INSTRUCTION MANUAL

HT14C

COMPUTER COMPATIBLE
COMBINED CONVECTION AND RADIATION

HT14C

ISSUE 4
NOVEMBER 2007

THIS INSTRUCTION MANUAL SHOULD BE USED IN CONJUNCTION WITH THE PRODUCT MANUAL SUPPLIED WITH THE HT10XC 'COMPUTER COMPATIBLE HEAT TRANSFER SERVICE UNIT'

NOTE: Compatibility of HT10XC with HT14C & HT16C

In February 2006 a component becoming obsolete forced Armfield Ltd to change the mains outlet connector (OUTPUT 1) at the rear of the HT10XC console and the corresponding plug on the mains lead of the HT14C and HT16C. No other accessories to the HT10XC are affected by this change.

An adaptor 'ADAPTOR1–HT10' is available from Armfield Ltd that allows a current HT10XC to be used with an original HT14C or HT16C. If the mains plug on your HT14C or HT16C has exposed pins that do not mate with OUTLET 1 on HT10XC then 'ADAPTOR1–HT10' is required.

Similarly 'ADAPTOR2-HT10' is available from Armfield Ltd that allows an original HT10XC to be used with a current HT14C or HT16C. If the mains plug on your HT14C or HT16C has pins protected by a shrouded cover that does not mate with OUTLET 1 on HT10XC then 'ADAPTOR2-HT10' is required.

If you need an adaptor please contact Armfield Ltd at the address below specifying if 'ADAPTOR1-HT10' or 'ADAPTOR2-HT10' is required for correct functioning of the equipment:

Armfield Ltd
Bridge House
West Street
Ringwood
Hampshire
England
BH24 1DY

Telephone number:	+44 (0)142578781
Fax number:	+44 (0)1425470916
Email address:	support@armfield.co.uk

IMPORTANT SAFETY INFORMATION

All practical work areas and laboratories should be covered by local regulations which must be followed at all times. If required, Armfield can supply a typical set of laboratory safety rules.

The HT14C Combined Convection and Radiation Accessory has been designed to be safe in use when installed, operated and maintained in accordance with the instructions in this manual. As with any piece of sophisticated equipment, dangers may exist if the equipment is misused, mishandled or badly maintained.

⚠ ELECTRICAL SAFETY

The equipment described in this Instruction Manual operates from a mains voltage electrical supply. It must be connected to a supply of the same frequency and voltage as marked on the equipment or the mains lead. If in doubt, consult a qualified electrician or contact Armfield. The equipment must not be operated with any of the panels removed.

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

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

⚠ HOT SURFACES

The unit incorporates a cartridge type electric heating element, and is capable of producing temperatures that could potentially cause skin burns.

Do not touch any surfaces close to 'Hot Surfaces' warning labels whilst the equipment is in use.

ARMFIELD LIMITED

OPERATING INSTRUCTIONS AND EXPERIMENTS

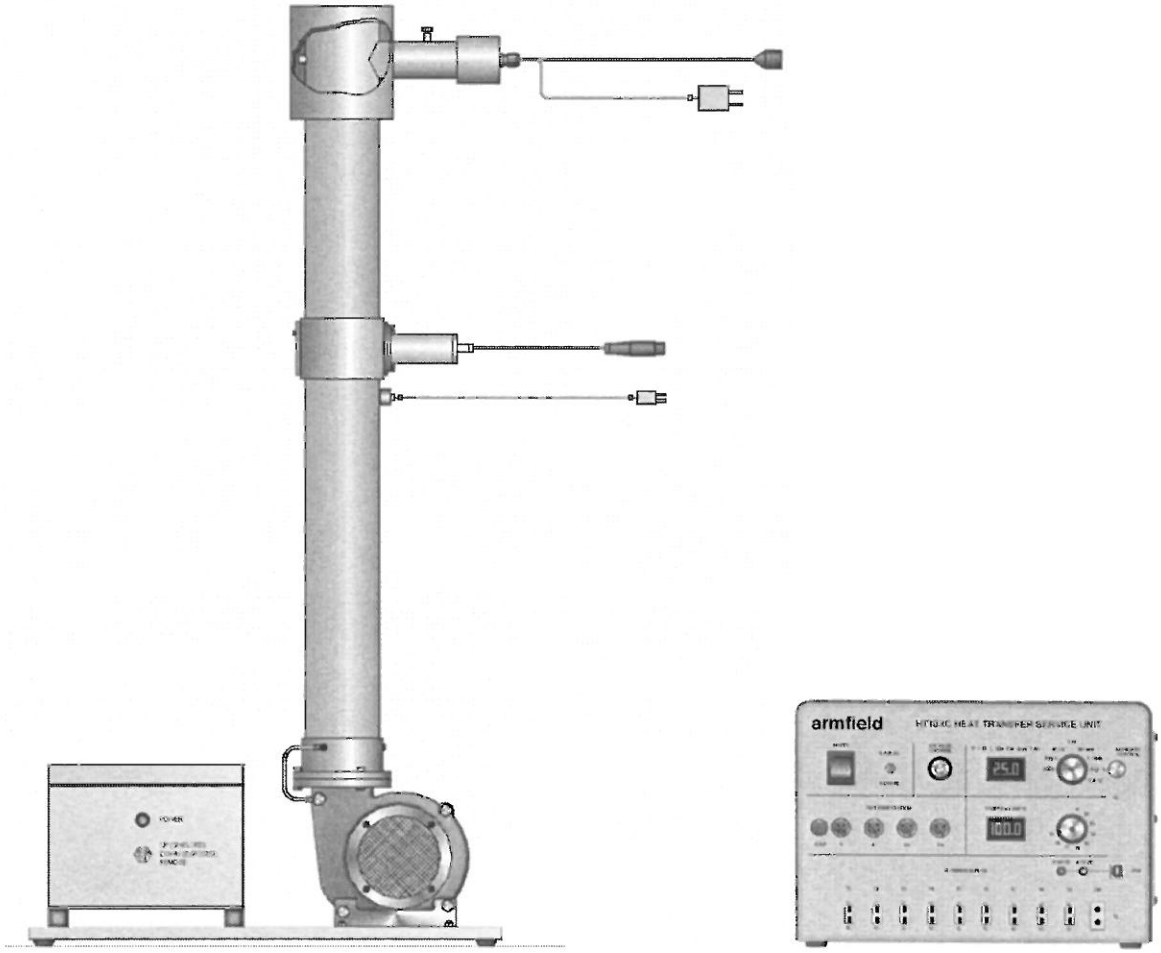
HT14C COMBINED CONVECTION AND RADIATION TEACHING EQUIPMENT

1 INTRODUCTION

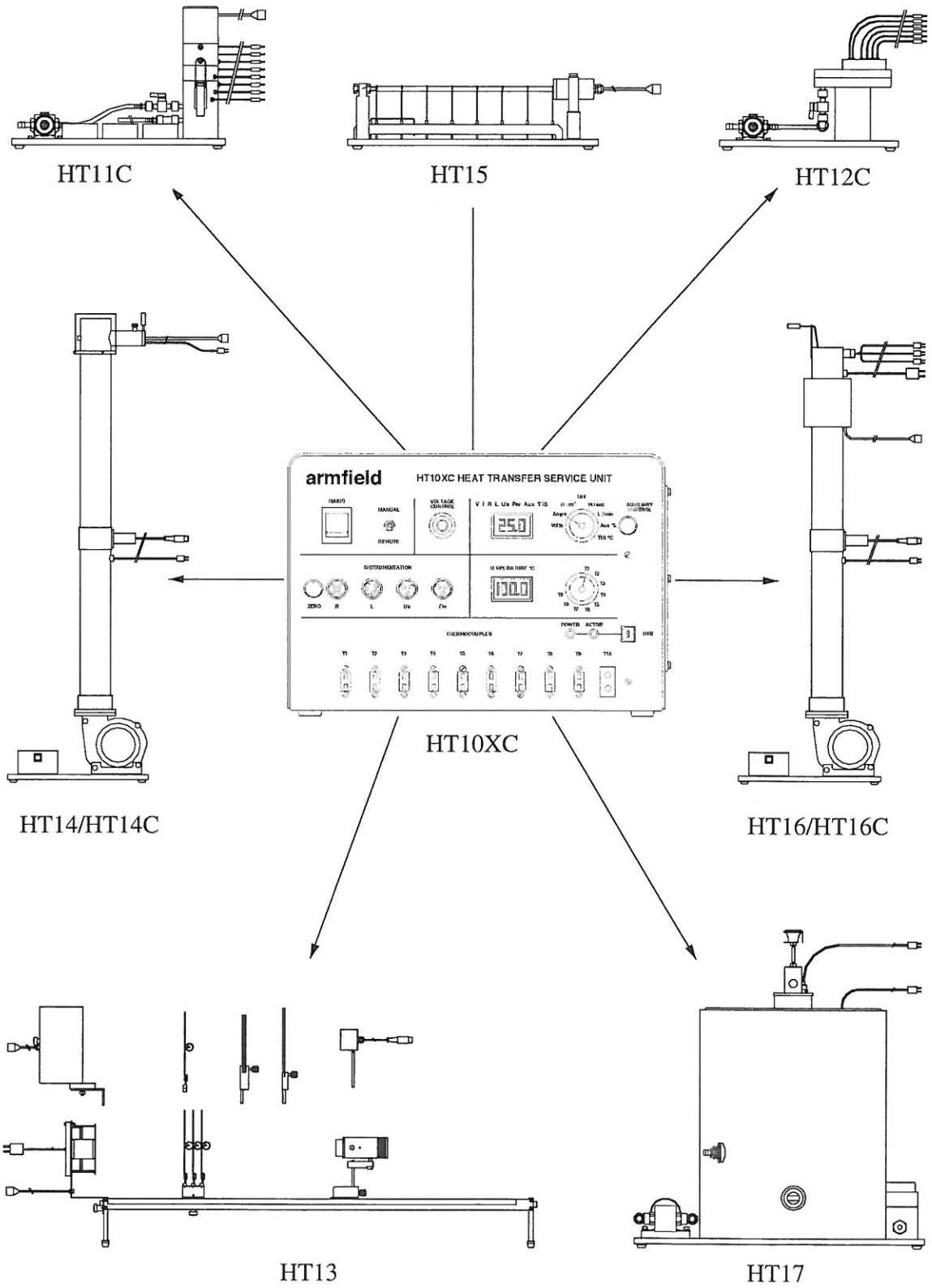
The Armfield 'Computer Compatible Combined Convection and Radiation' accessory HT14 has been designed to demonstrate heat transfer from a solid surface to its surroundings. A hot surface loses heat (heat is transferred) to its surroundings by the combined modes of convection and radiation. In practice these modes are difficult to isolate and therefore an analysis of the combined effects at varying surface temperature and air velocity past the surface provides a meaningful teaching exercise. The heated surface studied is a horizontal cylinder which can be operated in free convection or forced convection when located in the stream of moving air. Measurement of the surface temperature of the uniformly heated cylinder and the electrical power supplied to it allows the combined effects of radiation and convection to be compared with theoretical values. The dominance of convection at lower surface temperatures and the dominance of radiation at higher surface temperatures can be demonstrated as can the increase in heat transfer due to forced convection.

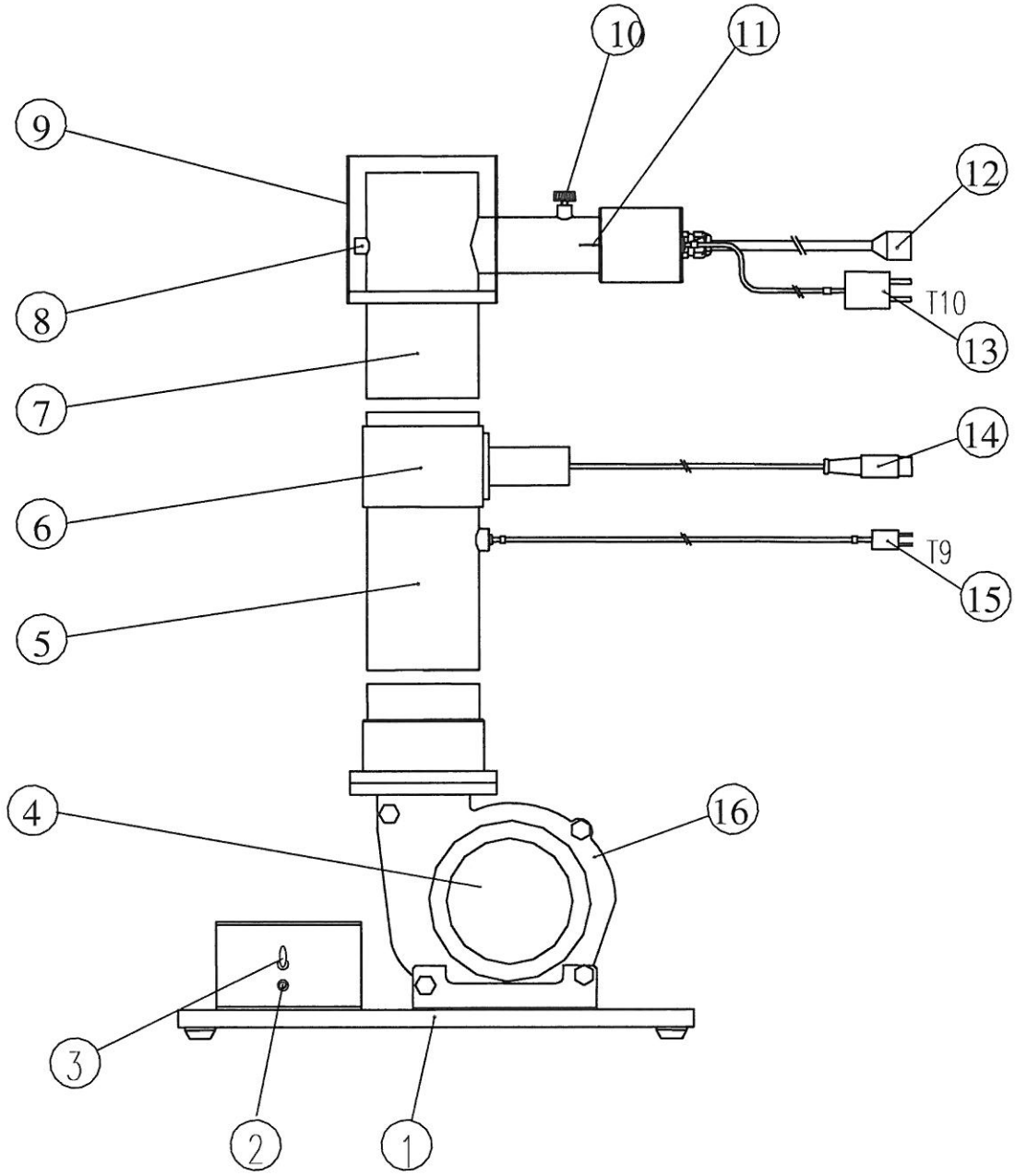
This instruction manual describes the operation of the HT14C Computer Compatible Combined Convection and Radiation' accessory, which must be used in conjunction with the HT10XC Heat Transfer Service Unit (supplied separately) and may be operated remotely from a Windows™-compatible PC via the USB interface device included within the console. Details of the service unit are given in a separate instruction manual which is supplied with the unit. This manual describes the operation of the HT14C accessory and includes a set of Laboratory Teaching Exercises.

The HT14C is one of a range of seven small scale heat transfer laboratory teaching accessories which demonstrate the basic modes of heat transfer (conduction, convection and radiation). These accessories may be individually connected to a common bench top service unit (HT10XC) which provides the necessary electrical supplies and measurement facilities for investigation and comparison of the different heat transfer characteristics.



The HT14C Computer Compatible
Combined Conduction and Radiation Accessory
with
HT10XC Control Console


HT11C
HT15
HT12C
armfield
HT10XC HEAT TRANSFER SERVICE UNIT
HT10XC
HT14/HT14C
HT16/HT16C
HT13
HT17



Front view of HT14C

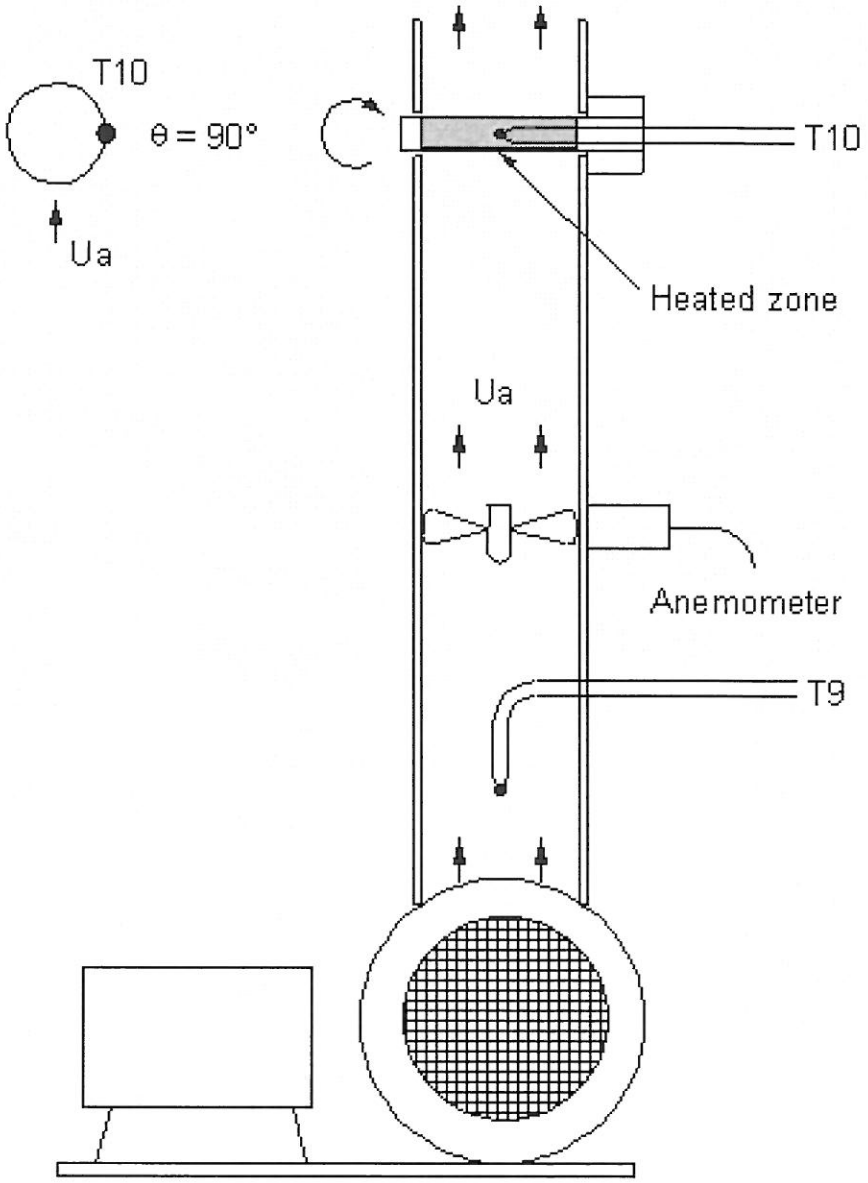
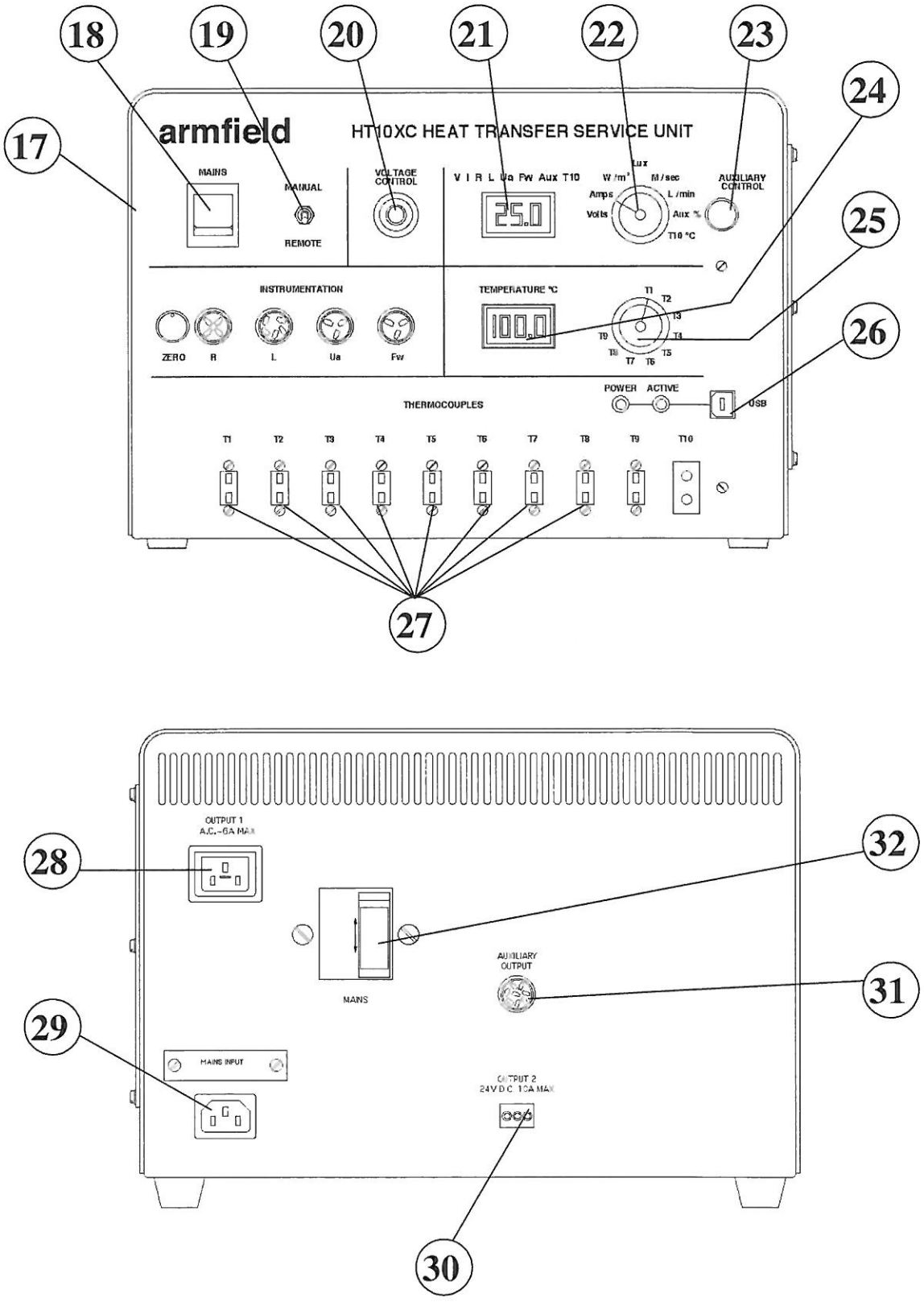


Diagram of HT14C



HT10XC Service Unit

2 EQUIPMENT DESCRIPTION

Refer to the diagrams on pages 1-4, 1-5and 1-6.

The 'Combined Convection and Radiation' accessory comprises a centrifugal fan (16) with a vertical outlet duct (5 and 7) at the top of which is mounted a heated, horizontal cylinder (8). The mounting arrangement for the cylinder is designed to minimise loss of heat by conduction to the wall of the duct allowing the combined effects of convection (free or forced) and radiation to be measured. A thermocouple attached to the wall of the heated cylinder provides a measurement of the surface temperature from which heat transfer calculations can be performed.

2.1 Baseplate

The accessory is mounted on a PVC baseplate (1) which stands on the bench top alongside the HT10X.

2.2 Heated Cylinder

The heated cylinder (8) has an outside diameter of 10 mm, a heated length of 70 mm and is internally heated throughout its length by an electric heating element which is operated at low voltage for increased operator safety. The surface of the cylinder is coated with heat resistant paint which provides a consistent emissivity close to unity.

The heated cylinder is mounted in such a way that the body can be rotated to allow the position of the thermocouple to be varied and the temperature distribution around the surface of the cylinder to be determined. An insulated cover allows the hot cylinder to be rotated and a locking screw (10) allows any position to be retained. The position of the thermocouple on the heated cylinder is indicated by a dot on the end of the insulated cover. An index mark (11) on the side of the boss shows the datum position for the thermocouple.

The maximum surface temperature of the cylinder is in excess of 600°C when operated in free convection at full heater power. However, to preserve the life of the heating element the maximum temperature should be limited to 500°C in normal use.

2.3 Heating Element

The heating element is rated to produce 100 Watts nominally at 24 VDC into the heated cylinder. The power supplied to the heated cylinder can be varied and measured on the HT10XC. The electrical connections to the cylinder incorporate temperature resistant insulation, with plug connection (12) to the variable 24 Volt DC supply socket marked OUTPUT 2 on HT10XC.

2.4 Cylindrical Duct

The heated cylinder is mounted horizontally at the top of a cylindrical duct which is attached to the outlet of a centrifugal fan. The inside diameter of the duct is 70 mm. The cylindrical duct is fabricated in two parts (5 and 7) with a rotating vane type anemometer (6) mounted between the two sections to allow the velocity of the air approaching the heated cylinder to be measured.

2.5 Thermocouples

Thermocouple T9 is fitted in the wall of the duct, upstream of the anemometer to measure the temperature of the air upstream of the heated cylinder. This thermocouple is fitted with a miniature plug (15) for direct connection to the HT10XC service unit. The resolution of the temperature reading is 0.1°C.

Thermocouple T10 is attached to the wall of the heated cylinder to indicate the surface temperature of the cylinder mid way along the cylinder. This type K thermocouple is fitted with a standard plug (13) for direct connection to the HT10XC service unit. The resolution of the temperature reading is 1°C.

2.6 Anemometer

A rotating vane type anemometer (6) is mounted between the two duct sections to allow the velocity of the air approaching the heated cylinder to be measured. The lead from the anemometer (14) connects directly to the socket marked Ua on the HT10X to provide readings of air velocity directly in units of metres/sec. The operating range of the anemometer is 0 - 10 metres/sec.

2.7 Fan

A centrifugal fan (16) is mounted at the base of the vertical outlet duct to provide a controllable air current through the duct. In normal operation the maximum air velocity is approximately 8 metres/sec when the fan is operated from a 50 Hz electrical supply (-A version).

The velocity of the air through the outlet duct may be controlled by varying the voltage supplied to the fan. The centrifugal fan is mains operated and obtains its supply from a mains outlet (OUTPUT 1) at the rear of the service unit. The connecting lead is connected to this socket on the HT10X. The control signal to the fan is obtained via a second cable from the electrical enclosure mounted beside the fan. This cable should be connected to the socket marked AUXILIARY OUTPUT at the back of the HT10XC service unit.

A thermal switch protects the fan against overcurrent, in the event of a fault condition. A manual switch (3) allows the fan to be operated manually when not using the associated computer software. A guard (4) covering the outlet from the vertical duct prevents inadvertent contact with the heated cylinder or the hot wall of the duct when the accessory is in use or cooling down following operation.

3 OPERATION

Refer to the diagrams on pages 1-4, 1-5 and 1-6.

The apparatus must be set up in accordance with the Installation Guide supplied (see Appendix A for details). Additionally, ensure that you have read the safety information at the beginning of this manual.

3.1 Setting the Heater Voltage

The heater is designed to be operated remotely from a PC. The manual/remote selector switch (19) on the front panel of the HT10XC (17) should be set to REMOTE for normal operation. The heater voltage may then be set using the voltage control box on the mimic diagram software screen.

The heater may also be operated manually, using the front panel controls. To control the heater manually, set the selector switch (19) to the MANUAL position. The voltage supplied to the heater may then be adjusted using the multi-turn potentiometer (20) marked VOLTAGE CONTROL.

The range of the output voltage is continuously adjustable from 0 Volts to 24 Volts DC using the multi-turn potentiometer. Ensure that the clamp on the side of the knob is released before turning the knob.

3.2 Measuring the Power to the Heater

While adjusting the heater voltage the actual voltage supplied to the heater can be monitored on the software mimic diagram.

If operating the equipment using the console, with the selector switch (19) set to MANUAL, the heater voltage may be monitored by setting the top measurement selector switch (22) to position V. The reading is displayed directly in Volts on the top panel display (21).

The current drawn by the heater in the accessory can be monitored by setting the top measurement selector switch (22) to position I. The reading is displayed directly in Amps on the top panel display (21).

As the electrical supply to the heater is Direct Current the power supplied to the heater is simply obtained from the product of the Voltage and Current, i.e.

Heater Power Q = Voltage V x Current I

E.g. If V = 15.0 Volts and I = 2.00 Amps then Q = 2 x 15 = 30.0 Watts

3.3 Temperature Measurement

The outputs of the thermocouples T9 and T10 are displayed on the mimic diagram of the HT14C software. All temperatures on the HT14C are indicated with a resolution of one decimal place.

They may also be monitored on the HT10XC console, with the selector switch (19) set to MANUAL, by setting the temperature selector switch (25) to the required position and read the corresponding value on the lower panel display (24).

3.4 Setting the Air Velocity

When the fan is running, the velocity of the air through the outlet duct can be adjusted by varying the power to the fan. This may be achieved using the HT14C software, or by using the AUXILIARY CONTROL knob on the HT10XC console.

3.5 Measuring the Air Velocity

To monitor the air velocity set the top measurement selector switch (22) to position M/sec (Ua). The reading is displayed on the top panel meter directly in units of metres/sec with a resolution of 0.1 m/s.

4 SPECIFICATIONS

4.1 Overall dimensions

Height: - 1200mm
Width - 485mm
Depth - 440mm

4.2 Electrical supply

	HT14C-A	HT14C-B	HT14C-G
Green/yellow lead	Earth (Ground)	Earth (Ground)	Earth (Ground)
Brown lead	Live (Hot)	Live (Hot)	Live (Hot)
Blue lead	Neutral	Neutral	Neutral
Fuse rating	13A	15A	13A
Voltage	220-240V	110-120V	220V
Frequency	50Hz	60Hz	60Hz

4.3 Channel Numbers

The HT14C includes Windows™-compatible software for full remote operation of the equipment and data logging of all output signals. However, users may prefer to write their own software for control and data logging. For the convenience of those wishing to do so, Armfield has provided additional USB drivers allowing operation of the equipment via the USB socket on the HT10XC console. The relevant channel numbers for the HT14C are as follows:

CHANNEL NO	SIGNAL FUNCTION
Analog Inputs (0-5 V dc):	
Ch 0 signal	Temperatures T9 and T10 via analog switch Temperature T9 (0 - 200°C) Temperature T10 (0 - 600°C) Note: T1-8 not used with HT14C
Ch 0 return	
Ch 1 signal	Voltage to fan (0 - 24 Volts DC)
Ch 1 return	
Ch 2 signal	Current to heater I (0 - 10 Amps)
Ch 2 return	
Ch 3 signal	Not used with HT14C
Ch 3 return	
Ch 4 signal	Not used with HT14C
Ch 4 return	
Ch 5 signal	Velocity of air Ua (0 - 10 m/s)
Ch 5 return	
Ch 6 signal	Not used with HT14C
Ch 6 return	
Not used	
Analog Outputs (0-5 V dc):	
DAC0 signal	Output signal from fan (0 – 24V)
DAC0 ground	
Not used	
Digital Inputs (0/5 V dc):	
Not used	
Digital Outputs (0/5 V dc):	
Ch 0	Analog switch
Ch 1	Analog switch
Ch 2	Analog switch
Ch 3	Analog switch
Digital ground	
Ch 4	Inhibit analog switch
Not used	
Digital ground	
Not used	

5 ROUTINE MAINTENANCE

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

5.1 General

- The equipment should be disconnected from the electrical supply when not in use.
- The HT14C accessory should be disconnected from the service unit when not in use.

5.2 Cleaning

- The heated section should NOT be cleaned, as this could damage the heat resistant surface. It is therefore very important that the accessory is stored correctly to ensure that it remains clean and free of dust.

5.3 Storage

- The HT14C accessory should be allowed to cool before storage.
- The HT14C accessory should be covered when not in use to prevent build up of dust on the heat transfer surface. Any covering must be of a sort that will not cause damage to the accessory through to abrasion or excessive weight/pressure.
- Any cover MUST be removed before connecting the HT14C to the HT10X service unit. If the heated cylinder is powered with the outlet of the duct covered then the equipment will be damaged and the cover could catch fire.

5.4 RCD test

- Test the RCD (32) by pressing the TEST button at least once a month. If the RCD button does not trip when the Test button is pressed then the equipment must not be used and should be checked by a competent electrician.

6 Laboratory Teaching Exercises

6.1 Nomenclature

Name	Symbol	SI unit
Voltage to heated cylinder	V	V
Current to heated cylinder	I	A
Power supplied to heated cylinder	Qin	W
Diameter of heated cylinder	D	m
Heated length of cylinder	L	m
Heat transfer area	As	m^2
Air velocity in duct (free stream velocity)	Ua	ms^{-1}
Corrected air velocity (due to blockage)	Uc	ms^{-1}
Heat loss due to natural convection	Qc	W
Heat loss due to forced convection	Qf	W
Heat loss due to radiation	Qr	W
Total heat loss from cylinder	Qtot	W
Heat transfer coefficient for natural convection	Hc	$Wm^{-2}K^{-1}$
Heat transfer coefficient for forced convection	Hf	$Wm^{-2}K^{-1}$
Heat transfer coefficient for radiation	Hr	$Wm^{-2}K^{-1}$
Stefan Boltzmann constant	σ (= 56.7 x 10^{-9})	$Wm^{-2}k^{-4}$
Emmisivity of cylinder	ξ	Dimensionless
Area factor (geometric factor)	F	Dimensionless
Dynamic viscosity of air	ν	m^2s^{-1}
Thermal conductivity of air	k	$Wm^{-1}K^{-1}$
Reynolds number (local)	Re	Dimensionless
Nusselt number (local)	Nu	Dimensionless
Prandtl number	Pr	Dimensionless
Angular position of thermocouple (measured from the stagnation point)	θ	Degrees
Surface temperature of heated cylinder	T10	°C
Surface temperature of heated cylinder	Ts (=T10 + 273)	K
Temperature of ambient air/surroundings	T9	°C
Temperature of ambient air/surroundings	Ta (=T9 + 273)	K
Film temperature of air	Tfilm	K
Subscripts:		
d	diameter	
m	mean (average)	
f	film	

6.2 Table of physical properties for air at atmospheric pressure

T_{film} (K)	ν (m^2s^{-1})	k ($Wm^{-1}K^{-1}$)	Pr (Dimensionless)
300	1.684×10^{-5}	0.02624	0.708
350	2.076×10^{-5}	0.03003	0.697
400	2.590×10^{-5}	0.03365	0.689
450	3.171×10^{-5}	0.03707	0.683
500	3.790×10^{-5}	0.04038	0.680
550	4.434×10^{-5}	0.04360	0.680
600	5.134×10^{-5}	0.04659	0.680