INSTRUCTION MANUAL

HT11C

COMPUTER COMPATIBLE
LINEAR HEAT CONDUCTION ACCESSORY

HT11C

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

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.

Your HT11C Linear Heat Conduction 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.

⚠ WATER-BORNE HAZARDS

The equipment described in this instruction manual involves the use of water which under certain conditions can create a health hazard due to infection by harmful micro-organisms.

For example, the microscopic bacterium called Legionella pneumophila will feed on any scale, rust, algae or sludge in water and will breed rapidly if the temperature of water is between 20 and 45°C. Any water containing this bacterium which is sprayed or splashed creating air-borne droplets can produce a form of pneumonia called Legionnaires Disease which is potentially fatal.

Legionella is not the only harmful micro-organism which can infect water, but it serves as a useful example of the need for cleanliness. Under the COSHH regulations, the following precautions must be observed:

Any water contained within the product must not be allowed to stagnate, i.e. the water must be changed regularly.

Any rust, sludge, scale or algae on which micro-organisms can feed must be removed regularly, i.e. the equipment must be cleaned regularly.

Where practicable the water should be maintained at a temperature below 20°C or above 45°C. If this is not practicable then the water should be disinfected if it is safe and appropriate to do so. Note that other hazards may exist in the handling of biocides used to disinfect the water.

A scheme should be prepared for preventing or controlling the risk incorporating all of the actions listed above.

Further details on preventing infection are contained in the publication "The Control of Legionellosis including Legionnaires Disease" - Health and Safety Series booklet HS (G) 70.

⚠ 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 AND LIQUIDS

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

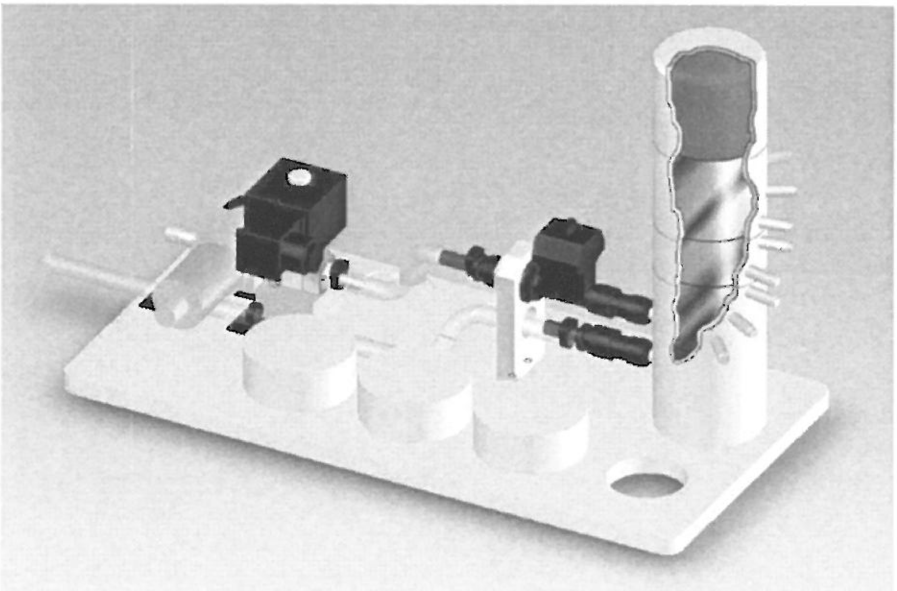
HT11C LINEAR HEAT CONDUCTION TEACHING EQUIPMENT

1 INTRODUCTION

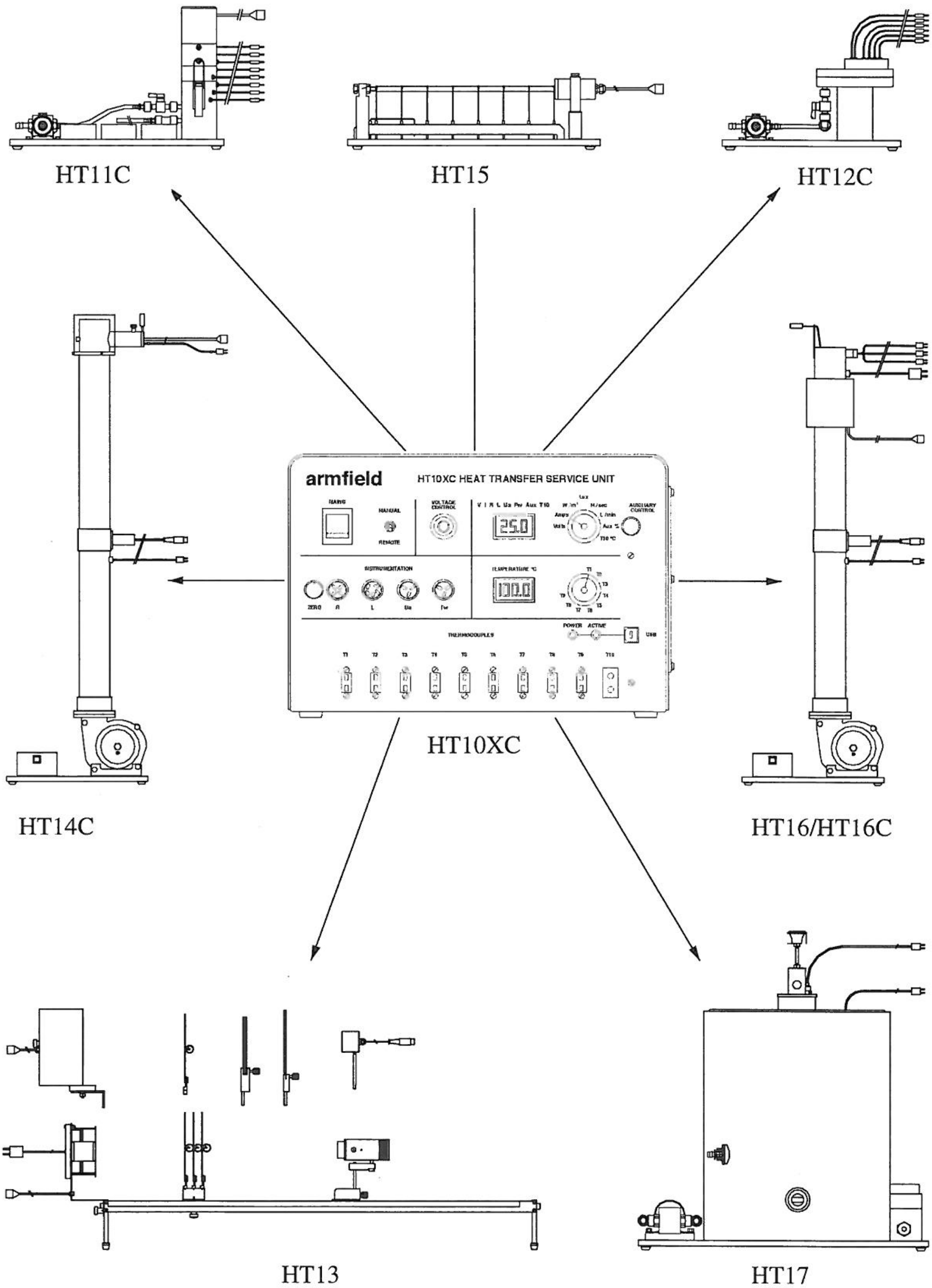
The Armfield Computer Compatible Linear Heat Conduction accessory HT11C has been designed to demonstrate the application of the Fourier Rate equation to simple steady-state conduction in one dimension. The unit can be configured as a simple plane wall of uniform material and constant cross sectional area or composite plane walls with different materials or changes in cross sectional area to allow 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. The design allows the conductivity of thin samples of insulating material to be determined.

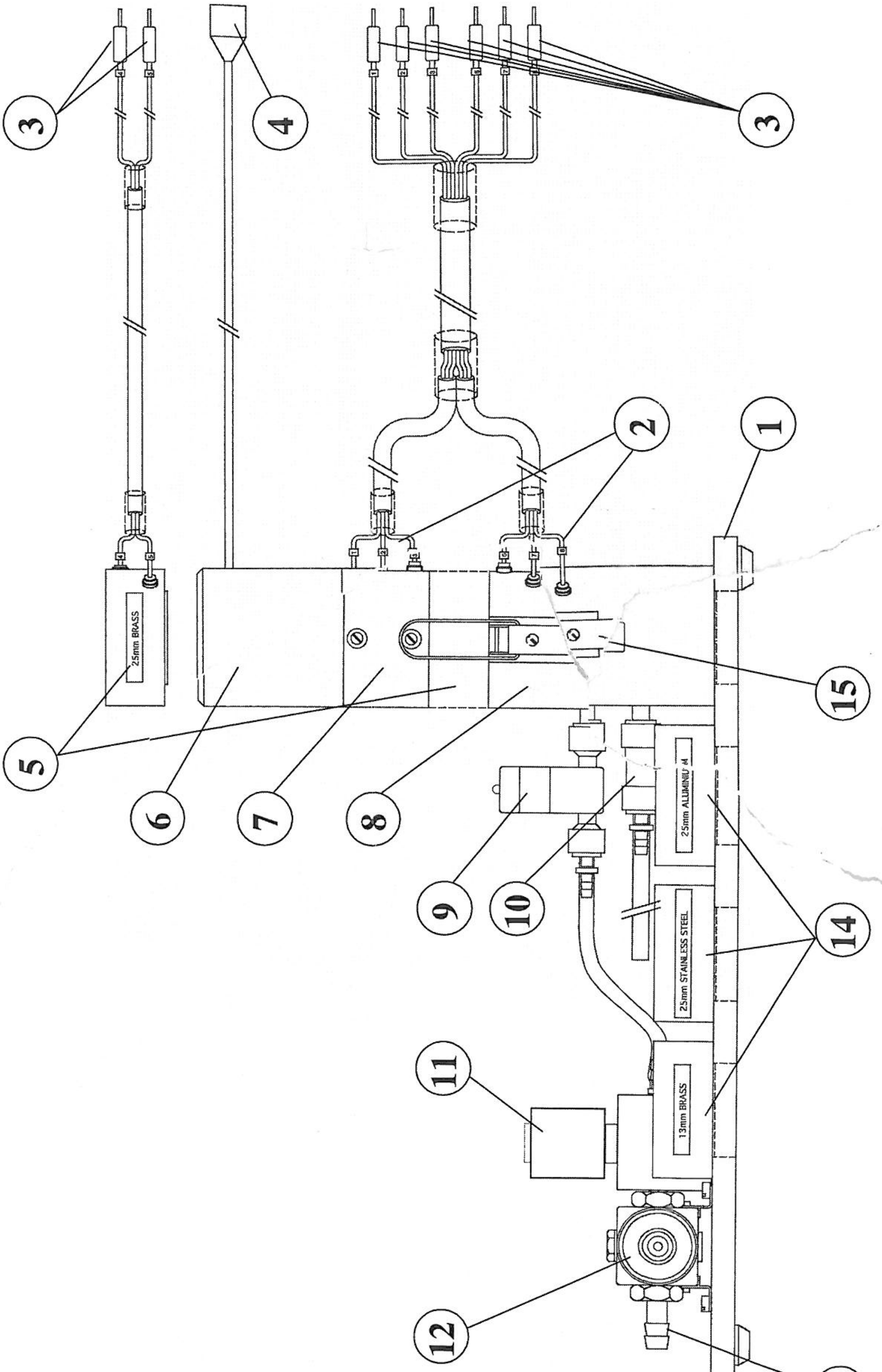
This instruction manual describes the operation of the HT11C Computer Compatible Linear Heat Conduction accessory, which must be used in conjunction with the HT10XC Heat Transfer Service Unit (supplied separately) and may be operated remotely from a Windows™-compatible PC via the USB interface device 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 HT11C accessory and includes a set of Laboratory Teaching Exercises.

The HT11C 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 HT11C Computer Compatible Linear Heat Conduction Accessory


HT11C
HT15
HT12C
armfield
HT10XC HEAT TRANSFER SERVICE UNIT
HT10XC
HT14C
HT16/HT16C
HT13
HT17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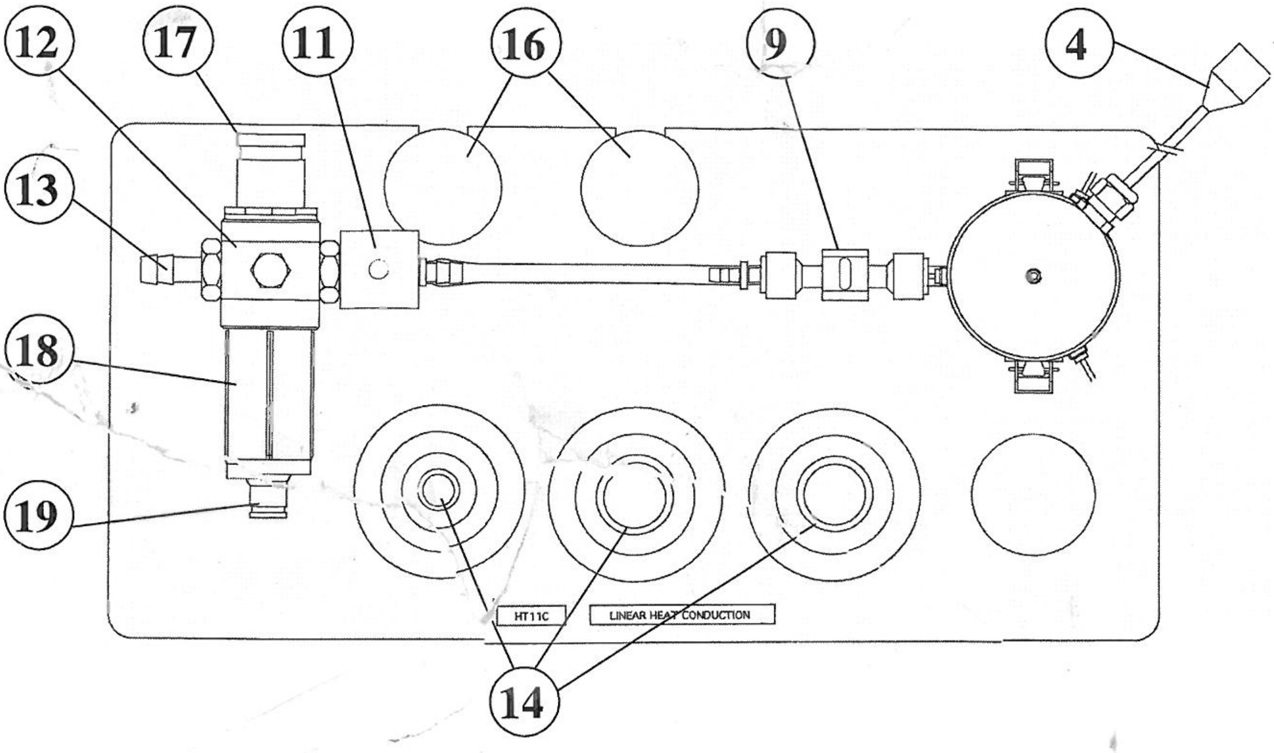
15
25mm BRASS
25mm ALUMINIUM
25mm STAINLESS STEEL
13mm BRASS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17
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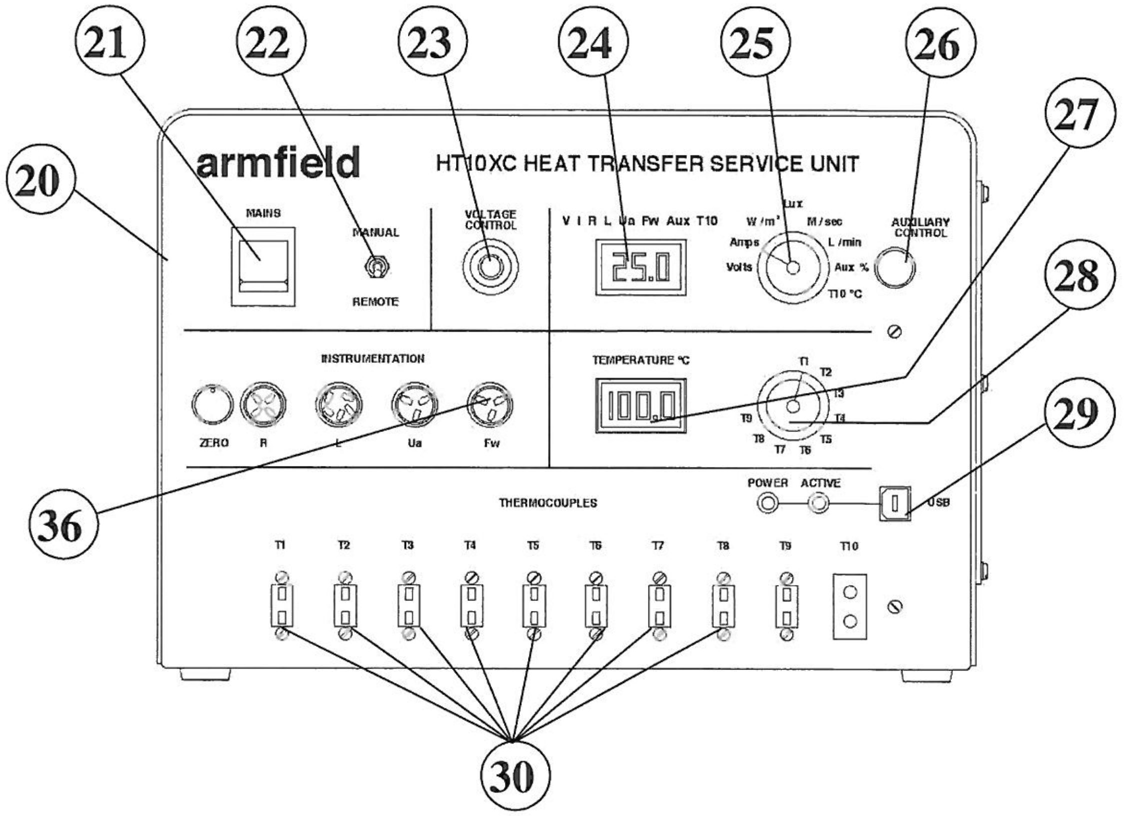
HT11C
LINEAR HEAT CONDUCTION
14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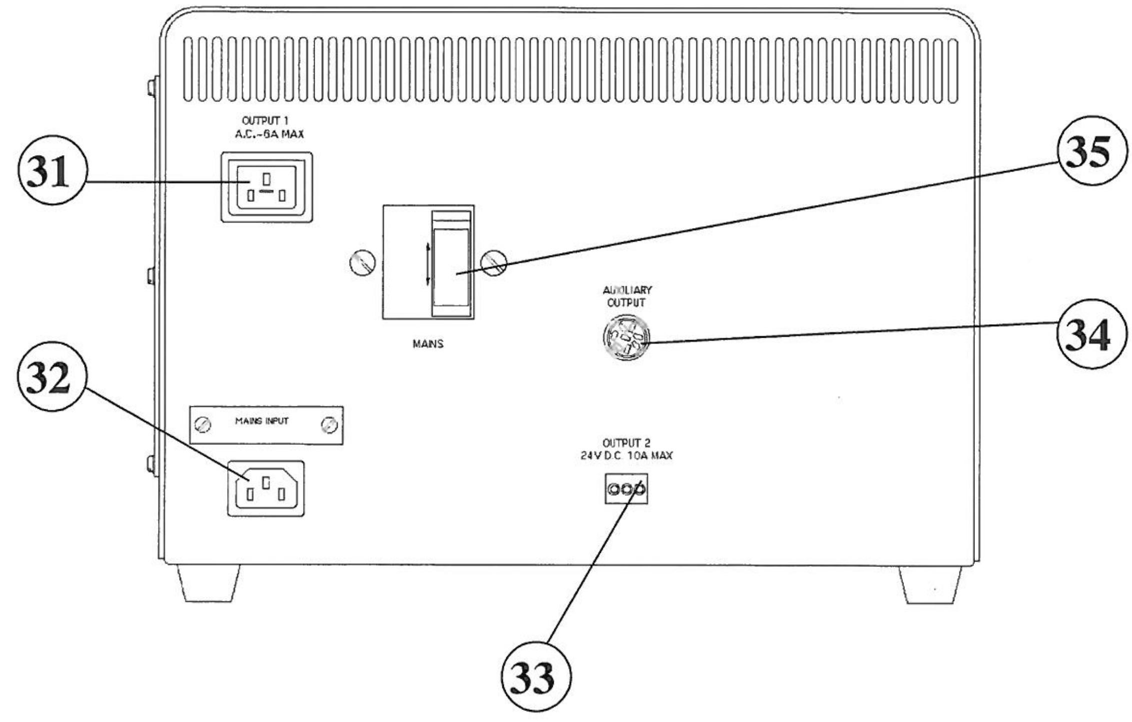
30
36
armfield
HT10XC HEAT TRANSFER SERVICE UNIT
MAINS
MANUAL
REMOTE
VOLTAGE CONTROL
V I R L Ua Fw Aux T10
25.0
Lux
W/m²
M/sec
Amps
L/min
Volts
Aux %
T10 °C
AUXILIARY CONTROL
INSTRUMENTATION
ZERO
R
L
Ua
Fw
TEMPERATURE °C
100.0
T1
T2
T3
T4
T5
T6
T7
T8
T9
POWER
ACTIVE
USB
THERMOCOUPLES
T10


31
32
33
34
35
OUTPUT 1
A.C.-6A MAX
MAINS
AUXILIARY OUTPUT
MAINS INPUT
OUTPUT 2
24V D.C. 10A MAX

2 EQUIPMENT DESCRIPTION

Refer to the diagrams on pages 1-3, 1-4 and 1-5.

2.1 Overview

The Computer Compatible Linear Heat Conduction accessory comprises heating and cooling sections which can be clamped together directly or clamped with interchangeable intermediate sections as required. Each interchangeable section contains a different specimen of metal conductor which allows a plane wall of the same material, a plane wall of different cross section or composite walls with different materials to be created for evaluation. 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.

2.2 Heating Section

The heating section (7) is manufactured from 25 mm diameter cylindrical brass bar with a cartridge type electric heating element (6) installed at one end.

2.3 Heating Element

The heating element (6) is operated at low voltage for increased operator safety and is protected by a thermostat to prevent damage from overheating. The heating element is rated to produce 60 Watts nominally at 24 VDC. The power supplied to the heating element can be varied and measured using the HT10XC. The lead from the heating element (4) is connected to the DC outlet socket marked OUTPUT 2 on the HT10XC (33).

2.4 Cooling Section

The cooling section (8) is manufactured from 25 mm diameter cylindrical brass bar to match the heating section and cooled at one end by water passing through galleries in the section.

2.5 Cooling Water

A proportioning solenoid valve (11) allows the flow of cooling water to be varied, if required, over the operating range of 0 - 1.5 litres/min. The valve should be connected to the socket marker AUXILARY OUTPUT (34) on the rear of the HT10XC console. The cold water supply is connected to the serrated ferrule (13) on the side of the pressure regulator using reinforced flexible tubing (not supplied).

2.6 Cooling Water Flow Measurement

The HT11C includes a turbine-type flow sensor (9) for measurement of the cooling water flow rate directly in litres per minute. The flow sensor should be connected to the socket marked Fw (36) on the front of the HT10XC console.

2.7 Intermediate Sections

Four intermediate sections (5 and 14) are supplied, each incorporating a different metal specimen as follows:

2.7.1 Brass specimen

30 mm long brass section (5) of the same diameter as the heating and cooling sections (25 mm diameter) and fitted with two thermocouples at the same intervals (15 mm). 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.

The thermal conductivity of the Brass specimen is typically in the range 110 to 128 W/m°C over the range of operating temperatures in the HT11C.

2.7.2 Stainless Steel specimen

30 mm long stainless steel specimen (14) of the same diameter as the heating and cooling sections (25 mm diameter) to demonstrate the effect of a change in thermal conductivity. The specimen does not incorporate thermocouples.

The thermal conductivity of the Stainless Steel specimen is approximately 25 W/m°C at the typical operating temperatures in the HT11C.

Note: The poor conductivity of the stainless steel specimen means that operation with high settings of the voltage control will cause the thermal trip to operate. Stabilisation of the temperature readings will take considerably longer than when using the brass or aluminium specimens.

2.7.3 Aluminium Alloy specimen

30 mm long Aluminium Alloy specimen (14) of the same diameter as the heating and cooling sections (25 mm diameter) to demonstrate the effect of a change in thermal conductivity. The specimen does not incorporate thermocouples.

The thermal conductivity of the Aluminium Alloy specimen is approximately 180 W/m°C at the typical operating temperatures in the HT11C.

2.7.4 Brass specimen with reduced diameter

30 mm long brass specimen (14) reduced in diameter to 13 mm to demonstrate the effect of a change in cross sectional area. The specimen does not incorporate thermocouples.

The thermal conductivity of the reduced diameter Brass specimen is typically in the range 110 to 128 W/m°C over the range of operating temperatures in the HT11C.

Note: The reduced area of heat flow in this specimen means that operation with high settings of the voltage control will cause the thermal trip to operate. Stabilisation of the temperature readings will take considerably longer than when using the standard brass specimen.

2.8 Thermal Properties of Insulators

The heat conducting properties of insulators (16) may be found by simply inserting the paper or cork specimens supplied between the heating and cooling sections. The specimens must be extremely thin to compensate for their poor conductivity.

Note: The very poor conductivity of the insulators means that the voltage control must be set to extremely low settings (typically 1.5 Volts) to prevent the thermal trip from operating. Stabilisation of temperatures will take considerably longer than when using specimens with high conductivity.

2.9 Section Construction

The heating section, cooling section and all intermediate sections are located co-axially inside plastic housings which provide an air gap and insulate the section to minimise heat loss to the surroundings and prevent burns to the operator. The plastic housings incorporate shallow shoulders to ensure that each section aligns concentrically with the adjacent section. This means that the interchangeable sections can only be installed one way round. A pair of toggle clamps (15) ensures that the sections are held tightly together when in use. Two alternative studs are located on the heated section to allow the clamp to operate with or without an intermediate section installed.

2.10 Thermocouples

Three thermocouples (T1, T2 and T3) are positioned along the heated section at uniform intervals of 15 mm. Three thermocouples (T6, T7 and T8) are positioned along the cooling section at uniform intervals of 15 mm. Two thermocouples (T4 and T5) are positioned along the brass intermediate section, also at 15 mm intervals. These thermocouples measure the temperature gradient along the section to which they are attached.

Each type K thermocouple is fitted with a miniature plug (3) for direct connection to the front panel of the service unit HT10XC (26). The thermocouple beads are located on the centreline of each section in holes at different angular positions to minimise the disturbance to heat flow along the sections.

2.11 Thermal Paste

A tube of thermal paste is provided. The paste is applied between the adjacent faces to minimise the temperature gradient across the joints. The effect of poor thermal contact between the sections can be demonstrated by taking equivalent readings with no paste applied then with the sections unclamped.

2.12 Measurement of Temperature Gradient

When the Brass Specimen, which incorporates thermocouples, is clamped between the heated and cooled sections the two thermocouples installed in the specimen assume the identities T4 and T5 to provide a continuous plane wall with eight thermocouples T1 - T8

When the non-instrumented specimens or insulated disks are installed between the heated and cooled sections, the temperature at the interfaces must be calculated from the temperature measurements taken in the appropriate section. The thermocouples in each section are located 15 mm apart. T3 and T6 are located 7.5 mm away from the end surface.

In the case of the heated section the temperature of the end face will be lower than T3 and can be calculated as follows:

$$T_{hotface} = T3 - \frac{(T2 - T3)}{2}$$

In the case of the cooled section the temperature of the end face will be higher than T6 and can be calculated as follows:

$$T_{coldface} = T6 + \frac{(T6 - T7)}{2}$$

Details of connections between the HT11C and the HT10XC service unit are given in the Installation Guide (Appendix A).

3 OPERATION

Refer to the diagrams on pages 1-3, 1-4 and 1-5.

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 (22) on the front panel of the HT10XC (20) 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 (22) to the MANUAL position. The voltage supplied to the heater may then be adjusted using the multi-turn potentiometer (23) 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 (22) set to MANUAL, the heater voltage may be monitored by setting the top measurement selector switch (25) to position V. The reading is displayed directly in Volts on the top panel display (24).

The current drawn by the heater in the accessory can be monitored by setting the top measurement selector switch (25) to position I. The reading is displayed directly in Amps on the top panel display (24).

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

Note: The heating section of HT11C incorporates a thermostat to limit the maximum operating temperature. If the heater voltage is set too high, resulting in excessive temperature, the current to the heater will be disconnected until the thermostat resets when the temperature falls. If the display shows no current when voltage is applied to the heating element check that temperature T1 is below 100°C.

If temperature T1 is excessive ensure that cooling water is flowing through the cooling section to drain and check that the heating and cooling sections are clamped tightly together. If temperature T1 does not reduce set the Heater Voltage to zero and allow the thermostat to reset.

If temperature T1 is not excessive but the display shows no current when voltage is applied to the heating element check the following:

Check that the RCD at the rear of the service unit is latched (up).

Check that the heater lead (4) on the HT11C is connected to the socket marked Output 2 at the rear of the service unit.

3.3 Temperature Measurement

The outputs of the either thermocouples T1 to T8 are displayed on the mimic diagram of the HT11C software. All temperatures on the HT11C are indicated with a resolution of one decimal place.

They may also be monitored on the HT10XC console, with the selector switch (22) set to MANUAL, by setting the temperature selector switch (28) to the required position and read the corresponding value on the lower panel display (27).

3.4 Setting the Cold Water Pressure Regulator

Before using the cooling water system it will be necessary to adjust the pressure regulating valve.

Ensure that the cold water pressure regulating valve (12) is fully off by pulling the knob (17) outwards from the body of the regulator, then turning the knob fully anticlockwise. Ensure that the drain/vent (19) on the transparent filter bowl (18) is closed by turning it fully clockwise.

Connect the cold water flow control valve (11) to the socket marked AUXILARY OUTPUT (34) on the rear of the HT10XC console.

Connect the cold water flow rate sensor (9) to the socket marked Fw (36) on the front of the HT10XC console.

Open the cold water flow control valve (11) fully using the flow control box on the mimic diagram software screen*. Gradually open the pressure regulating valve by turning the knob clockwise until the cold water flow through the cooling section is approximately 1.5 litres/ min.

*If using the HT11 instead of the HT11C, the cold water flow is regulated using a manual valve situated next to the test section column. If operating the equipment manually via the console, the flow rate can controlled using the AULILIARY CONTROL knob (26). The flow rate can be read on the top panel display (24) with the selector switch (25) set to position Fw.

(If using the HT11 without the optional flow sensor SFT2 then the actual flow can be checked using a stopwatch and measuring cylinder).

When the flow rate is acceptable push the knob down to lock the setting of the pressure regulator.

If it is required to reduce the cooling water flow rate adjust the flow rate using the flow control valve (11) by adjusting the valve setting within the software (or, if operating manually, using the AULXILIARY CONTROL knob (26). Do not use the pressure regulating valve to adjust the flow of cooling water.

3.5 Measuring the Cold Water Flow Rate

The HT11C includes a flow meter and corresponding measurement channel in the HT11C software, which allows the cold water flow rate to be measured and logged. Provided that the pressure regulator is set as instructed above, the flow of cooling water should remain constant provided that the flow control valve is left fully open.

(If the HT11 accessory is used with the HT10XC, the cold water flow rate can only be easily monitored if the optional flow sensor SFT2 is fitted. If a flow rate must be obtained then it is possible to perform a timed volume collection using a measuring cylinder and a stopwatch).

3.6 Applying the Thermal Paste (Conductive compound)

The end faces of the heating section, cooling section and appropriate intermediate section should be coated with the thermal paste supplied to minimise temperature gradients across the joints. The paste should be applied sparingly and smeared as thinly as possible over the entire contact area before clamping the sections together. To ensure an even spread of the paste twist the sections by a few degrees clockwise then anticlockwise while holding them together, then operate the clamps simultaneously.

4 SPECIFICATIONS

4.1 Overall dimensions

Height:	-	282mm
Width	-	427mm
Depth	-	210mm

4.2 Electrical supply

	HT11C-A	HT11C-B	HT11-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 HT11C 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, and 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 HT11C are as follows:

CHANNEL NO SIGNAL FUNCTION

Analog Outputs (0-5 V dc exported from socket):

CHANNEL NO	SIGNAL FUNCTION
Ch 0 signal	Temperatures T1 to T8 via analog switch Temperatures T1 - T8 (0 - 133°C) Note: Temperatures T9 - T10 not used
Ch 0 return	
Ch 1 signal	Flow Control Valve (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 on HT11C
Ch 3 return	
Ch 4 signal	Not used on HT11C
Ch 4 return	
Ch 5 signal	Not used on HT11C
Ch 5 return	
Ch 6 signal	Flowrate of water Fw (0 - 1.5 l/min)
Ch 6 return	
Not used	

Analog Inputs (0-5 V dc input to socket):

DAC0 signal	Voltage output V (Remote operation of 0-24 Volts)
DAC0 ground	
Not used	

Digital Outputs (0-5 V dc):

Not used

Digital Inputs (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 cooling water supply should be disconnected from the inlet on the HT11C when not in use.

5.2 Draining the Cooling Water Pipework

Water should be drained from the cooling section of the HT11C after use to minimise build up of scale or fouling inside the cooling section. The water can be drained by simply disconnecting the top flexible tube from the inlet to the flow control valve and allowing the water to flow out through the outlet tube under gravity, ensuring that the valve is fully open. To remove the ferrule from the control valve depress the collar on the valve while pulling the ferrule. To reassemble simply push the ferrule fully into the control valve.

5.3 Storing the Intermediate Sections

After use the intermediate sections should be located in the recesses on the baseplate to avoid damage to the contact surfaces. The shallow lip on one side of the section should be located in the recess.

5.4 Cleaning the Contact Surfaces

Any build up of thermal paste or other contamination on the contact surfaces of the heating section, cooling section and intermediate sections can be removed by carefully polishing the surfaces using a proprietary liquid metal polish applied to a clean, soft cloth.

Note: Correct operation of the equipment depends on the contacting surfaces remaining flat and square. It is therefore important to take care not to damage the surfaces or round the corners by applying too much force or using a coarse abrasive cleaner.

5.5 Cleaning the Pressure Regulator Filter

The pressure regulator incorporates an integral filter to prevent particles or fibres in the water from entering the delicate regulator. The transparent bowl allows the condition of the filter element to be inspected. Any contamination in the bowl or on the filter should be removed by unscrewing the transparent bowl and rinsing the bowl and element in clean water before reassembling.

5.6 Adjusting the Clamps and Bars

With prolonged use the clamps or the position of the brass bars inside the heating and/or cooling sections may require adjustment to ensure good thermal contact between the end faces (poor contact may be indicated by a large temperature gradient across the junction).

5.6.1 Adjusting the Clamps

Clamp the heating and cooling sections together by operating the clamping levers simultaneously. The clamp levers should be tight to operate and the two sections should be held firmly together. If the clamping action is too light then length of the metal wire clasps should be reduced by increasing the curvature (the wire can be easily bent by supporting the centre of the clasp in one hand and applying pressure to the free end using the other hand).

When correctly adjusted equal pressure should be required to operate both clamp levers.

5.6.2 Adjusting the Bars

The position of the brass bars may be checked and adjusted as follows:

Check the position of the brass end face in the heating (top) section. It should be flush with the plastic insulator which surrounds it. If the position is not correct partially unscrew the M4 securing screw on the side of the insulated housing using an M2 hexagonal key (Allen key measuring 2mm across the flats). Adjust the position of the brass bar by turning the M6 adjusting screw on the top of the insulated housing using an M3 hexagonal key (Allen key measuring 3mm across the flats) while keeping the brass bar pressed against the adjusting screw. When the face is flush tighten the securing screw on the side of the insulated housing to retain the position.

The brass end face in the cooling (bottom) section should be recessed approximately 1mm below the outer diameter of the plastic insulator which surrounds it.

Clamp the heating section to the cooling section. If correctly adjusted there should be a visible gap of approximately 0.5mm but no more than 1mm between the end faces of the plastic insulators (outer diameters only).

If the gap is too large or too small, partially unscrew the M4 securing screw on the side of the insulated housing using an M2 hexagonal key. Adjust the position of the brass bar by turning the M6 adjusting screw, accessible through a hole in the underside of the base plate using an M3 hexagonal key while keeping the brass bar pressed against the adjusting screw. When the face is correctly positioned tighten the securing screw on the side of the insulated housing to retain the position.

As a final check, lightly smear the metal contact surfaces with thermal paste before clamping the heating section and the cooling section together. Release the two sections and check that the thermal paste has been uniformly displaced.

5.7 RCD test

Test the RCD (35) 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.