HT SERIES

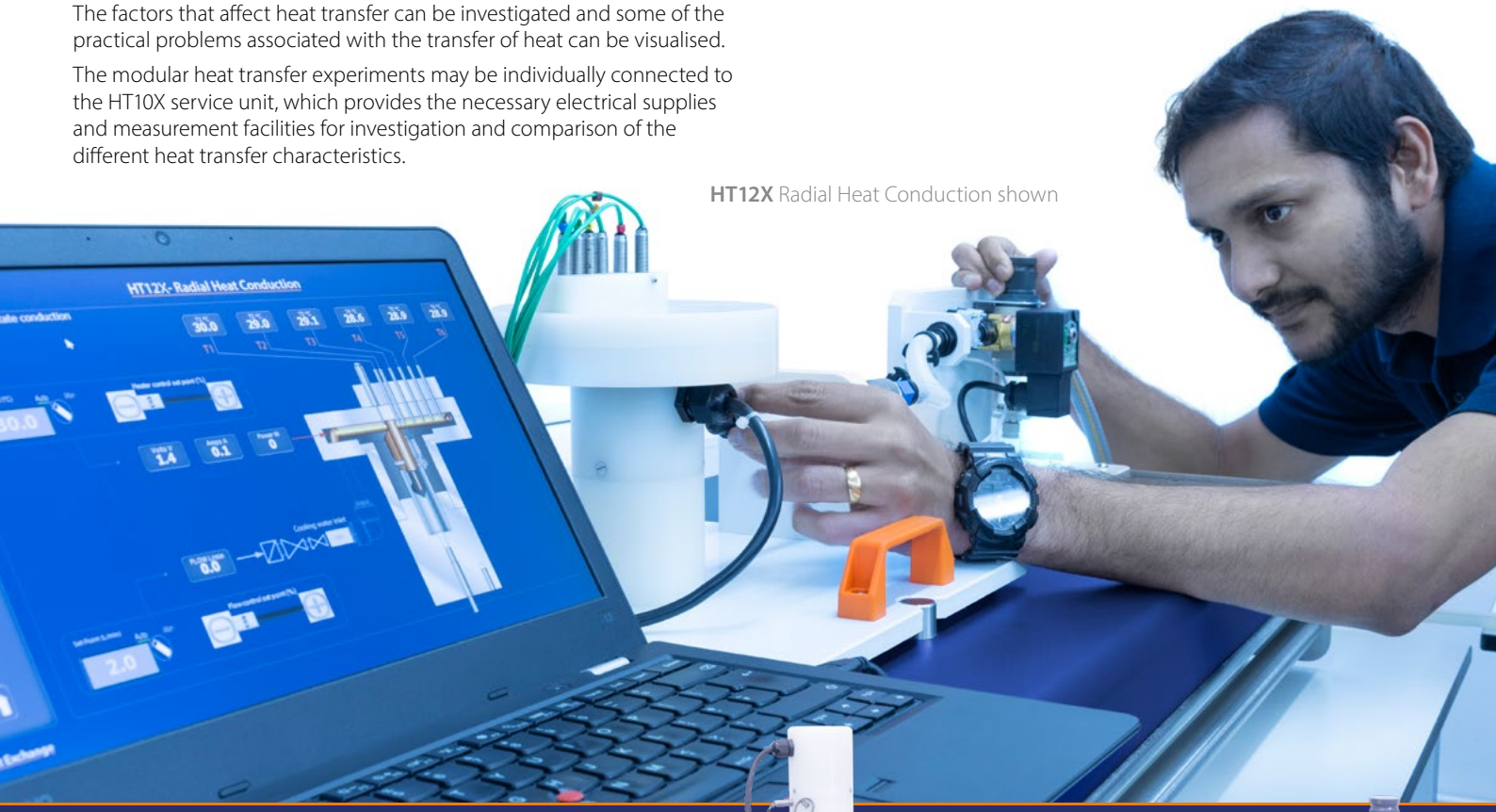
COMPUTER CONTROLLED HEAT TRANSFER TEACHING EQUIPMENT

The Armfield HT10X PC controlled heat transfer service unit is utilised in conjunction with a wide range of modular-small-scale experiment accessories in order to demonstrate several modes of heat transfer.

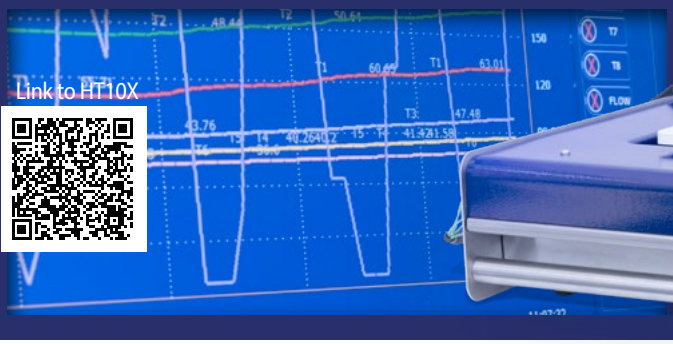
The factors that affect heat transfer can be investigated and some of the practical problems associated with the transfer of heat can be visualised.

The modular heat transfer experiments may be individually connected to the HT10X service unit, which provides the necessary electrical supplies and measurement facilities for investigation and comparison of the different heat transfer characteristics.

STEADY STATE ACHIEVED IN LESS THAN TWO MINUTES



HT12X Radial Heat Conduction shown



Link to HT10X

Key features

- Small-scale, computer control bench top equipment
- A common service unit avoids unnecessary cost duplication for control and instrumentation
- Multiple accessories available covering a wide range of heat transfer investigations
- Fail-safe hardware facilities for remote operation, via NetCan
- Connects armBUS via USB
- 20 users can connect to view the live readings within the local network. (Requires ArmBus-NetCan)
- Full control or read only access available at the time of setup when multiple users are operating the machine
- Educational software, including mimic diagrams, real-time control, data logging and graph plotting
- Embedded software based PID control of heater and water flow control enabling steady state to be achieved in less than two minutes

UK office - email: sales@armfield.co.uk tel: +44 (0) 1425 478781 (for ROW)
USA office - email: info@armfield.inc tel: +1 (609) 208-2800 (USA only)

Issue: 1
URL: http://www.armfield.co.uk/ht10x
Applications
ChE Me CE IP

HT SERIES

Computer Controlled Heat Transfer Service Unit - HT10X

A bench top service unit, designed to accommodate a range of modular small scale experiment accessories, which demonstrate several modes of heat transfer phenomena.

STEADY STATE ACHIEVED IN LESS THAN TWO MINUTES

HT10X Heat Transfer Service Unit

HT10X Input Board

Outputs

- ABMC 24V port for linear actuator and Peltier plate
- DC1 24V port for DC blower fan (HT14X, HT16X, HT19X)
- DC2 24V port for the heater power (All accessories except HT17X)
- AUX 24V port for centrifugal pump (HT17X)

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

Inputs and Instrumentation

- Thermocouples: up to 10, dependent on accessory, 12 thermocouple ports available in total
- Heat radiation meter (HT13X)
- Light radiation meter (HT13X)
- Air velocity meter (HT14X HT16X, HT19X)
- Solenoid valve for water flow rate control (HT11X, HT12X, HT18X)
- The HT10X has some inbuilt potential for future expansion of the armBUS systems and sensors. This includes:
  - 2x 5-way M12 ports
  - 2x K-type thermocouple ports

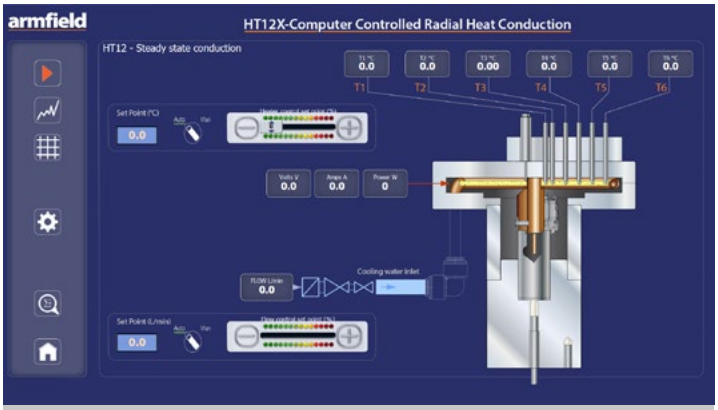
HT10X Computer Controlled Heat Transfer Service Unit

Software

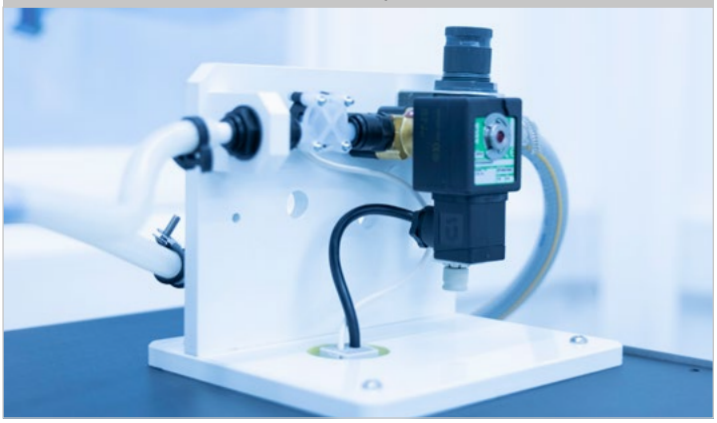
A full ArmBus educational software suite is provided with the HT10X for all the Armfield heat transfer accessories.

Individual experiment interfaces and displayed data types vary to match selected experiment accessories, common examples are listed below:

- Temperatures and other signals such as flow rates, heater voltage and current are displayed on a diagrammatic representation of the equipment
- Control outputs are operated by a control slider or typing in a value between 0 and 100%. Sensor values are read directly in engineering units
- PID automatic control option is available, permitting the temperature set-point to be achieved quickly and precisely, coping with disturbance rejection
- A maintenance screen allows for PID parameter adjustment and thermocouple calibration
- Data from the sensors are logged into a spreadsheet format, with operator control over the sampling intervals (or 'single-shot')
- Sophisticated graph-plotting facilities are provided, including plotting of both measured and calculated values
- Graphs update in real-time as the samples are being taken
- Processing of measured values to obtain calculated values is linked to the questions and answers to ensure student understanding
- Experiment data samples are saved, or exported in Microsoft Excel format
- Real-time sensor data is displayed independently from the data logging. It is possible to check the recent history graphical display to inspect the temperature stability prior to taking a sample



Above HT12X Software screen - Below HT10X Water Regulator



Ordering specification

A compact PC-Controlled bench top service unit, designed to accommodate a range of modular small scale experiment accessories, which demonstrate several modes of heat transfer phenomena.

- Comprises of controlled cold water control system (pressure regulator and water control valve), flowmeter, computer interface and all necessary instrumentation
- Through USB connection the same PC or multiple PC's utilise the Armsoft GUI to control the cold-water flow rate, temperature of the heater and air velocity induced by the centrifugal blower
- Adjustable parameters can be controlled using PID set-point tracking control, therefore achieving the steady-state faster and rejecting disturbances better than conventional control
- Flowmeter operating range 0.6 to 10 L/min, resolution 0.1 L/min, operating temperature 0-125°C
- Up to twelve temperatures (K-type thermocouples) can be monitored using the service unit. Operating range, 0-133°C, resolution <0.1°C
- Low control voltage (~27V) protects against short circuiting and eliminates electrical hazards
- A full educational software and data logging suite is included, covering all modular heat transfer accessory modules
- A comprehensive instructional manual describing how to carry out practical teaching exercises in heat transfer is supplied. Assembly, installation and commissioning is detailed in the manual and within the ArmBus software help menu

Requirements

Scale

Single Phase Electrical supply:
90-240V 5.5A 50/60Hz or 277V 5.5A 50/60Hz

- Software requires a computer running Windows 7 or above with a USB port (computer not supplied by Armfield)
- At least one heat transfer module is required
- Cold water supply and drain: 1.5 Litres/minute at 1bar gauge (min)

Overall dimensions

Length	0.51m
Width	0.95m
Height	0.33m
Packed and crated shipping specifications	
Volume	0.33m^3
Gross weight	33kg

Ordering codes

HT10X

ArmBUS NetCan: Network Interface

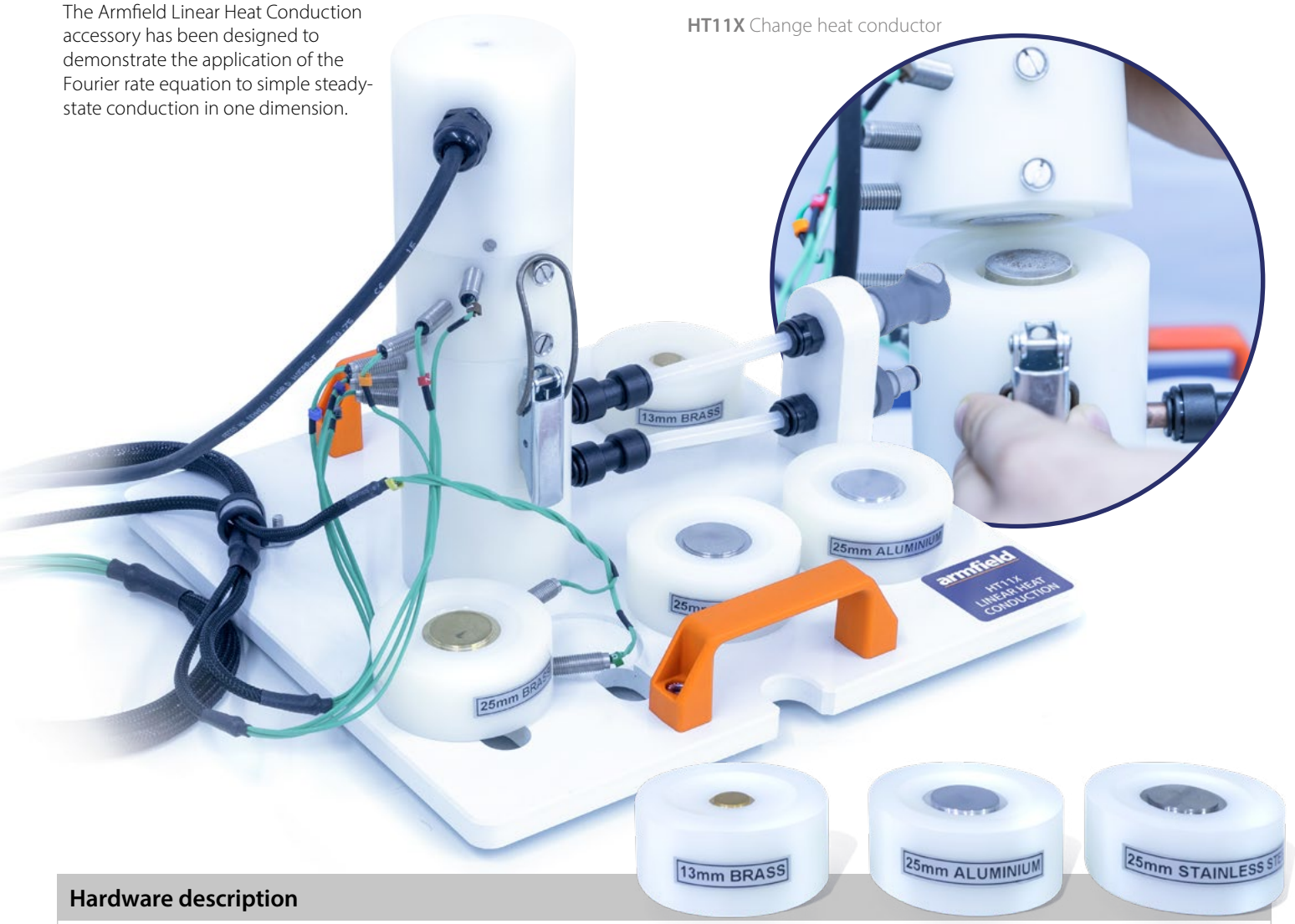
Issue: 1
URL: http://www.armfield.co.uk/ht10x
Applications
Me ChE CE IP

HT SERIES

Linear Heat Conduction - HT11X

The Armfield Linear Heat Conduction accessory has been designed to demonstrate the application of the Fourier rate equation to simple steady-state conduction in one dimension.

HT11X Change heat conductor



Hardware description

The accessory comprises a heating section and a cooling section, which is clamped together or clamped with interchangeable intermediate sections between them, as required. The temperature difference created by the application of heat to one end of the resulting wall and cooling at the other end results in the flow of heat linearly through the wall by conduction.

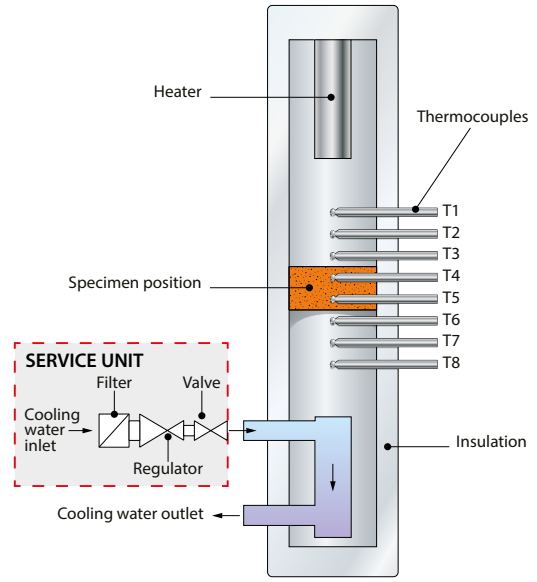
- Thermocouples are positioned along both the heated section and cooled section at uniform intervals of 15mm to measure the temperature gradient along the sections
- Heater is voltage or PID controlled allowing for the temperature set-point to be achieved rapidly and maintained within 0.1°C
- The HT10X service unit provides the accessory with the cooling water system
- A pressure regulator is incorporated to minimise the effect of fluctuations in the supply pressure
- The cooling water flow rate is measured by a turbine type flow sensor
- A control valve on the HT10X service unit allows the flow of cooling water to be varied, if required, over the operating range of 0-1.5 L/min. The valve can be PID controlled for improved supply pressure disturbance reduction

Four intermediate sections are supplied as follows:

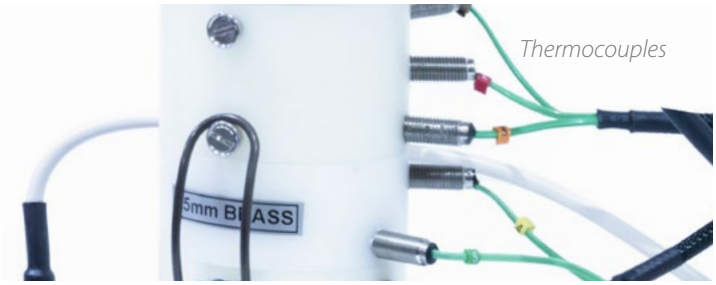
- 30mm-long brass section of the same diameter as the heating and cooling sections are fitted with two thermocouples at the same intervals. When this section is clamped between the heating and cooling sections, a long plane wall of uniform material and cross-section is created with temperatures measured at eight positions
- A stainless-steel section of the same dimensions as the brass section demonstrates the effect of change in thermal conductivity
- Aluminium section of the same dimensions as the brass section to demonstrates the effect of change in thermal conductivity
- 30mm-long brass section reduced in diameter to 13mm to demonstrate the effect of change in cross-sectional area
- The heat-conducting properties of insulators may be found by simply inserting the paper or cork specimens supplied between the heating and cooling sections
- A tube of thermal paste is provided to demonstrate the difference between good and poor thermal contact between the sections

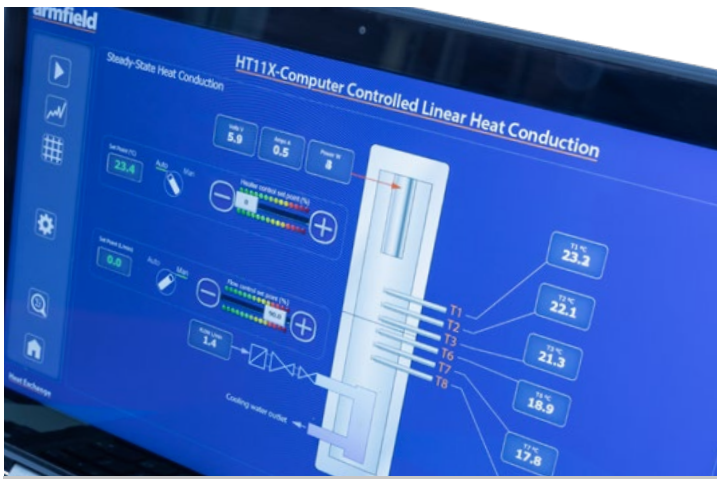
Experimental capabilities

- Understanding the use of the Fourier rate equation in determining rate of heat flow through solid materials
- Measuring the temperature distribution for steady-state conduction of energy through a uniform plane wall and a composite plane wall
- Overall heat transfer coefficient for differing materials in series
- Determining the constant of proportionality (thermal conductivity k) of different materials (conductors and insulators)
- Relationship of temperature gradient to cross-sectional area
- Effect of contact resistance on thermal conduction
- Understanding the application of poor conductors (insulators)
- Observing unsteady-state conduction (qualitative only)



Schematic diagram showing construction of HT11X





HT11X mimic and control screen

Requirements

HT 10X

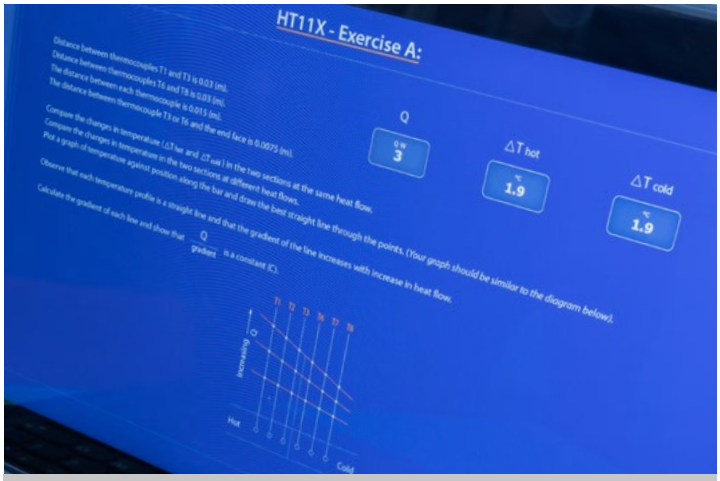
Scale

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

Ordering specification

A small-scale accessory designed to introduce students to the principles of linear heat conduction, and to enable the conductivity of various solid conductors and insulators to be measured.

- Comprises a PID controlled heating section and cooling section, plus four intermediate section conductor samples and two insulator samples
- The heating section, cooling section and one of the intermediate sections are fitted with thermocouples (eight in total) evenly spread along the length of the assembled conduction path
- All sections are thermally insulated to minimise errors due to heat loss
- Heater power variable up to 60W
- Water flow rate variable up to 1.5 L/min
- Heating and cooling sections, 25mm diameter
- A comprehensive instruction manual is included



HT11X armBUS exercise and calculation screen

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Overall dimensions

Length	0.43m
Width	0.21m
Height	0.29m
Packed and crated shipping specifications	
Volume	0.05m^3
Gross weight	10kg

Ordering codes

HT11X

Issue: 1

URL: http://www.armfield.co.uk/ht10x

Applications: Me ChE CE IP

HT SERIES

Radial Heat Conduction - HT12X

The Armfield Radial Heat Conduction accessory has been designed to demonstrate the application of the Fourier rate equation to simple steady-state conduction radially through the wall of a tube.

HT12X in Operation

Hardware description

The arrangement, using a solid metal disk with temperature measurements at different radii and heat flow radially outward from the centre to the periphery, enables the temperature distribution and flow of heat by radial conduction to be investigated.

For the HT12X the heater power and the cooling water flow rate are regulated by PID controlled via the HT10X armBUS computer software.

- The accessory comprises a solid disk of material, which is heated at the centre and cooled at the periphery to create a radial temperature difference with corresponding radial flow of heat by conduction
- Six K-type thermocouples are positioned at different radii in the heated disk to indicate the temperature gradient from the central heated core to the periphery of the disk
- The radial distance between each thermocouple in the disk is 10mm
- Quick-release connections facilitate rapid connection of the cooling tube to a cold water supply
- Heater is voltage or PID controlled allowing for the temperature set-point to be achieved rapidly and maintained within 0.1°C
- The HT10X service unit provides the accessory with the cooling water system:
  - A pressure regulator is incorporated to minimise the effect of fluctuations in the supply pressure
  - The cooling water flow rate is measured by a turbine type flow sensor
  - A control valve on the HT10X service unit allows the flow of cooling water to be varied, if required, over the operating range of 0-1.5 L/min. The valve can be PID controlled for improved supply pressure disturbance reduction

Experimental capabilities

- Understanding the use of the Fourier rate equation in determining rate of heat flow through solid materials
- Measuring the temperature distribution for steady-state conduction of energy through the wall of a cylinder (radial energy flow)
- Determining the constant of proportionality (thermal conductivity k) of the disk material

HT12X exercise and calculations screen

Quick release connectors fitted to all accessories that require water cooling (non drip)

HT12X mimic and control screen

Requirements

HT 10X

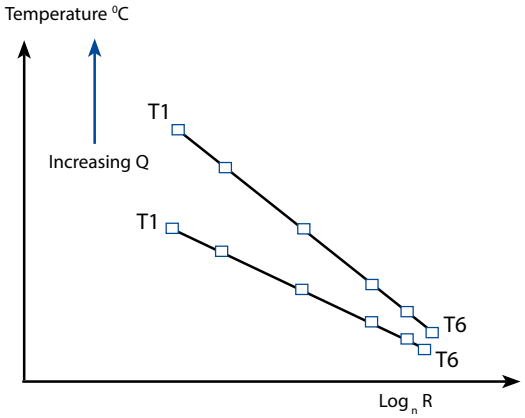
Scale

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

Ordering specification

A small-scale accessory designed to introduce students to the principles of radial heat conduction, and to allow the conductivity of a solid brass disk to be measured:

- Comprised of a brass disk which with a PID controlled heating section heated at the centre and a cooling water tube attached to the periphery to create a radial temperature difference with corresponding radial flow of heat by conduction
- Conduction disk 110mm diameter and 3.2mm thick
- Heater power must be variable up to 100 Watts
- Six K-type thermocouples positioned at different radii in the heated disk to indicate the temperature gradient from the central heated core to the periphery of the disk.
- PID Controller of water flow rate variable up to 1.5 L/min



Temperature distribution for radial conduction through the wall of a cylinder

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Overall dimensions

Length	0.35m
Width	0.18m
Height	0.19m
Packed and crated shipping specifications	
Volume	0.05m^3
Gross weight	6kg

Ordering codes

HT12X

Issue: 1
URL: http://www.armfield.co.uk/ht10x
Applications
Me ChE CE IP

HT SERIES

This Armfield accessory has been 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.

Laws of Radiant Heat Transfer and Radiant Heat Exchange – HT13X

HT13X Radiometer

HT13X Instruments, filters and plates

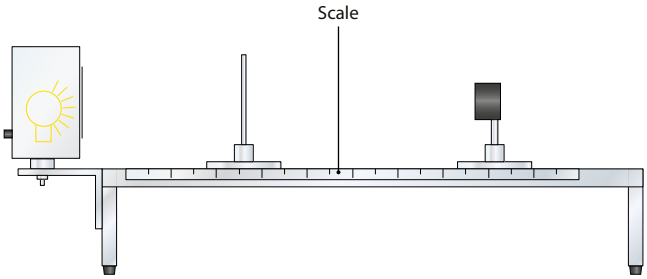
Hardware description

The equipment supplied comprises an arrangement of energy sources, measuring instruments, aperture plates, filter plates and target plates, which are mounted on a linear track, in different combinations to suit the particular laboratory teaching exercise chosen.

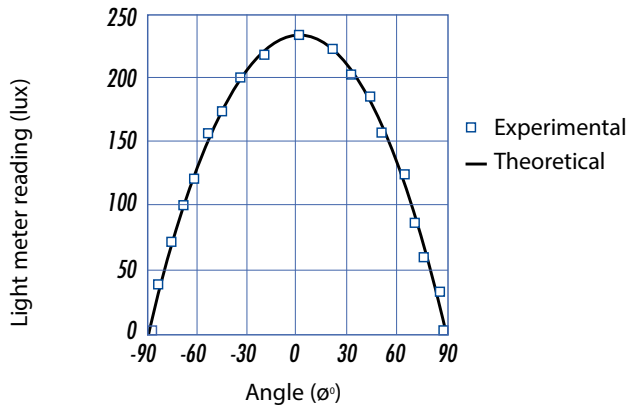
- The track consists of a rigid aluminium frame with twin horizontal rails which incorporates sliding carriages to enable the positions of the instrumentation, filters and plates to be varied
- The heat source consists of a flat copper plate 100mm diameter, which is heated from the rear by an insulated electric heating element operating at low voltage for increased operator safety
- Heater can be voltage or PID controlled allowing for the temperature set-point to be achieved rapidly and maintained within 0.1°C
- The front of the plate is coated with a heat-resistant matte black paint which provides a consistent emissivity close to unity. The surface temperature of the plate is measured by a thermocouple, which is attached to the front of the plate
- Radiation from the heated plate is measured using a heat radiation detector (radiometer), which can be positioned along the graduated track on the carriage
- Two cork-coated metal plates are supplied that enable a vertical slot aperture of adjustable width to be created between the source and detector to demonstrate area factors
- The position of the carriages relative to the energy source can be measured using a graduated scale attached to the side of the track
- Metal plates with different surface finishes are supplied to demonstrate the effect of emissivity on radiation emitted and received. Two black plates, one grey plate and one polished plate, supplied together with a track-mounted carrier which positions the plates in front of the heat source. Each plate incorporates a thermocouple to indicate the surface temperature of the plate
- Plastic filter plates of varying optical density (absorptivity) are supplied to demonstrate the laws of absorption
- The light source consists of a lamp in a housing with a glass diffuser and operates at low voltage for increased operator safety. The source may be rotated through 180° where the angle is measured using an integral scale. The power supplied to the lamp can be varied and measured using the armBUS software
- The radiation from the light source is measured using a light meter which can be positioned along the graduated track on the carriage. Filter plates of varying opacity and thickness are supplied to demonstrate the laws of absorption

Experimental capabilities

- Inverse-square law using the heat source and radiometer or light source and light meter
- Stefan-Boltzmann law using the heat source and radiometer
- Determination of the View Factor
- Emissivity using the heat source, metal plates and radiometer
- The Inverse Square Law for Light
- Kirchhoff's circuit laws using the heat source, metal plates and radiometer
- Area factors using the heat source, aperture and radiometer
- Lambert's Cosine Law using the light source (rotated) and light meter
- Lambert's law of absorption using the light source filter plates and light meter



Schematic diagram showing HT13X set up for exercises using light



Typical result showing Lambert's cosine law using the light source and light meter

HT13X mimic and control screen

Requirements Scale

HT 10X

HT10X Computer Controlled Heat Transfer Service Unit

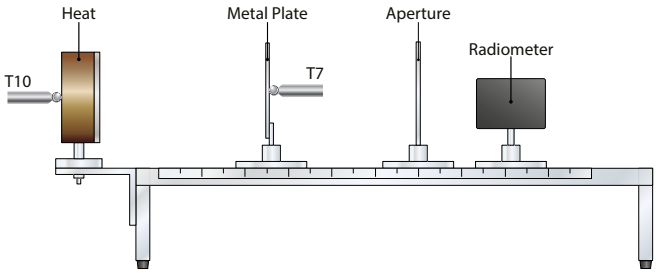
Essential accessories

HT10X Computer Controlled Heat Transfer Service Unit

Ordering specification

A small-scale accessory designed to introduce students to the basic laws of radiant heat transfer and radiant heat exchange.

- A heat source with radiometer and a light source with light meter are used where appropriate to demonstrate the principles
- The heat source consists of a flat circular plate 100mm in diameter, which incorporates a 216W electric heating element (operating at 24V DC maximum)
- The PID controller in the heat source allows for fast temperature set-point achievement and control to 0.1°C
- The light source consists of a 60W light bulb (operating at 24V DC maximum) mounted inside a housing with a glass diffuser
- The heat and light sources, instruments, filters and plates are mounted on an aluminium track with graduated scale, which is designed to stand on the benchtop and connect to the Heat Transfer Service Unit (HT10X) without the need for tools
- A comprehensive instruction manual describing how to carry out the laboratory teaching exercises in radiant heat transfer/ exchange and their analysis as well as assembly, installation and commissioning is included



Schematic diagram showing HT13X set up for exercises using heat

Overall dimensions

Length	1.23m
Width	0.30m
Height	0.44m
Packed and crated shipping specifications	
Volume	0.3m^3
Gross weight	14kg

Ordering codes

HT13X

HT SERIES

The HT14X is one of a range of small scale heat transfer laboratory teaching accessories which demonstrate the basic modes of heat transfer (conduction, convection and radiation).

Combined Convection and Radiation – HT14X

HT14X Heated Cylinder with Guard

HT14X Mimic and control screen

Hardware Description

The equipment consists of a centrifugal fan with a vertical outlet duct. At the top of the duct there is a heated cylinder.

The mounting arrangement for the cylinder in the duct is designed to minimise loss of heat by conduction to the wall of the duct.

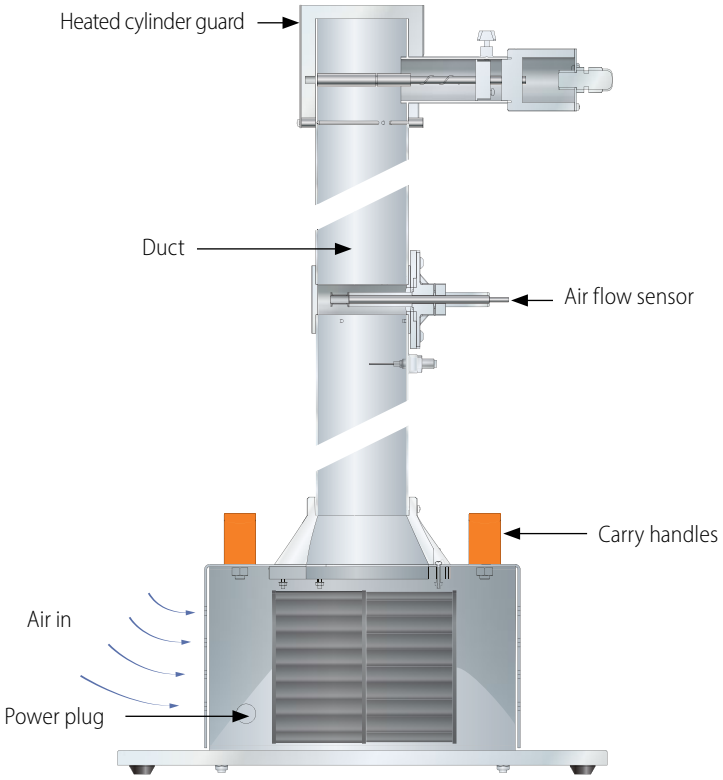
The surface of the cylinder is coated with heat-resistant paint which provides a consistent emissivity close to unity. A K-type thermocouple (T10) attached to the wall of the cylinder, at mid position, enables the surface temperature to be measured under the varying operating conditions.

ArmBUS controlled variable-speed fan blows air through the outlet duct. A vane-type anemometer within the fan outlet duct enables the air velocity in the duct to be measured. Air velocity can be set within the accuracy of ±0.05m/s.

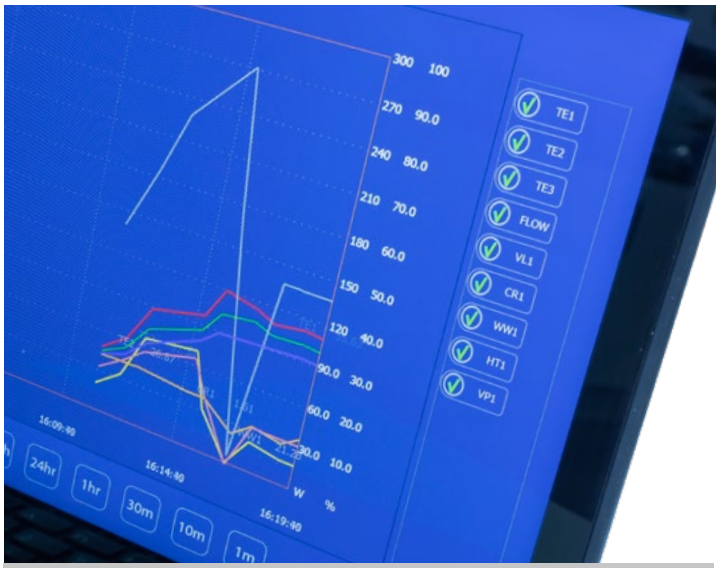
A K-type thermocouple (T9) in the outlet duct allows the ambient air temperature to be measured upstream of the heated cylinder. PID controller allows rapid heater's temperature set-point achievement and control to ±0.1°C.

Experimental Capabilities

- Determining the combined heat transfer (Q radiation + Q convection) from a horizontal cylinder in natural convection over a wide range of power inputs and corresponding surface temperatures
- Measuring the domination of the convective heat transfer coefficient Hc at low surface temperatures and the domination of the radiation heat transfer coefficient Hr at high surface temperatures
- Determining the effect of forced convection on the heat transfer from the cylinder at varying air velocities



Schematic diagram showing construction of HT14X



Features include 6 axis customisable graph screen

Requirements Scale

HT 10X

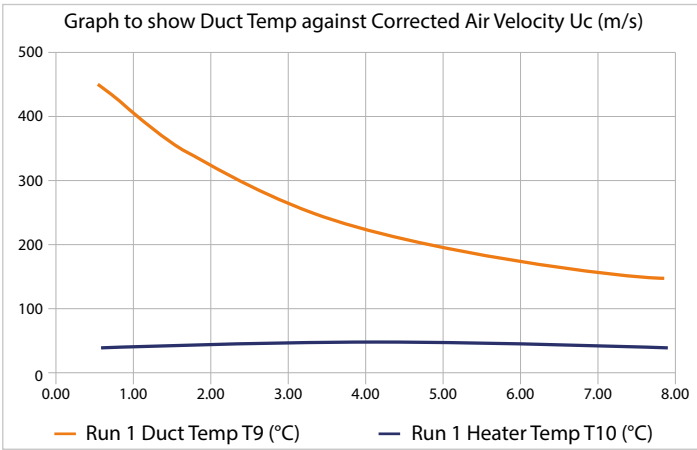
All electrical requirements are obtained from the service unit

Essential accessories

HT10X Computer Controlled Heat Transfer Service Unit

Ordering specification

- A small-scale accessory to introduce students to the principles of combined convection (free and forced) with radiation from horizontal heated cylinder
- Comprises a heated cylinder mounted in a vertical air duct, with a fan at the base of the duct, which can be used to provide a variable air flow over the cylinder
- Heater rating 100W at 24V DC
- K-type thermocouples measure the air temperature upstream and the surface temperature of the cylinder
- Air flow velocity through the duct, under computer control
- A comprehensive instruction manual is included



Typical result showing the effect of changing the air velocity obtained using Armfield educational software

Overall dimensions

Length	0.35m
Width	0.30m
Height	1.20m
Packed and crated shipping specifications	
Volume	0.2m^3
Gross weight	29kg

Ordering codes

HT14X

Issue: 1

URL: http://www.armfield.co.uk/ht10x

Applications: Me ChE CE IP

armfield.co.uk

HT SERIES

Extended Surface Heat Exchanger – HT15X

A long horizontal rod, which is heated at one end, provides an extended surface (pin) for heat transfer measurements.

Thermocouples at regular intervals along the rod allow the surface temperature profile to be measured.

HT15X Mimic and control screen

Hardware Description

The rod is manufactured from brass and coated with a heat-resistant matte black paint, which provides a consistent emissivity close to unity. It is mounted horizontally with support at both ends positioned to avoid the influence of adjacent surfaces.

It is heated by an electric heating element, which operates at low voltage for increased operator safety and is protected by a thermostat to prevent damage from overheating.

Eight thermocouples are attached to the surface of the rod at equal intervals of 50mm, giving an overall instrumented length of 350mm.

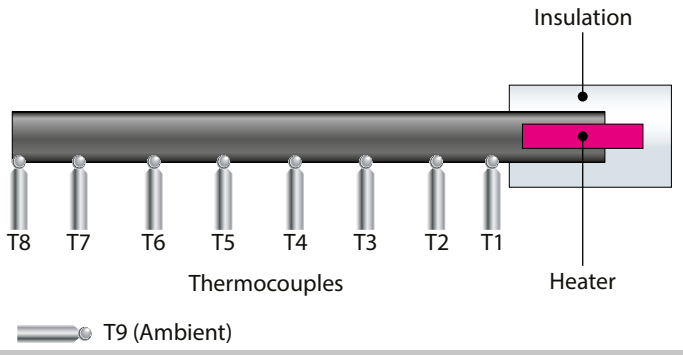
Another thermocouple is mounted adjacent to the heated rod to measure the ambient air temperature.

The heated end of the rod is mounted coaxially inside a plastic housing, which provides an air gap and insulates the area occupied by the heater, in order to minimise heat loss and prevent burns to the operator.

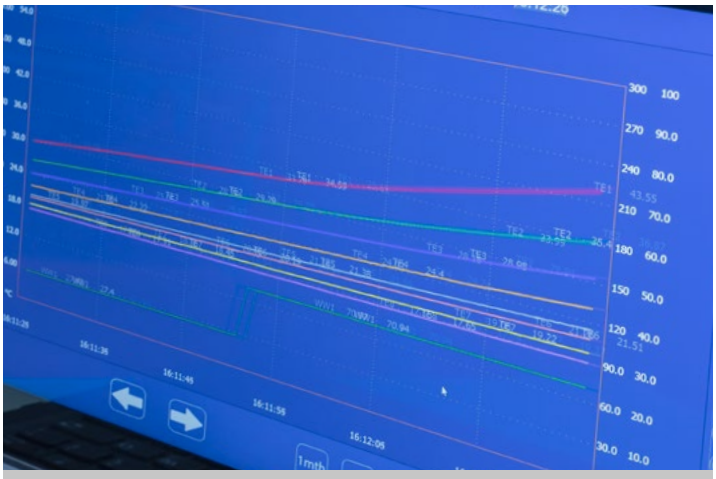
The measurements obtained can be compared with a theoretical analysis of thermal conduction along the bar combined with heat loss (heat transferred) to the surroundings by the modes of free convection and radiation simultaneously.

Experimental Capabilities

- Measuring the temperature distribution along an extended surface (pin) and comparing the result with a theoretical analysis
- Calculating the heat transfer from an extended surface resulting from the combined modes of free convection and radiation heat transfer and comparing the result with a theoretical analysis
- Determining the constant of proportionality of the rod material (Thermal Conductivity K)

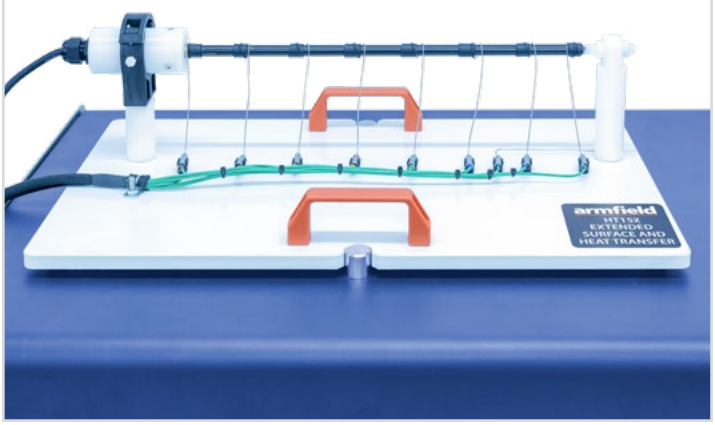


Schematic diagram of HT15X construction



Graph display screen, has many features and is exportable to Excel in .vts file format

HT15X Accessory On The Service Unit



Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Requirements	Scale
HT 10XC	

All electrical requirements are obtained from the service unit

Ordering specification

A small-scale accessory designed to demonstrate the temperature profiles and heat transfer characteristics for an extended surface when heat flows along the rod by conduction and heat is lost along the rod by combined convection and radiation to the surroundings.

- The extended surface comprises a 10mm-diameter long solid brass rod mounted horizontally and heated at one end with a 20W, 24V DC heater
- Eight thermocouples mounted at 50mm intervals along the rod provide the temperature distribution
- PID controller allowing for a rapid heat temperature set-point achievement and controlled within 0.1°C
- The temperature of the ambient air is measured by an independent thermocouple
- The accessory is mounted on a PVC baseplate, which is designed to sit on and connect to the HT10X Heat Transfer Service Unit without the need for tools
- A comprehensive instruction manual is included

Overall dimensions

Length	0.50m
Width	0.15m
Height	0.15m
Packed and crated shipping specifications	
Volume	0.05m^3
Gross weight	5kg

Ordering codes

HT15X

Issue: 1
URL: http://www.armfield.co.uk/ht10x
Applications: Me ChE CE IP

Radiation Errors in Temperature Measurement – HT16X

HT16X armBUS mimic and control screen

Heated Cylinder with Guard

The 'Radiation Errors in Temperature Measurement' accessory comprises a tubular metal duct through which air, at ambient temperature, is blown vertically upwards by a centrifugal fan.

The velocity of the air can be changed by adjusting a throttle plate at the fan inlet and measured by an anemometer in the fan outlet duct.

Thermocouples indicate the wall temperature at the heated end of the duct and the temperature of the air stream before it reaches the heater section.

Three test thermocouples are suspended at the centreline of the heated section. A radiation shield may be positioned to shield these from the heated duct wall.

Hardware Description

Radiative heat transfer between a thermometer and its surroundings may significantly affect temperature readings obtained from the thermometer, especially when the temperature of a gas is to be measured while the thermometer 'sees' surrounding surfaces at a higher or lower temperature than the gas.

The error in the reading from the thermometer is also affected by other factors such as the gas velocity over the thermometer, the physical size of the thermometer and the emissivity of the thermometer body. In this equipment a group of thermocouples are used to measure the temperature of a stream of air, at ambient temperature, passing through the centre of a duct while the wall of the duct is elevated in temperature to subject the thermocouples to a source of 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. The net result is an increase in the temperature of the thermocouple above the temperature of the air stream it is supposed to measure. The result is an error in the reading from the thermocouple. A radiation shield can be positioned in the duct to show the effect of screening the thermocouples from thermal radiation from the duct wall.

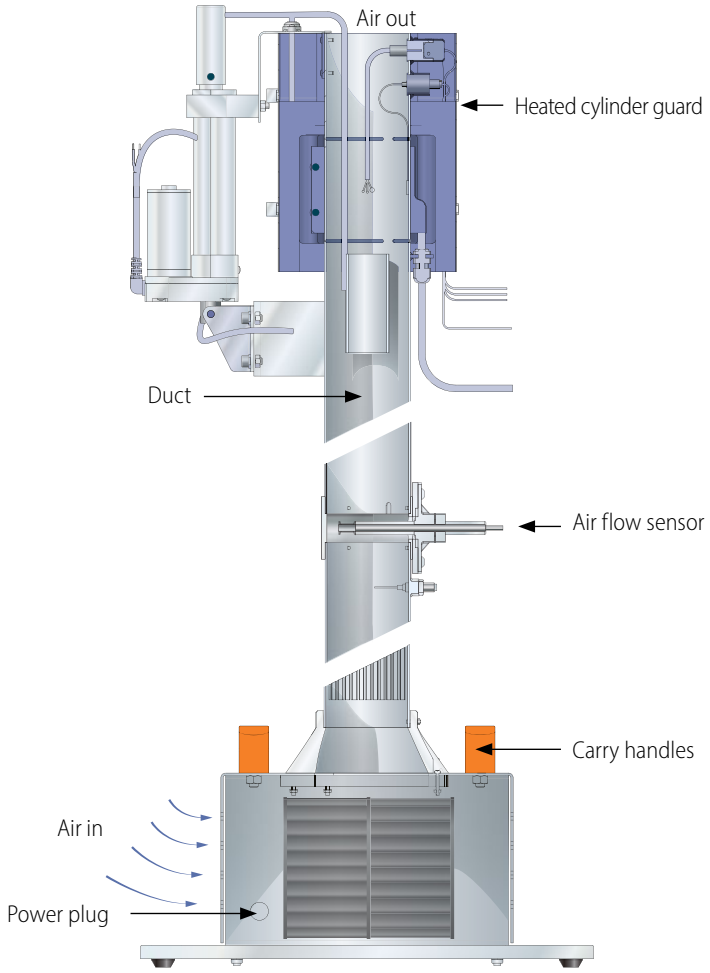
The effect of air velocity past the test thermocouples can be demonstrated by adjusting the air flow. This is achieved by a variable speed fan controlled using the software, by adjusting the power supplied or using a PID controller to automatically achieve air velocity set-point.

A vane-type anemometer within the fan outlet duct enables the air velocity through the heated section to be measured.

A radiation shield, which remains close to the air temperature, can be raised or lowered over the thermocouples to demonstrate the change in readings when a radiation shield is used. This radiation shield is controlled by an electro-mechanical servo actuator under software control.

Experimental Capabilities

- Errors associated with radiative heat transfer:
  - Effect of wall temperature on measurement error
  - Effect of air velocity on measurement error
  - Effect of thermocouple style on measurement error
- Methods for reducing errors due to radiation:
  - Design of a radiation-resistant thermometer
  - Use of a radiation shield to surround the thermometer



Graph display screen, has many features and is exportable to Excel in .vts file format

Requirements Scale

HT 10X

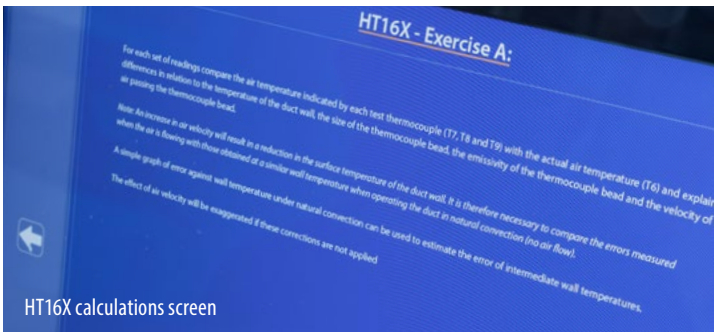
All electrical requirements are obtained from the service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering specification

- A small-scale accessory to demonstrate how temperature measurements can be influenced by sources of thermal radiation
- Comprises three K-type thermocouples with different styles of bead mounted in a vertical air duct. A fan at the base of the duct provides a variable air flow over the cylinder. A band heater heats the duct wall adjacent to the thermocouple beads
- Heater rating 216W at 24V DC
- K-type thermocouples measure the air temperature upstream and the surface temperature of the heated duct section
- Air flow is electronically adjustable over the range of 0-9 m/s by a variable-speed centrifugal blower
- Heater and centrifugal blower are software adjustable.
- The air flow rate is measured by a vane-type anemometer in the outlet duct
- A radiation shield can be lowered over the thermocouples to demonstrate the improvement in reading accuracy when the thermocouples are shielded from the source of radiation
- The accessory is mounted on a PVC baseplate, which is designed to stand on the benchtop and connect to the Heat Transfer Service Unit without the need for tools
- A comprehensive instruction manual is included



HT16X calculations screen

Overall dimensions

Length	0.35m
Width	0.30m
Height	1.22m
Packed and crated shipping specifications	
Volume	0.2m^3
Gross weight	28kg

Ordering codes

HT16X

HT SERIES

Unsteady-State Heat Transfer – HT17X

The HT17X equipment consists of a heated water bath together with a set of instrumented shaped test pieces. Each of the shapes incorporates a thermocouple to measure the temperature at the centre of the shape.

Shape holder and solid shapes supplied with **HT17X**

HT17X mimic diagram and control screen

HT17X graphing screen

Hardware Description

The equipment consists of a heated water bath together with a set of instrumented shaped test pieces. Each of the shapes incorporates a thermocouple to measure the temperature at the centre of the shape.

A total of six shaped test pieces are provided, i.e. three simple shapes (a rectangular slab, a long solid cylinder and a solid sphere) each manufactured in two different materials (brass and stainless steel).

Measurements taken on a shape in one material can be used to confirm the conductivity of a similar shape constructed from a different material. Transient-temperature/heat-flow charts are supplied for each of the shapes.

A circulating pump mounted alongside the water bath draws water from the bath and returns it at the base of a vertical cylindrical duct, which is located inside the water bath at the centre. A holder ensures each of the shapes is quickly and correctly positioned within the vertical duct for measurements to be taken.

The upward flow of water at constant velocity passing the shape ensures the heat transfer characteristic remains constant and also ensures the water surrounding the shape remains at a constant temperature.

The rate of water recirculation can be varied by using the software to adjust the DC voltage on the pump or use PID controller to achieve flow-rate set-point automatically. The shape holder has been carefully designed to eliminate the need to touch the shape while its temperature stabilises in air, and also to position the shape accurately inside the water bath while transient measurements are taken.

A thermocouple mounted on the shape holder contacts the hot water at the same instant as the solid shape and provides an accurate datum for temperature/time measurements.

A thermostat allows the water to be heated to a predetermined temperature before taking measurements. The large volume of water in the bath ensures that any change in the temperature of the water, as the measurements are taken, is minimal.

The water bath is heated by a mains powered electrical heater, and protected by a residual current device for operator safety. A thermocouple located in the water bath enable the temperature of the water to be monitored and adjusted to the required temperature.

Experimental Capabilities

- To observe unsteady state conduction of heat to the centre of a solid shape, when a step change is applied to the temperature at the surface of the shape
- Using analytical transient-temperature/heat flow charts to determine the conductivity in cylinders with different conductivity
- Investigating the effect of shape, size and material properties on unsteady heat flow using analytical transient-temperature/heat flow charts

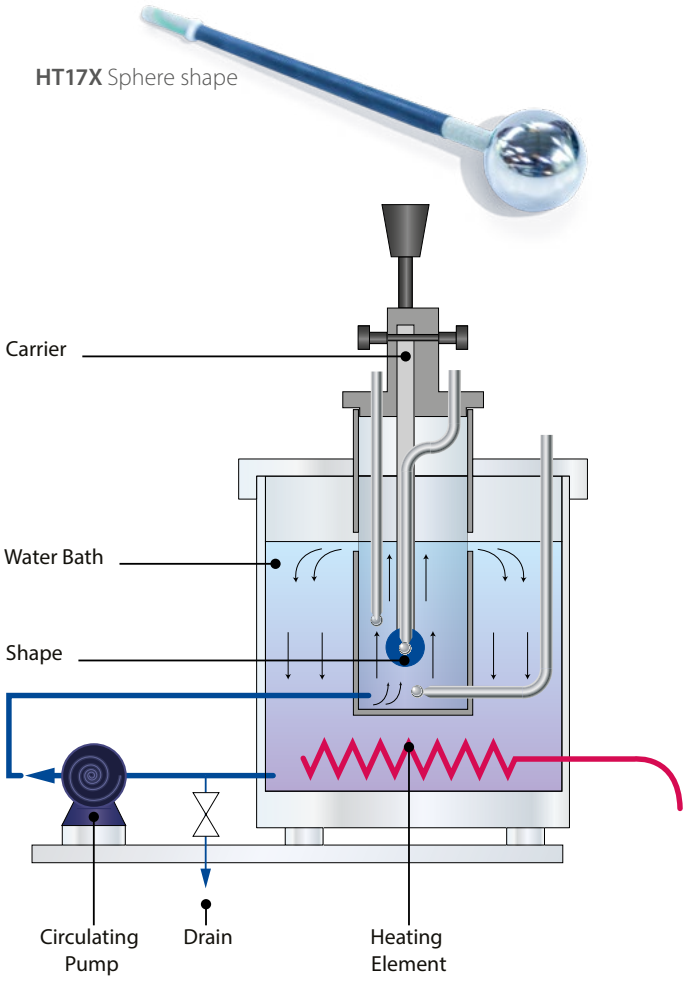
Description

Analytical solutions are available for temperature distribution and heat flow as a function of time and position for simple solid shapes, which are suddenly subjected to convection with a fluid at a constant temperature.

Simple shapes are provided together with appropriate classical transient-temperature/heat-flow charts, which enable a fast analysis of the response from actual transient measurements. Each shape is allowed to stabilise at room temperature then suddenly immersed in a bath of hot water at a steady temperature.

Monitoring of the temperature at the centre of the shape allows analysis of heat flow using the appropriate transient-temperature/heat-flow charts provided.

An independent thermocouple mounted alongside the shape indicates the temperature of the water adjacent to the shape and provides an accurate datum for measurement of the time since immersion in the hot water.



Schematic diagram showing operation of the HT17X

Requirements

HT 10X

All electrical requirements are obtained from the service unit

Scale

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering specification

The Armfield 'Unsteady State Heat Transfer' accessory HT17X has been designed to allow exercises to be performed in unsteady state heat conduction, when simple solid shapes which are suddenly subjected to convection with a fluid at a constant temperature.

- The water is heated by an electric heating element in the base of the bath having a nominal rating of 3.0 kW
- An adjustable thermostat, at the base of the water heater allows the water to be heated to a predetermined temperature before taking measurements
- Thermocouple at the base of the flow duct, inside the water bath, allows the temperature of the water to be monitored and adjusted to the required temperature
- Comprises of a set of seven solid shapes, manufactured in three simple shapes and two materials. Each sample has a permanently installed K-type thermocouple inside
- The thermocouple mounted on the shape holder contacts the hot water at the same instant as the solid shape and provides an accurate datum for temperature/time measurements
- The resolution of all temperature readings is 0.7°C
- A circulating pump mounted alongside the water bath draws water from the bath and returns it to the base of the vertical cylindrical flow duct
- The accessory is mounted on a PVC baseplate, which is designed to stand on the bench top and connect to the HT10X service unit without the need of tools
- A comprehensive instruction manual is included

Overall dimensions

Length	0.60m
Width	0.40m
Height	0.67m
Packed and crated shipping specifications	
Volume	0.29m^3
Gross weight	23kg

Ordering codes

HT17X

HT SERIES

Thermo-Electric Heat Pump – HT18X

Based on a Peltier device, the Armfield HT18X Thermo-Electric Heat Pump demonstrates how electrical power can be used to extract heat from a cool surface and transfer it to a hot surface.

This effect is becoming widely used for point cooling (e.g. of semiconductor devices) and small-scale volumetric cooling.

Calculation screen displays formula's, sample diagrams and exercise questions

Hardware Description

The HT18X is designed for use with the Armfield HT10X Heat Transfer Service Unit.

Based on a Peltier device, the Armfield HT18X Thermo-Electric Heat Pump demonstrates how electrical power can be used to extract heat from a cool surface and transfer it to a hot surface. This effect is becoming widely used for point cooling (e.g. of semiconductor devices) and small-scale volumetric cooling.

The thermoelectric Peltier device is positioned in a heat transfer path, between two copper blocks. It extracts heat from one block (cold reservoir) and transfers it to the other block (hot reservoir). In order to measure the heat transfer rate, the cold reservoir is fitted with an electric heater, powered by the HT10X service unit. By varying the electric power into the system, the behaviour of the system at different operating points and temperatures can be established.

The heat extracted is transferred to the hot reservoir, together with heat generated by the electrical supply to the Peltier device. This heat is removed by a water-cooled heat exchanger. The flow rates can be adjusted to provide a range of operating temperatures.

The Peltier device can also be used to generate a small quantity of electric power when a temperature difference is applied. This effect can also be demonstrated with this unit.

When used in conjunction with HT10X, the instrumentation is provided to measure the temperatures of the blocks, the electric power supplied to the Peltier device, the cooling water flow rate and the cooling water temperature rise. Heater power measurement allows you to establish a complete energy balance for the system.

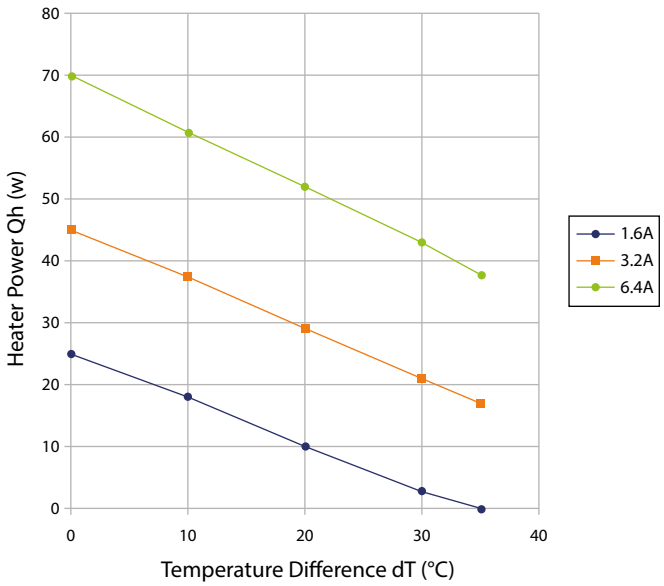
The cooling water flow rate is measured by a turbine type flow sensor.

A control valve on the HT10X service unit allows the flow of cooling water to be varied, if required, over the operating range of 0-1.5 l/min. The control valve can be PID controlled for improved supply pressure disturbance reduction.

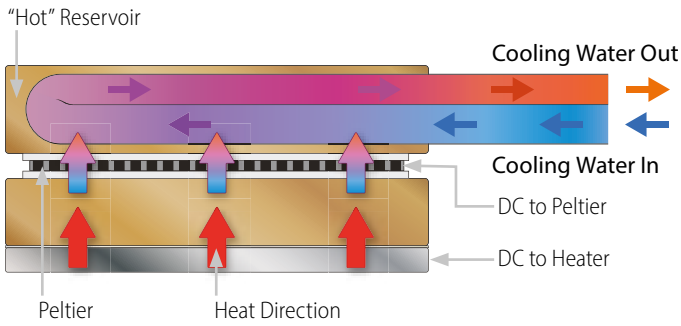
All facilities are controlled directly from the PC (not supplied), including heater power, Peltier power and water flow rate. All measured information is available on the PC. The HT18X includes its own integral USB interface, connecting to the same PC as the HT10X. The software supplied integrates the data to and from both these interfaces into a simple, user-friendly software control environment.

Experimental Capabilities

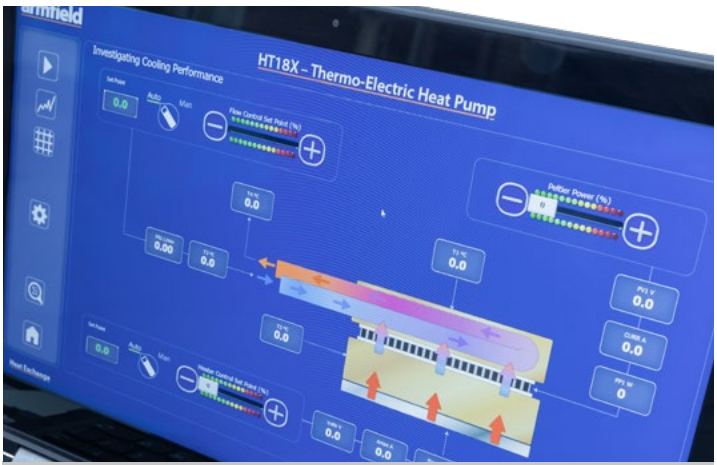
- Performance of a Peltier device as a cooler
- Heat transfer characteristics as a function of temperature and drive current
- Measurement of the coefficient of performance
- Energy balance
- Demonstration of a Peltier device as an electrical generator



HT18X Performance curves



Thermoelectric device with thermal reservoir – HT18X



HT18X mimic and control screen

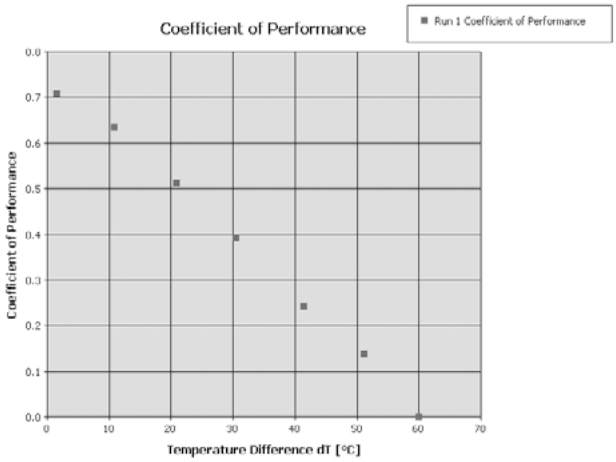
Requirements Scale

HT 10X

All electrical requirements are obtained from the service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit



HT18X graph

Ordering specification

- Small-scale accessory designed to demonstrate the use of a Peltier device to transfer heat across surfaces
- Comprises a Peltier device, a heater, and a water-cooled heat exchanger
- Heat transfer rates up to 68W
- Heater power, Peltier drive and cooling flow rate all fully electronically adjustable under computer control
- Service unit allows for measurement of cooling water temperatures and flow to allow an overall energy balance
- The accessory is mounted on a PVC baseplate, which is designed to sit on the heat transfer service unit without the need for tools
- A comprehensive instruction manual is provided

Overall dimensions

Length	0.53m
Width	0.43m
Height	0.13m
Packed and crated shipping specifications	
Volume	0.09m^3
Gross weight	15kg

Ordering codes

HT18X

Issue: 1
URL: http://www.armfield.co.uk/ht10x
Applications: Me ChE CE IP

Free and Forced Convection - HT19X

The Armfield Free and Forced Convection unit has been specifically designed to demonstrate the phenomena of natural (free) and forced convection.

Hardware Description

The Armfield Free and Forced Convection unit has been specifically designed to demonstrate the phenomena of natural (free) and forced convection. Temperature profiles and heat flux over three different heat transfer surfaces can be easily studied.

The HT19X is designed for use with the Armfield HT10X Heat Transfer Service Unit.

This unit consists of a bench mounted vertical air duct positioned on the top of a centrifugal fan. The air duct incorporates an aperture positioned at the rear wall of the duct, into which three different types of heat-transfer surfaces can be inserted. The three types of heat exchangers supplied are; flat plate, cylindrical pins and finned surface.

Incorporating an electrical heating element, with positive thermal cut-out, and thermocouples for precise temperature measurement. The clamping mechanism ensures accurate alignment of the surface inside the duct. The front wall of the duct is acrylic to allow viewing of the heated surface and measurement sensors.

For forced convection, the centrifugal fan draws ambient air upward through a flow straightener and over the heated surface. A manually variable throttle controls the air flow.

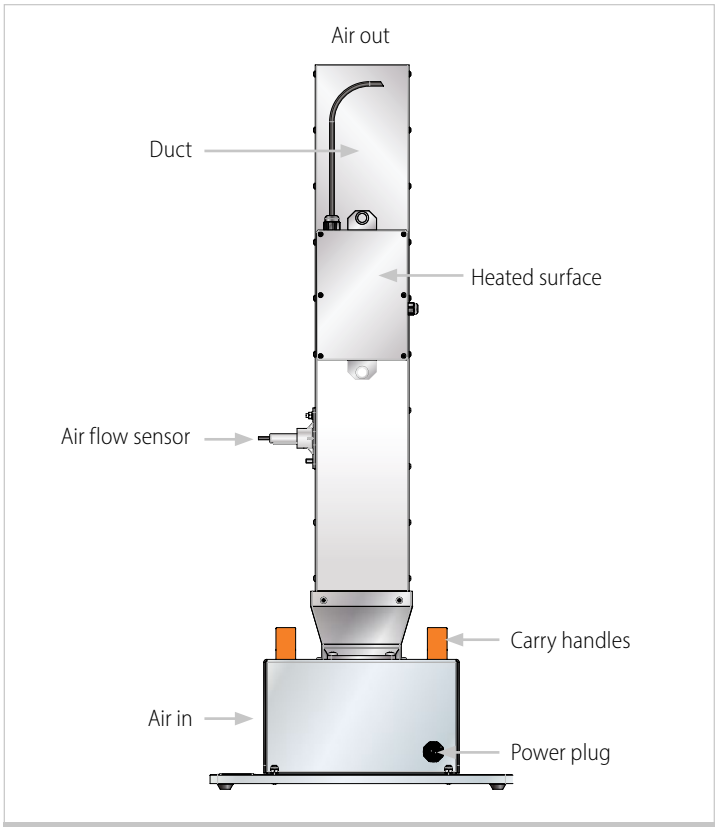
An air-velocity sensor measures the air velocity inside the duct upstream of the heat exchanger.

Thermocouples measure the air temperature before and after the heated surface, together with the surface temperature at three positions along the extended surface exchangers.

On the HT19X heater power, air flow rate and the configuration of the heated surfaces can all be controlled via the ArmBUS Desktop software, from where PID controller settings for heater temperature are located. Air velocity can be adjusted through the HT19X software control screen.

Experimental Capabilities

- Relationship between surface temperature and power input in free convection
- Relationship between surface temperature and power input in forced convection
- Understanding of the use of extended surfaces to improve heat transfer from the surface
- Determining the temperature distribution along an extended surface
- Comparing characteristics of a vertical and horizontal flat plate in free convection
- Determining the characteristic velocity, the Reynolds, Grashof and Rayleigh numbers for a flat plate in free convection
- Calculation of the average heat-transfer coefficient of the pinned heater in forced convection
- Comparing horizontal and vertical configurations for a finned exchanger in free convection



Schematic diagram – HT19X

HT19X mimic diagram and control screen

Requirements Scale

HT 10X

All electrical requirements are obtained from the service unit

Essential accessories

HT10X Computer-Controlled Heat Transfer Service Unit

Ordering specification

- A bench mounted unit specifically designed to demonstrate the phenomena of free and forced convection and to measure temperature profiles from three different heat transfer surfaces
- Comprises a vertical air duct, with a transparent front for visibility mounted on a fan at the base of the duct, three heat transfer surfaces, air flow, and temperature probes
- Technical data is included for each of the three heat transfer surfaces, which will enable students and researchers to compare practical results with theoretical analysis for free and forced convection
- Three heat transfer surfaces supplied: a flat plate surface area 0.011m^2, pinned extended surface area 0.0525m^2, and finned extended surface area 0.1414m^2
- Vertical duct incorporates a transparent front wall allowing complete visualisation of the process and identification of the air flow and temperature sensors
- Each heat transfer surface is fitted with its own heater (240W) and thermocouples, to enable easy interchange
- All heat transfer surfaces incorporate guards to permit safe use outside of the duct for performing free convection experiments
- ArmBUS software includes separate exercises for each of the heat transfer surfaces in free or forced convection and records of all measured variables for analysis and comparison of the performances
- K-type thermocouples measure the air temperature in the duct before and after the heater, as well as the surface temperature of the heat transfer surfaces
- Heater can be voltage or PID controlled allowing for the temperature set-point to be achieved rapidly and maintained within 0.1°C
- The air flow is measured by an air-velocity sensor, which is inserted inside the duct
- Mounted on a PVC baseplate which is designed to stand on the Heat Transfer Service Unit with simple plug-in connections
- A comprehensive instruction manual is included

Overall dimensions

Length	0.35m
Width	0.30m
Height	0.95m
Packed and crated shipping specifications	
Volume	0.2m^3
Gross weight	24kg

Ordering codes

HT19X

Issue: 1
URL: http://www.armfield.co.uk/ht10x
Applications: Me ChE CE IP

HT SERIES

Conductivity of Liquids and Gases - HT20X

The Armfield Conductivity of Liquids and Gases unit has been specifically designed to enable students to measure and compare the thermal conductivities of various liquids and gases.

HT20X Mimic and control screen

Hardware Description

The Armfield Conductivity of Liquids and Gases unit has been specifically designed to enable students to measure and compare the thermal conductivities of various liquids and gases. It's designed to facilitate quick and effective cleaning and to minimise thermal losses.

The unit comprises a cylindrical, electrically heated, nickel-plated aluminium core surrounded by a nickel-plated aluminium sleeve. The core and the sleeve are arranged so that a uniform narrow annular gap is created between the two parts, which is filled by the liquid or gas to be analysed.

The temperature on each side of the fluid is measured by thermocouples in the surface of the core and the sleeve.

The HT10X service unit is provided with an electronic proportioning valve and flow meter to control and measure the water flow. The unit incorporates an insulated jacket to minimise heat exchange from and to the atmosphere.

The fluid to be tested is injected into the annular gap between the heated core and the cooled jacket using a hypodermic syringe.

Measurement of the temperature difference between the heated and cooled surfaces together with the power supplied to the heater (measurement of DC voltage and current) using HT10X allows the conductivity of the fluid to be calculated. The surface area and thickness of the fluid sample remain constant during all tests.

Experimental Capabilities

- Understanding the use of the Fourier rate equation in determining the rate of heat flow by conduction through liquids or gases
- Measuring the constant of proportionality (the thermal conductivity k) of different liquids such as water and glycerol
- Calibrating the unit for heat losses using a gas, such as air with known thermal conductivity, then measuring the temperature difference across different gases, such as carbon dioxide and helium to determine their thermal conductivity k

Note: ***Flammable, explosive, corrosive or toxic liquids and gases must not be used in the equipment.***

Unique features

- Thickness of the fluid sample is restricted to 0.5mm to minimise convection in the fluid sample
- Concentricity of the heated and cooled surfaces is accurately maintained using a spiral insulator
- Trapped bubbles of the previous liquid or gas sample are prevented by the spiral flow path when injecting a different liquid or gas
- ArmSoft software is supplied, with separate exercises for determining the thermal conductivity of liquids and gases

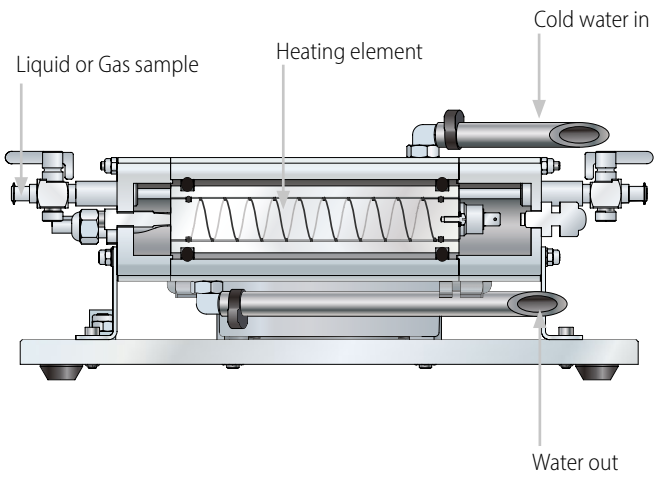


Diagram – HT20X

Requirements

HT 10X

Scale

All electrical requirements are obtained from the service unit

Essential accessories

HT10X Heat Transfer Service Unit

Ordering specification

- A small-scale accessory to allow students to measure the thermal conductivity k of various liquids and gases
- Comprises a water-cooled, aluminium outer sleeve surrounding a heated aluminium core creating an annular gap 0.5mm wide that is filled with the fluid under test
- Nominal heat transfer area 1.225 x 10-2 m^2
- Gas or liquid sample volume 6.126ml
- Heater power is variable up to 200W at 24V using the Heat Transfer Service Unit
- Overheating is prevented by an integral thermostat
- Heater can be voltage or PID controlled allowing for the temperature set-point to be achieved rapidly and maintained within 0.1°C.
- Two k-type thermocouples measure the temperature gradient across the liquid or gas under test
- Nickel-plated surfaces to minimise radiation losses, narrow annular gap to minimise convection losses and thermally insulated to minimise heat exchange with the atmosphere
- Includes a pressure regulator to provide a steady flow of cooling water
- Computer-controlled unit includes an electronic proportioning valve and flow meter to vary and measure the flow of cooling water
- A comprehensive instruction manual describing how to carry out the laboratory teaching exercises to measure thermal conductivity as well as installation and commissioning is included

Technical details

Thickness of fluid sample	0.5mm (Fixed by the annular gap)
Nominal heat transfer area	1.225 $x10^{-2}$ m^2
Gas / liquid sample volume	6.126ml
Maximum heater power	200W at 24V
Maximum operating temperature	90°C (limited by integral thermostat)

Overall dimensions

Length	0.30m
Width	0.25m
Height	0.16m
Packed and crated shipping specifications	
Volume	0.04m^3
Gross weight	8kg

Ordering codes

HT20X

armfield

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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 here: **www.armfield.co.uk**, or contact Armfield HQ directly using the information below.

Your local Armfield Agent:

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