics *(Psychrometrics of moist air)*
- Batch and Continuous Processing
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Cross Flow Heat Exchange -** Heat transfer between streams flowing perpendicular to one another, characteristic of water-to-air exchangers
- **First Law of Thermodynamics -** Energy balance across the exchanger comparing heat lost by the water with heat gained by the air ($Q = \dot{m}C_p\Delta T$)
- **Humid Heat of Air -** Effect of air humidity on the specific heat used in the air-side energy balance
- **Logarithmic Mean Temperature Difference (LMTD) -** Mean driving force used to determine the overall heat transfer coefficient for the cross flow configuration
- **Overall Heat Transfer Coefficient (U) -** Determination of U and its dependence on water flow rate and inlet water temperature
- **Effectiveness–NTU Method -** Prediction of outlet temperatures from the overall coefficient and stream capacity rates, compared against measured values
- **Effect of Flow Rate and Driving Force -** Influence of water flow rate and inlet temperature on temperature efficiencies and heat transfer

Learning Outcomes

Remember & Understand

Students describe the cross flow arrangement and its industrial applications, explain why the humid heat of moist air must be considered in air-side energy balances, and define LMTD, the overall heat transfer coefficient and the effectiveness–NTU parameters for a cross flow exchanger.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure water and air temperatures and flow rates, perform energy balances across the exchanger including the effect of humidity, determine the overall heat transfer coefficient using the LMTD, investigate the effects of water flow rate and inlet water temperature, and apply the effectiveness–NTU method to predict outlet temperatures for comparison with measured values.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the agreement between NTU-based predictions and experimental results, assess the sources of imbalance in the water- and air-side energy balances, and apply cross flow exchanger analysis to the design of practical liquid-to-air heat transfer equipment.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT30X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.

HT35X Cross Flow Heat Exchanger module installed on the HT30X Service Unit.



Requirements	Dimensions		Scale
HT 30X	Length	0.150	
	Width	0.750	
	Height	0.400	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT30X Computer-Controlled Heat Transfer Service Unit

Ordering codes

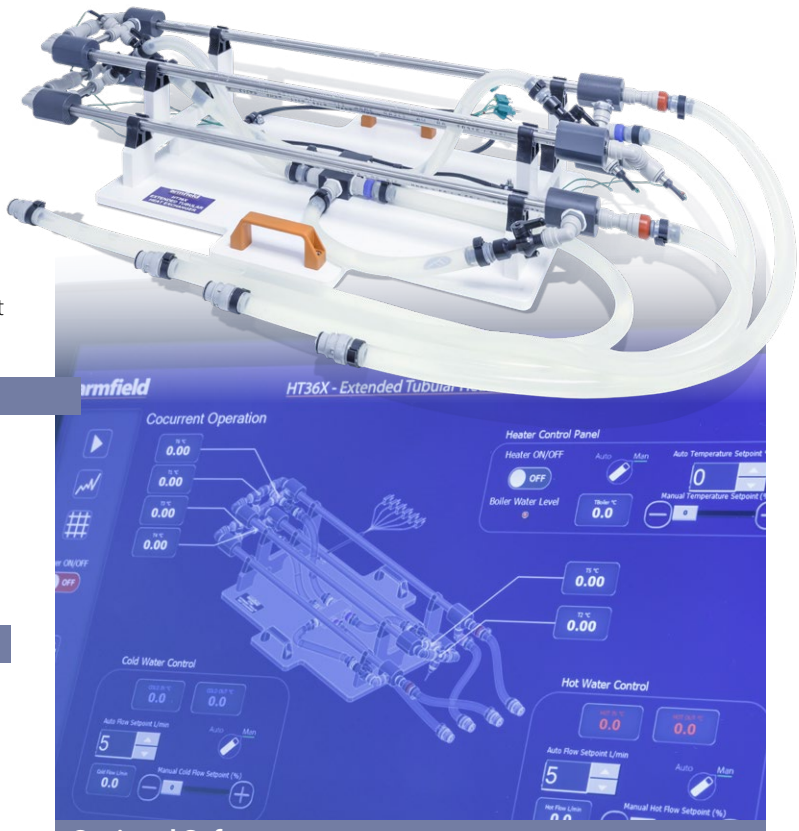
- HT35X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Extended Tubular Heat Exchanger HT36X

The Armfield HT36X Extended Tubular Heat Exchanger demonstrates the principles of concentric tube heat exchange using an extended transfer area with intermediate temperature measurement, allowing detailed temperature profiles through the exchanger to be established. Hot water flows through the inner tube and cold water through the outer annulus, in co-current or countercurrent configuration.

The HT36X is used in conjunction with the HT30X Heat Exchanger Service Unit and a connected PC running the Armfield software, with the service unit providing the hot and cold water streams, flow and temperature measurement and computerised data logging.



Relevant Curriculum Modules

- Heat Transfer *(Heat exchanger design, temperature profiles and performance)*
- Thermodynamics
- Fluid Mechanics
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fluid to Fluid Heat Transfer -** Indirect heating or cooling by transfer of heat between streams in the inner tube and outer annulus of a concentric tube exchanger
- **First Law of Thermodynamics -** Energy balance across the exchanger and calculation of Overall Efficiency at different flow rates ($Q = \dot{m}C_p\Delta T$)
- **Temperature Profiles -** Development of stream temperatures along the extended exchanger length in co-current and countercurrent operation
- **Co-current and Countercurrent Flow -** Effect of relative flow direction on heat transferred, temperature efficiencies and temperature profiles
- **Logarithmic Mean Temperature Difference (LMTD) -** Mean driving force used to determine the overall heat transfer coefficient in each flow configuration
- **Overall Heat Transfer Coefficient (U) -** Determination of U from measured duty, transfer area and LMTD, and its variation with fluid flow rate
- **Driving Force -** Effect of hot fluid inlet temperature on temperature efficiencies and overall heat transfer coefficient

Learning Outcomes

Remember & Understand

Students describe the construction and operation of a concentric tube heat exchanger with extended transfer area, sketch the expected temperature profiles for co-current and countercurrent flow, and define efficiency, LMTD and the overall heat transfer coefficient.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students measure stream temperatures at intermediate positions along the exchanger to construct temperature profiles, perform energy balances to calculate Overall Efficiency, compare co-current and countercurrent operation, determine the overall heat transfer coefficient using the LMTD, and investigate the effects of flow rate and driving force.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

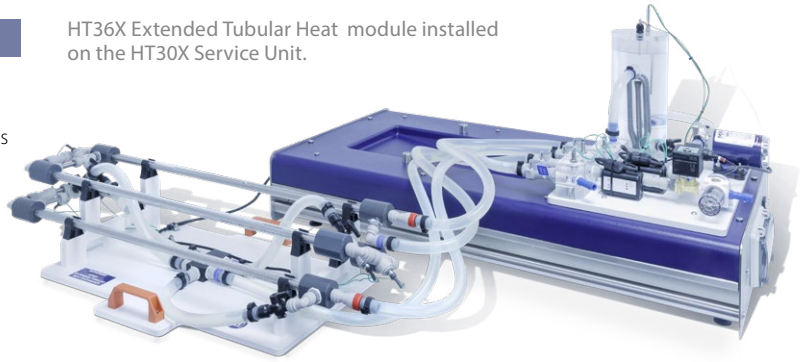
Evaluate & Create

Students evaluate the measured temperature profiles against theoretical expectations for each flow configuration, assess experimental uncertainty and energy balance closure, and apply their results to the analysis and specification of tubular heat exchangers for practical duties.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Optional Software

HT30X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.



HT36X Extended Tubular Heat module installed on the HT30X Service Unit.

Requirements	Dimensions		Scale
HT 30X	Length	0.400	
	Width	0.180	
	Height	0.390	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT30X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT36X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Extended Plate Heat Exchanger HT37X

The HT37X Extended Plate Heat Exchanger is a miniature scale version of a typical industrial plate heat exchanger, extended so that the plate arrangement can be reconfigured to investigate the effect of available surface area, and provided with a regenerator to demonstrate heat recovery between the cold inlet and outlet streams.

The plate design is extremely versatile and commonly used in the food and chemical processing industries. The HT37X is used in conjunction with the HT30X Heat Exchanger Service Unit, which provides the variable flow rate hot and cold water streams together with instrumentation and data logging.

Relevant Curriculum Modules

- Heat Transfer *(Plate heat exchangers, surface area and heat recovery)*
- Thermodynamics
- Process Design & Energy Efficiency
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Fluid to Fluid Heat Transfer -** Indirect heating or cooling by heat transfer between streams on alternate sides of the plates, and the effect of available surface area on performance
- **First Law of Thermodynamics -** Energy balance across the exchanger and calculation of Overall Efficiency at different flow rates ($Q = \dot{m}C_p\Delta T$)
- **Co-current and Countercurrent Flow -** Effect of relative flow direction on heat transferred and temperature efficiencies
- **Logarithmic Mean Temperature Difference (LMTD) -** Mean driving force, applied with an appropriate correction factor for the plate configuration
- **Overall Heat Transfer Coefficient (U) -** Determination of U from measured duty, plate area and corrected LMTD, and the effect of flow rate
- **Driving Force -** Effect of hot fluid inlet temperature on efficiencies and overall heat transfer coefficient
- **Regeneration -** Heat recovery between the cold inlet and outlet streams before and after the main exchanger, and its effect on overall energy use
- **Heat Exchanger Reconfiguration** - Effect of the number and arrangement of plates on transfer area and exchanger performance

Learning Outcomes

Remember & Understand

Students describe the construction of a reconfigurable plate heat exchanger and the purpose of regeneration, define efficiency, LMTD (with correction factor) and the overall heat transfer coefficient, and explain how transfer area and flow configuration influence performance.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

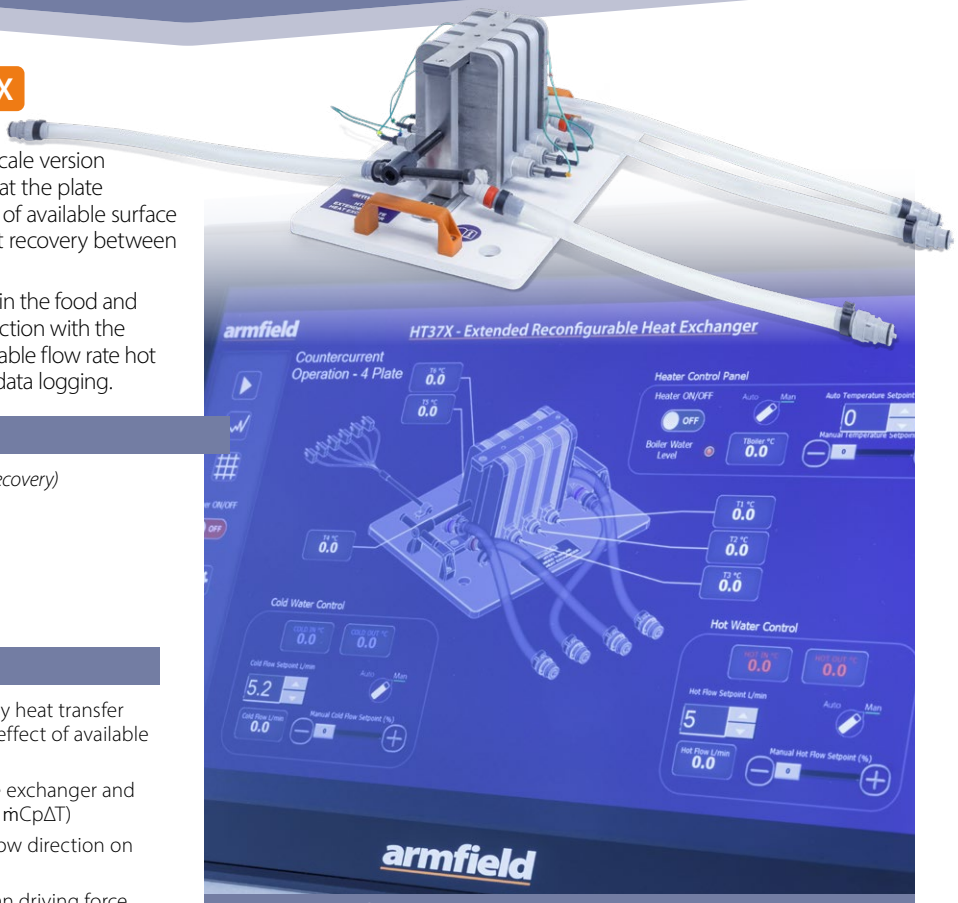
Students measure stream temperatures and flow rates for different plate configurations, perform energy balances to determine Overall Efficiency, compare co-current and countercurrent operation, calculate the overall heat transfer coefficient using the corrected LMTD, investigate the effects of flow rate, driving force and available surface area, and quantify the benefit of regeneration on heat recovery.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the trade-off between transfer area, pumping requirements and thermal performance, assess the energy savings achievable through regeneration, and design plate arrangements and heat recovery schemes for specified process duties, extending the work through independent project investigations.

- **IChemE outcomes: Design;** evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



Optional Software

HT30X Software - Armfield's purpose-built educational software connects each service unit to a Windows PC via a single USB interface, with real-time display of every temperature, flow and power measurement and continuous data logging with easy export, transforming each bench-top unit into a complete, computer-integrated investigation platform.

HT37X Extended Reconfigurable Plate Heat Exchanger module installed on the HT30X Service Unit.



Requirements	Dimensions		Scale
HT 30X	Length	0.400	
	Width	0.180	
	Height	0.390	

All electrical requirements and cold water supply are obtained from the HT10X service unit

Essential accessories

HT30X Computer-Controlled Heat Transfer Service Unit

Ordering codes

- HT37X

We reserve the right to amend these specifications without prior notice. E&OE © 2026 Armfield Ltd. All Rights Reserved

Fluid Science Heat Exchange Modules FS3.1–FS3.4

The Armfield Fluid Science heat exchange modules present four of the heat exchanger types most commonly found in industry.

The Shell and Tube *(FS3.1, a straight-tube, two pass tube-side design with shell baffles)*, the Tubular or double pipe *(FS3.2, two concentric tubes)*, the air-cooled Crossflow *(FS3.3, a finned multi-tubular exchanger with 24 V fan)* and the gasketed Plate *(FS3.4, corrugated plates clamped in a frame)*.

Each module mounts on the Fluid Science service units, which provide the pumped hot water stream with heater and temperature setpoint control, the cold water stream, flowmeters with needle valve control, and thermocouples read on a digital thermometer.

Inlet and outlet temperatures and flow rates are recorded so that the different designs, flow configurations and operating conditions can be analysed and compared on a consistent basis



Relevant Theories and Laws

- **Fluid to Fluid Heat Transfer -** Direct and indirect heat transfer between liquid, and liquid and gaseous, streams across a solid interface, involving conduction and convection
- **First Law of Thermodynamics -** Energy balance on each stream and on the complete exchanger ($Q = \dot{m}C_p\Delta T$)
- **Overall Efficiency -** Ratio of heat absorbed by the cold stream to heat emitted by the hot stream (Qa/Qe), with practical heat losses to the environment compared against theory
- **Co-current and Countercurrent Flow -** Effect of relative flow direction on temperature difference and heat transferred, and why the countercurrent driving force exceeds the co-current case
- **Logarithmic Mean Temperature Difference (LMTD) -** Calculation of the mean temperature driving force from the terminal temperature differences
- **Overall Heat Transfer Coefficient (U) -** Determination of U from measured duty, transfer area and LMTD ($U = Q/A{\cdot}\Delta T_{LM}$)
- **Natural and Forced Convection -** Comparison of crossflow exchanger cooling with the fan off and on, and the role of fins in compensating for the poor thermal conductivity of air
- **Shell and Tube Construction -** Tube bundle, shell and baffle arrangement promoting mixing and cross flow over the tubes
- **Compact Plate Exchanger Concepts -** Corrugated plates promoting turbulent mixing even at low Reynolds numbers, giving high heat transfer coefficients and reduced fouling
- **Heat Exchanger Design Parameters -** Controlling parameters of each design, such as the effect of tube wall thickness on heat transfer in a tubular exchanger

Learning Outcomes & Bloom Alignment

Remember & Understand

Students list the common types of heat transfer equipment and their industrial applications, describe the construction of the shell and tube, tubular, crossflow and plate exchangers, identify the modes of heat transfer occurring in each, and explain why the temperature difference for countercurrent flow exceeds that for co-current flow.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students record inlet and outlet temperatures at a range of hot and cold flow rates for each module, carry out energy balances using $Q = \dot{m}C_p\Delta T$, calculate the logarithmic mean temperature difference, overall heat transfer coefficient and overall efficiency, compare co-current and countercurrent operation, and contrast natural and forced convection cooling on the crossflow exchanger.

- **IChemE outcomes:** Analysis; investigation; experimental design; data interpretation and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice

Evaluate & Create

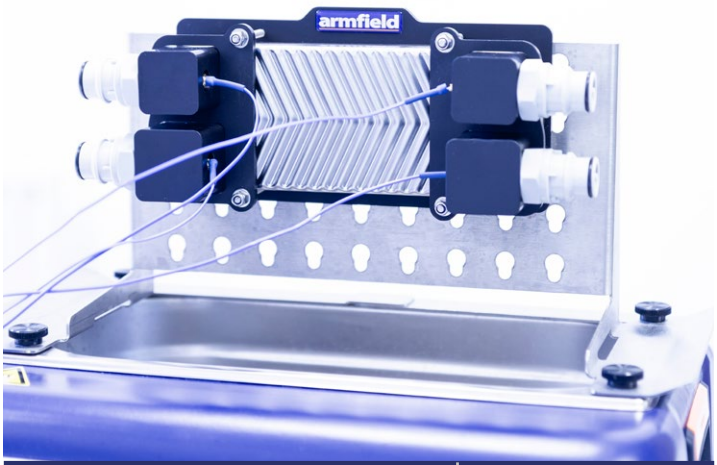
Students evaluate and compare the efficiency and heat exchange profile of the four exchanger types, account for deviations between theoretical and measured values including heat losses to the environment, and select and justify the appropriate exchanger type, flow configuration and operating conditions for a specified industrial duty in terms of thermal performance, capital and operating cost.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

Relevant Curriculum Modules

- Thermodynamics
- Fluid Mechanics
- Process Design & Energy Efficiency
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods
- Heat Transfer *(Industrial heat exchanger types and comparative performance)*

Desk top learning



Requirements	Service Unit	Scale
FS TRAY, 1Ph, PC, USB, COLD, DRAIN	Length: 0.385 Width: 0.314 Height: 0.387	

- **Electrical Supply:** 100-240V/1 Phase, 50-60Hz
- **Cold water:** Initial fill of 5ltrs water.
- **Level surface**

Ordering codes

- **FS-SU** Service Unit
- **FS-3.1** Heat Exchanger - Shell and tube
- **FS-3.3** Heat Exchanger - Cross Flow
- **FS-3.2** Heat Exchanger - Tubular
- **FS-3.4** Heat Exchanger - Plate

Fluid Science Heat Exchange Modules FS3.1–FS3.4

The Fluid Science range is an innovative suite of products designed to enable students to gain an understanding of the fundamentals of Fluid Mechanics and Thermo Fluids by the process of learning via hands-on experimentation.

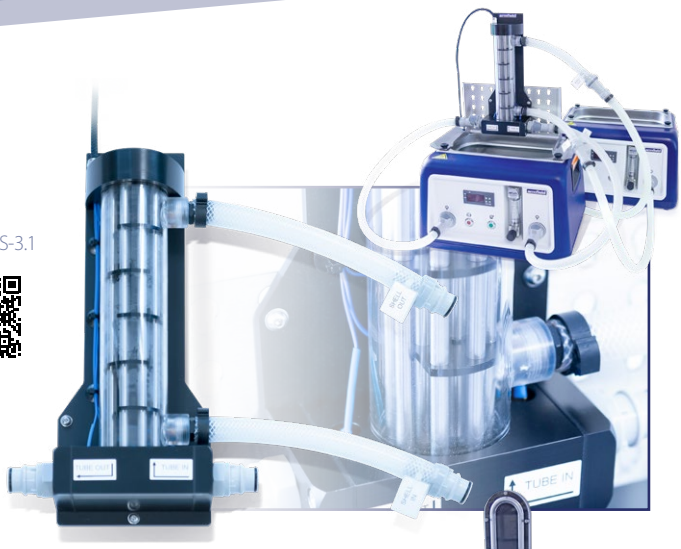
FS-3.1 – Fluid Science Shell and Tube Heat Exchanger

Link to FS-3.1

The FS-3.1 Fluid Science Shell and Tube Heat Exchanger Tray includes experimentation to demonstrate indirect heating or cooling by transfer of heat from one fluid stream to another when separated by a solid wall (fluid to fluid heat transfer) in a shell and tube heat exchanger.

The tray introduces students to concepts such as heat transfer coefficients, thermal resistances, controlling resistance and heat transfer driving forces.

The heat exchanger can be used in a co-current or counter-current configuration.



FS-3.2 – Fluid Science Tubular Exchanger

Link to FS-3.2

The FS-3.2 Fluid Science Tubular Heat Exchanger Tray includes experimentation to demonstrate indirect heating or cooling by transfer of heat from one fluid stream to another when separated by a solid wall (fluid to fluid heat transfer) in a tubular heat exchanger.

The tray introduces students to concepts such as heat transfer coefficients, thermal resistances, controlling resistance and heat transfer driving forces.

The heat exchanger can be used in a co-current or counter-current configuration.



FS-3.3 – Fluid Science Cross Flow

Link to FS-3.3

The FS-3.3 Fluid Science Cross Flow Heat Exchanger Tray includes experimentation to demonstrate indirect heating or cooling by transfer of heat from hot water to air (fluid to air heat transfer) in a cross flow heat exchanger.

The tray introduces students to concepts such as heat transfer coefficients, thermal resistances, controlling resistance and heat transfer driving forces.

The heat exchanger can be used in a co-current or counter-current configuration.



FS-3.4 – Fluid Science Plate Heat Exchanger

Link to FS-3.4

The FS-3.4 Fluid Science Plate Heat Exchanger Tray includes experimentation to demonstrate indirect heating or cooling by transfer of heat from one fluid stream to another when separated by a solid wall (fluid to fluid heat transfer) in a plate heat exchanger.

The tray introduces students to concepts such as heat transfer coefficients, thermal resistances, controlling resistance and heat transfer driving forces. The heat exchanger can be used in a co-current or counter-current configuration.



Computer Controlled Water Cooling Tower UOP6-MKII

The Armfield UOP6-MKII Basic Water Cooling Tower has been specifically designed to give students an appreciation of the construction, design and operational characteristics of a modern forced draught evaporative cooling system.

The unit is an excellent example of an open system through which two streams of fluid (water and air) flow in counter-current directions with heat and mass transfer from one stream to the other. It is completely self-contained, including a simulated cooling load, variable speed water pump and variable speed fan, and is fully instrumented with electronic sensors, operated and controlled from a PC.

Students can investigate the effects of air flow, water flow, water inlet temperature, cooling load, packing density and packing height on tower performance.

Relevant Curriculum Modules

- Heat & Mass Transfer *(Evaporative cooling and simultaneous heat and mass transfer)*
- Thermodynamics (Psychrometrics of moist air)
- Process & Utility Plant Design
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Evaporative Cooling -** Cooling of a water stream by evaporation of a small fraction of the water into a counter-current air stream
- **Simultaneous Heat and Mass Transfer -** Coupled transfer of sensible heat and water vapour between the falling water film and rising air
- **Counter-Current Contacting -** Flow of water and air in opposite directions through the packing to maximise the transfer driving force
- **Psychrometrics -** Humidity, relative humidity, wet bulb temperature and enthalpy of moist air governing tower performance and the approach to saturation
- **Range, Approach and Cooling Load -** Standard measures of cooling tower performance: water temperature drop, difference from the air wet bulb temperature, and heat rejected
- **Packing Characteristics -** Effect of packing density (surface area) and packing height on tower performance, including operation as a spray tower with no packing
- **Mass Balance -** Comparison of water lost from the sump with the water evaporated into the air stream
- **Energy Balance -** Comparison of heat gained by the air leaving the tower with the heat input to the system via the water heater

Learning Outcomes & Bloom Alignment

Remember & Understand

Students describe the construction and operation of a forced draught evaporative cooling tower with film packing, define Range, Approach and Cooling Load, and explain how simultaneous heat and mass transfer between the counter-current water and air streams produces cooling below the air dry bulb temperature

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students operate the instrumented tower while varying water inlet temperature, air flow, water flow, packing density and packing height, measure the resulting changes in Range, Approach and Cooling Load, apply psychrometric analysis to the entering and leaving air, and perform mass and heat balances across the tower, comparing evaporative water loss with sump make-up and air-side heat gain with heater input.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the limitations imposed by air saturation and ambient humidity, compare packed and spray tower operation, and propose packing selection and operating strategies to meet a specified cooling duty, extending the work into independent project investigations of alternative packings.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



UOP6-MKII-23 Packing Characteristics Accessory

The UOP6-MKII-23 is an optional Accessory for the UOP6-MKII Water Cooling Tower that extends the experiment from overall performance measurement to internal, stage-by-stage heat and mass-transfer analysis.

By replacing the standard tower with a four-section packed column incorporating intermediate air temperature, relative humidity, and water temperature measurements, enabling students to measure conditions within the packing

Additional educational value provided

- Direct measurement of temperature and humidity profiles through the packing height
- Construction of driving-force (enthalpy) diagrams for successive packing sections
- Determination of packing characteristic equations and comparison of spray vs packed tower operation
- Quantitative analysis of local heat and mass-transfer rates, not just overall tower effectiveness

The UOP6-MKII-23 upgrades the UOP6-MKII from a performance demonstration unit to a rigorous transport-phenomena teaching platform, suitable for higher-level analysis, design, and scale-up studies.

Requirements	Unit	Scale
1Ph PC USB COLD	Length: 0.850 Width: 0.630 Height: 0.990	

- **Electrical Supply:** Single phase (see Ordering codes)
- **Computer:** Requires a Windows PC (Windows 7 or later) with USB for data logging software
- **Demineralised Water**

Ordering codes

- **UOP6-MKII-A:** 220-240V / 1ph / 50Hz, 10A
- **UOP6-MKII-B:** 120V / 1ph / 60Hz, 20A
- **UOP6-MKII-G:** 220V / 1ph / 60Hz, 10A

Computer Controlled Tray Dryer UOP8-MKIIe



The Armfield UOP8-MKIIe Tray Drier provides an experimental facility based on one of the most fundamental industrial drying designs.

Tray drying is essentially a semi-batch operation with a stationary product and a continuous airflow: liquid is transferred from a wet solid to an unsaturated gas phase, with the solid itself exerting considerable influence on the process.

The unit enables the basic principles of drying to be investigated, allowing students to examine the fluid mechanics, surface chemistry, solid structure, and heat and mass transfer associated with general drying behaviour, under controlled air temperature, humidity and velocity.

Relevant Curriculum Modules

- Heat & Mass Transfer (*Drying and simultaneous heat and mass transfer)*
- Thermodynamics (Psychrometrics of moist air)
- Particle Technology & Solids Processing
- Process Control & Instrumentation
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Relevant Theories and Laws

- **Drying and Drying Rate Curves -** Characterisation of the drying of a wet solid through moisture content and drying rate as functions of time
- **Constant Rate Drying Period -** Evaporation from a liquid-covered surface at the wet bulb temperature of the air, with the rate controlled by external heat and mass transfer
- **Falling Rate Period and Critical Moisture Content -** Transition to internally controlled drying when liquid movement to the surface can no longer sustain the constant rate
- **Wet Bulb Temperature -** Steady-state temperature adopted by the wet solid during constant rate drying
- **Simultaneous Heat and Mass Transfer -** Coupled transfer of heat to the solid and moisture to the air stream across the gas boundary layer
- **Psychrometrics -** Humidity, relative humidity and the properties of moist air governing the driving force for drying
- **Effect of Particle Size -** Influence of solid structure and particle size on capillary liquid movement and drying behaviour
- **Effect of Air Velocity and Temperature -** Influence of the external drying medium conditions on the constant drying rate

Learning Outcomes & Bloom Alignment

Remember & Understand

Students describe the mechanism of drying a wet solid in a stream of unsaturated air, define moisture content, drying rate, critical moisture content and wet bulb temperature, and identify the constant rate and falling rate periods on drying and drying rate curves.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students weigh trays of wet solid continuously as they dry under air of controlled temperature, humidity and velocity, construct drying and drying rate curves, identify the constant rate period and critical moisture content, and investigate the influence of particle size, air velocity and air temperature on drying behaviour.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate which resistances control drying in each period, predict how changes in operating conditions would affect drying time and product quality, and apply their findings to the selection and specification of drying conditions for heat-sensitive and granular products in industrial practices.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.

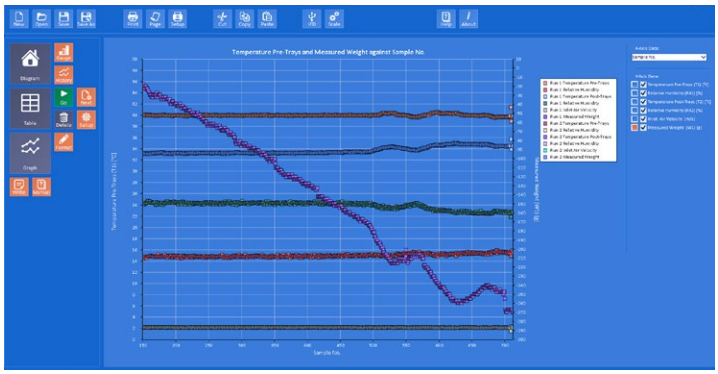
Software

The unit is supplied with a powerful educational software package, which includes a wide range of facilities and functions.

The computer is the primary interface between the user and the equipment. A mimic diagram displays the process in real-time with readings from the relevant sensor inputs and control outputs displayed numerically.

Results can be displayed graphically, or in tabular format, with full control over the displayed graphs, including scaling, axes and which variables are displayed.

Data exports seamlessly to spreadsheets and word processors.





Requirements	Unit	Scale
PC USB	Length: 1.780 Width: 0.340 Height: 0.315	

- **Electrical Supply:** Single phase (see Ordering codes)
- **Computer:** Requires a Windows PC (Windows 7 or later) with USB for data logging software

Ordering codes

- **UOP8-MKIIe-A:** 220-240V / 1ph / 50Hz, 13A
- **UOP8-MKIIe-B:** 120V / 1ph / 60Hz, 13A
- **UOP8-MKIIe-G:** 220V / 1ph / 60Hz, 13A

Temperature Control PCT62

Armfield PCT62 Temperature Control unit introduces students to fundamental process control concepts, **feedback**, **On/Off** and full **PID control** applied to temperature, arguably the most important controlled variable in industry.

The process comprises a resistive heat generator on a heatsink within a temperature chamber, a thermocouple sensor and a fan that blows ambient air over the block to act as a variable load and disturbance.

An integral digital controller with LCD display drives the heater and fan by Pulse Width Modulation from 0 to 100% in 1024 steps, communicating with the PC by USB, Bluetooth, Wi-Fi or LAN. Manual, On/Off and PID control applications are supplied with on-screen graphing of set point, process value and the Kp, Ki and Kd terms of the control equation, with data export to CSV and an API for Matlab integration.

Common worksheets across the PCT6X family allow the slow thermal process to be contrasted with the flow, level, pressure and servo pendulum rigs.

Relevant Theories and Laws

- **Open and Closed Loop Control** - Block diagram representation of set point, process value, error and control function in a feedback system
- **On/Off Control and Hysteresis** - Two-position control of the heater and the effect of turn-on/turn-off values on cycling behaviour
- **PID Control Equation** - Proportional, integral and derivative action on the system error and the effect of each term on performance
- **Ziegler–Nichols Tuning** - Determination of ultimate gain (Ku) and neutral stability period (Tu) and calculation of controller settings, including 'some overshoot' and 'no overshoot' variants and manual fine tuning
- **System Time Constant** - First-order response of the thermal process, its characteristically long time constant and its influence on control frequency selection
- **Pulse Width Modulation (PWM)** - Variable delivery of heater and fan power from a digital drive between 0 and 100%
- **Sensor Calibration and Scaling** - Zeroing, calibration and derivation of scaling factors for the thermocouple input and drive output
- **Digital Sampled Systems** - Effect of sampling and control frequency on the behaviour of a discrete controller
- **Integral Wind-Up and Derivative Filtering** - Practical refinements of the PID algorithm, including clamping of the integral term and filtering of the derivative term
- **Load Disturbance and Rejection** - Use of the fan as a measurable disturbance to test controller robustness

Learning Outcomes & Bloom Alignment

Remember & Understand

Students identify the components of the temperature control rig — heater, heatsink, temperature chamber, thermocouple, fan and digital controller — and explain the terms drive, load, set point, process value and error. They describe how PWM delivers variable power, draw block diagrams of open loop, On/Off and closed loop PID systems, and explain the role of the Kp, Ki and Kd terms in the control equation.

- **IChemE outcomes:** Knowledge and understanding; awareness of laboratory practice, safety, and equipment operation.
- **IMechE outcomes (AHEP4):** Science and mathematics; Engineering practice.

Apply & Analyse

Students derive scaling factors for the drive and calibrate the temperature sensor, implement On/Off control and analyse the effect of hysteresis, measure the system time constant from step response data, determine the ultimate gain and period at neutral stability, and apply the Ziegler–Nichols algorithm to calculate and verify P, PI and PID settings, analysing set point tracking and the response to fan load disturbances.

- **IChemE outcomes:** Analysis; investigation; experimental design; data handling and technical reporting.
- **IMechE outcomes (AHEP4):** Engineering analysis; Engineering practice.

Evaluate & Create

Students evaluate the suitability of On/Off, P, PI and PID strategies for a slow thermal process, manually tune Kp, Ki and Kd where the standard Ziegler–Nichols values are unsatisfactory to achieve a specified time/temperature profile with no overshoot, assess the effects of integral wind-up, derivative filtering and control frequency, and compare the behaviour of the temperature process with the other PCT6X systems, extending the work through Matlab-based project investigations via the API.

- **IChemE outcomes:** Design; evaluation; independent investigation; professional engineering judgement and decision-making.
- **IMechE outcomes (AHEP4):** Design and innovation; Engineering analysis; Engineering practice.



Relevant Curriculum Modules

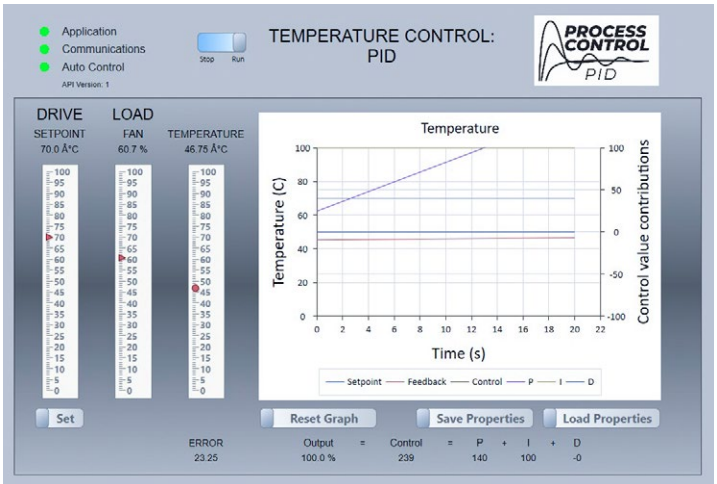
- Process Control & Instrumentation *(Feedback, On/Off and PID control of a thermal process)*
- Heat Transfer *(Heating and forced convection cooling of the process)*
- Instrumentation & Measurement
- Control Engineering & Digital Systems
- Chemical Engineering Laboratory Skills
- Engineering Science & Experimental Methods

Software

The PCT Series includes intuitive software, providing real-time control, monitoring, and data acquisition via a USB-connected Windows PC.

Students progress from Manual and On/Off control to advanced PID control, with live graphical displays, automatic data logging, and adjustable control parameters. An API enables integration with MATLAB®, LabVIEW®, and other third-party software.

Data exports seamlessly to spreadsheets and word processors.



Requirements	Unit	Scale
PC USB	Length: 0.640 Width: 0.450 Height: 0.330	

- **Electrical Supply:** 110-230V, AC 50-60 Hz.
- **Computer:** Requires a Windows PC (Windows 7 or later) with USB for data logging software

Ordering codes

- **PCT62-UK:** Temperature Control System
- **PCT62-EU:** Temperature Control System
- **PCT62-USA:** Temperature Control System

Laboratory Planning & Layout Support

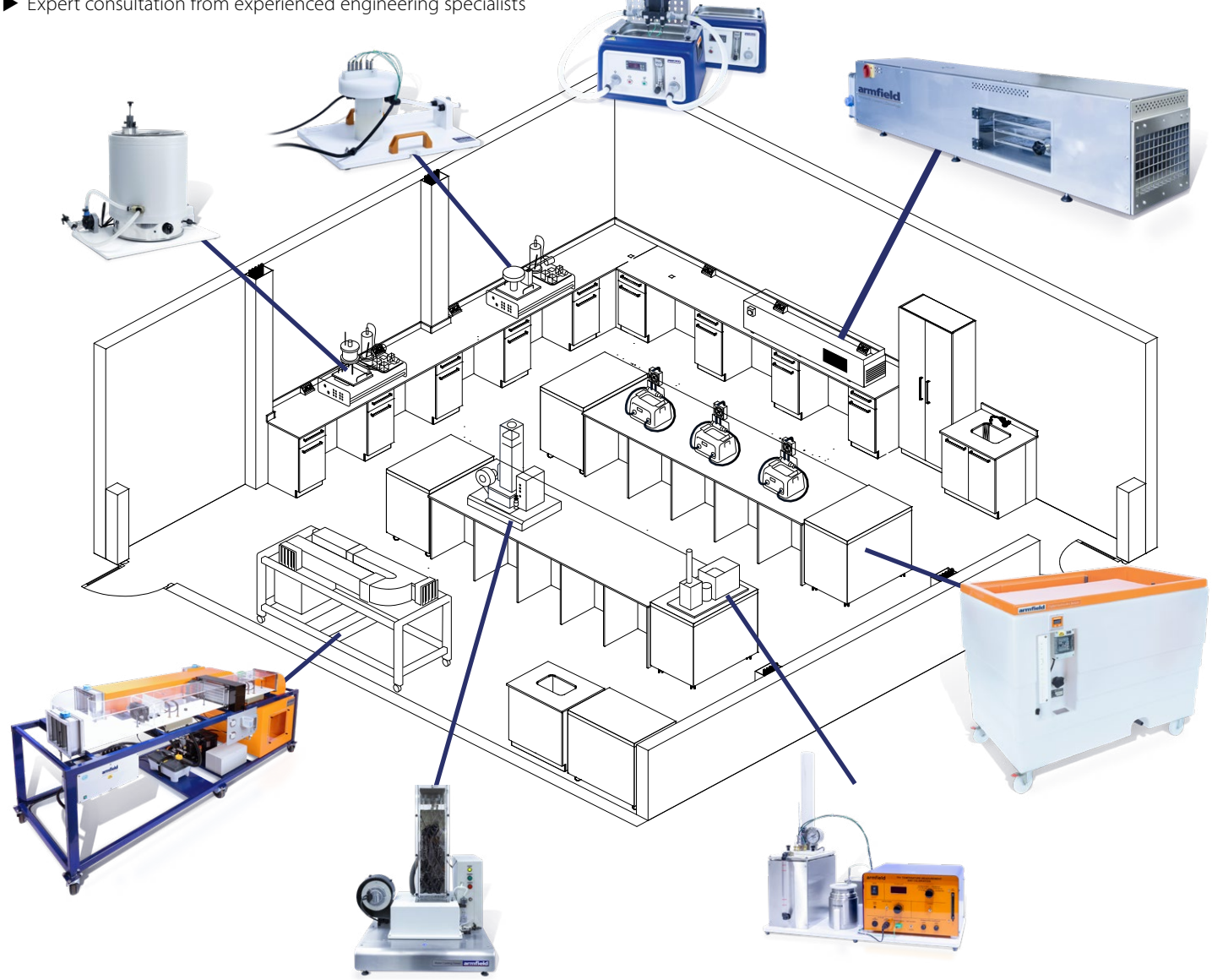
Designing an effective teaching laboratory requires more than selecting equipment. Armfield works with universities and colleges worldwide to help plan laboratory spaces that maximise teaching capability, student engagement, and future expansion.

Our team can provide guidance on equipment selection, laboratory layouts, utility requirements, room utilisation, and phased development plans, ensuring your facility delivers the best possible learning experience while making efficient use of available space and budget.



Our support includes:

- Laboratory layout and space planning
- Equipment selection and curriculum mapping
- Utility and infrastructure guidance
- Multi-disciplinary laboratory design
- Future expansion and development planning
- Expert consultation from experienced engineering specialists



Contact us *Support* *Download Catalogue*

www.armfield.co.uk

armfield
Part of Judges Scientific PLC

Social Media search Armfield Ltd

YouTube

Armfield Agents

A&P INSTRUMENT®
科 藝 儀 器

Armfield products are distributed throughout the world. It is our policy in most countries to deal direct or through proven and accredited sales agents, who after suitable approval, may become exclusive representatives.

In exchange for this exclusivity they are required to offer a comprehensive service including the highest degree of after sales support.

Customer Demonstration

To arrange a demonstration please contact your local Armfield representative. Details can be found on our website: **www.armfield.com**

Contact Armfield HQ directly using the information below:

armfield worldwide

www.armfield.com/contact

Head Office:

Armfield Limited
10 Headlands Business Park
Ringwood, Hampshire
BH24 3PB England

Telephone: +44 (0)1425 478781
E-mail: sales@armfield.co.uk
Support: *armfield.com/armfield-support/*

U.S. Head Office:

Armfield Inc.
9 Trenton Lakewood Road
Clarksburg NJ 08510
USA

Tel/Fax: +1 (609) 208-2800
E-mail: info@armfieldinc.com
Support: *armfield.com/armfield-support/*

UK CA

An ISO 9001:2015 Company

CE

Innovative engineering teaching and research equipment

2026 © Armfield Ltd. All Rights Reserved. We reserve the right to amend these specifications without prior notice. E&OE