

TD1007

Water to Air Heat Exchangers

User Guide

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TD1007

Water to Air Heat Exchanger

User Guide

Introduction

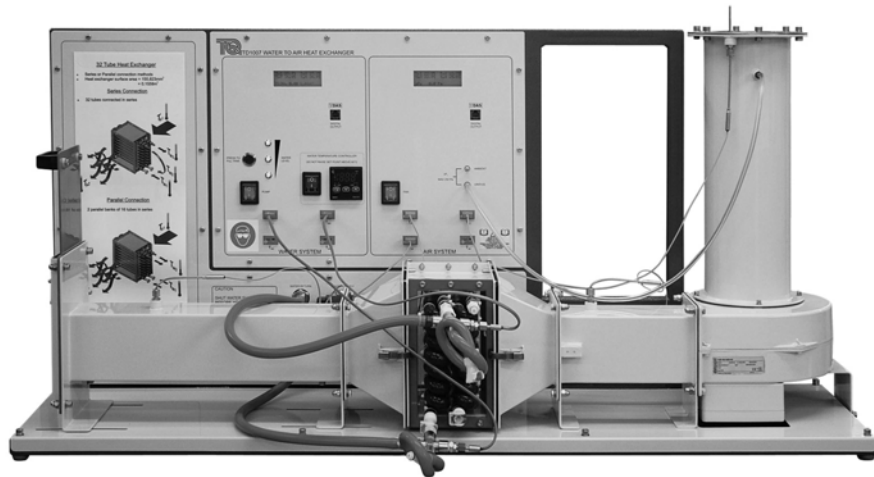


Figure 1 The Water to Air Heat Exchanger (TD1007)



This product works with VDAS[®]

Many thermodynamic applications use water to air heat exchangers. Examples include using circulated water to heat or cool air in a HVAC installation, or to cool hot water using a flow of air, as in the radiator of a combustion engine.

Engineers learning about thermodynamics and heat transfer need to know how heat exchangers work and under what conditions they work best. They can use this information to help them design their own heat exchanger for best efficiency. TecQuipment's Water to Air Heat Exchanger shows students how different types of cross-flow heat exchanger designs work and compares their efficiency for different configurations, flow rates and temperatures.

The main part is a compact frame that holds the water circuit and an air duct with fan. It has instruments to measure and display water and air conditions, such as air pressure, water flow and temperature. TecQuipment supply one heat exchanger as standard with the equipment. Two other designs are available as optional extras. The heat exchanger fixes to the midsection of the air duct.

Students test the heat exchangers and record the flow and temperature changes to see how well the heat exchanger works. The student can change the airflow and water flow rate and temperature to give a full range of tests on the heat exchangers.

To record your experiment results automatically and save time, the equipment works with TecQuipment's Versatile Data Acquisition System (VDAS).

Description

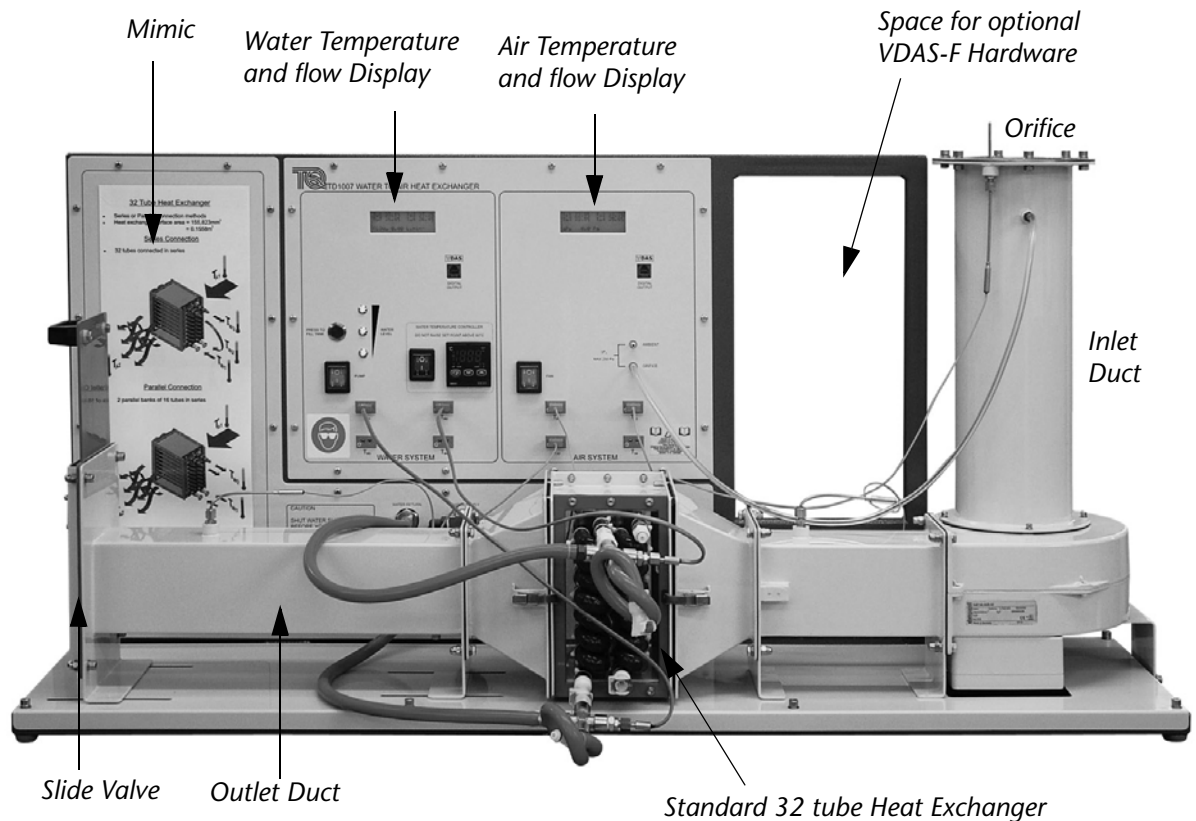


Figure 2 The Water to Air Heat Exchanger

The Main Part

The main part of the TD1007 unit is a compact bench-mounting frame that connects to a suitable electrical supply and a supply of clean, cold water to 'top up' its self-contained water circuit.

The frame holds a horizontal, rectangular section air duct, fed from an electric centrifugal fan. From the user's position, air passes from right to left along the equipment. Starting at the right hand side (inlet or upstream end), the air passes vertically down a circular inlet duct to the fan. The fan accelerates the air, turns it through 90 degrees and forces it along the horizontal rectangular section duct. The air passes through the heat exchanger and leaves the duct through an adjustable slide valve. The slide valve allows the user to adjust the air flow through the duct. A calibrated orifice at the top of the inlet duct works with an air pressure sensor to help measure the air flow rate through the duct (the optional VDAS calculates this automatically). Thermocouples along the air duct measure the ambient air temperature at the inlet and before and after the heat exchanger.

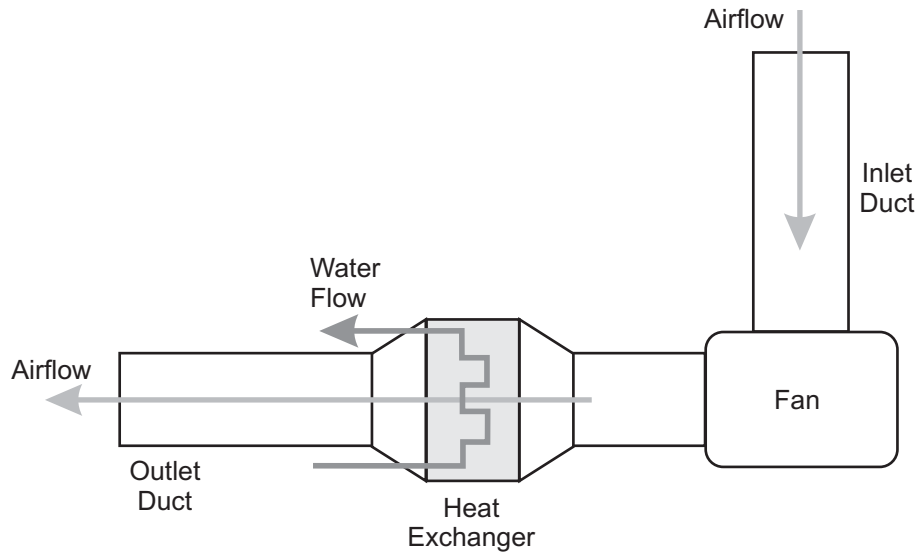


Figure 3 Flow Paths

Toggle clips hold the heat exchanger securely in the midsection of the air duct. They also allow the user to change the heat exchanger easily. The outlet duct can slide along to help when changing heat exchangers. A panel to the left of the main frame allows the student to attach the magnetic 'MIMIC' sheet supplied with each heat exchanger. The MIMIC helps the student understand how to connect the water pipes to the heat exchanger.

The water circuit has a flow sensor to measure and display the flow rate and an electric heater tank to heat the water. An adjustable controller sets the tank temperature and keeps it relatively constant (to within ± 2 degrees for most experiments). The heater tank has water level float sensors connected to three lamps to show you how much water is in the tank. A 'press to fill tank' button on the front panel works a solenoid valve that allows the user to add more water to the tank from the cold supply when needed. A pump in the water circuit recirculates hot water from the tank, through a hand-adjusted WATER SUPPLY valve, through the heat exchanger and back to the tank.



Figure 4 WATER SUPPLY Valve

The tank has a thermal safety switch that cuts off the power to the heater to keep the water temperature within suitable limits if the controller is set incorrectly or in the unlikely case of a control failure. The tank 'full' float sensor disconnects the tank filling solenoid, so you cannot overfill the tank.

NOTE



To protect the equipment, the pump and heater will not work unless the heater tank is at least half full of water.

Flexible pipes with quick-release self-sealing connectors connect the water supply to the heat exchangers. Thermocouples on the connectors measure the water temperature at the inlet and outlet of the heat exchangers. An extra water tube with thermocouple (SERIES ADAPTOR) allows you to measure water temperature at the mid point on the standard 32 tube heat exchanger.

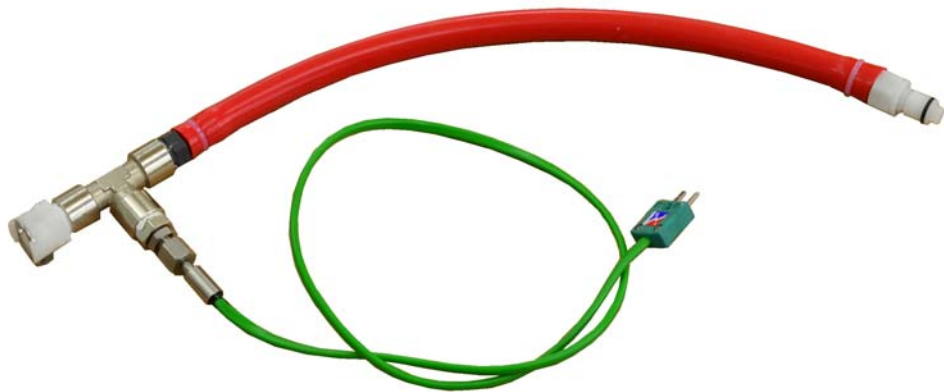


Figure 5 SERIES ADAPTOR

The water and air temperature thermocouples connect to the two display panels with multiline displays showing the water and air temperatures. The displays also show the water flow rate and air pressure change at the orifice plate for air flow calculations.

The water and air display panels each have a socket for connection to TecQuipment's optional VDAS. VDAS allows data acquisition from this equipment, with the use of a suitable computer (not supplied).

Thermocouple Connections and The Displays

Table 1 shows the symbols used on the thermocouple connections and the displays, and what they mean.

Symbol	What it means
T_{W1} , T_{W2} , T_{W3} , T_{W4}	Water circuit temperatures
T_{A1} , T_{A2} , T_{A3} , T_{A4}	Air circuit temperatures
$Flow_W$	Water circuit flow
ΔP_A	Air pressure difference at the orifice

Table 1 Symbols Used and What They Mean



The experiments may not use all eight thermocouple sockets. Some will be spare and for possible future use.

Water Filter



Figure 6 Water Filter

You must use clean water with this equipment. Dirty water or mineral-rich water will gradually damage the inside of the heat exchangers and parts of the main frame - especially the flow sensor. To help reduce problems, the main frame has a water filter to filter out small particles of dirt or debris that may be in your water supply.

Refer to **Maintenance, Spare Parts and Customer Care** for more details on the filter.

Extra Sockets

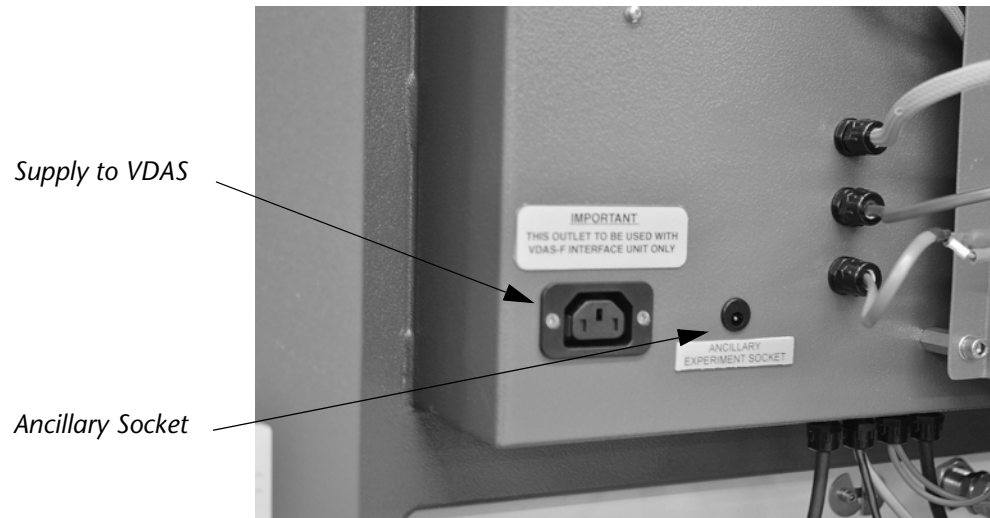


Figure 7 Extra Sockets

Supply to VDAS Interface

Determined by your local supply, the equipment may have a female IEC socket near to the space where you fit the VDAS-F interface.

CAUTION



This socket is only for connection to the VDAS-F Interface. Do not use it for any other reason.

Ancillary Experiment Socket

The TD1007 has a low voltage Ancillary Experiment Socket to the rear of the display panels. This is for possible future ancillaries.

CAUTION



This socket is only for connection to TecQuipment products as supplied with the TD1007. Do not use it for any other purpose.

Standard 32 Tube Heat Exchanger

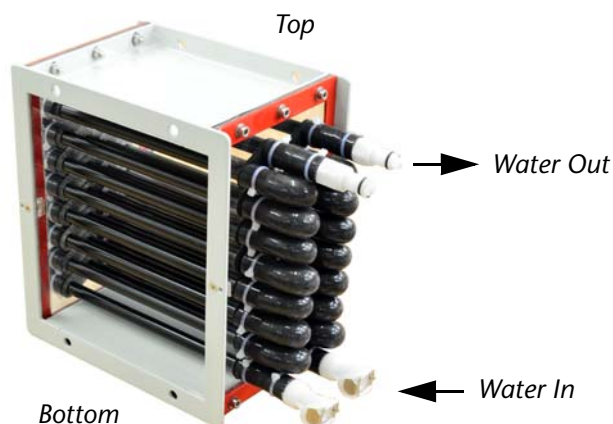


Figure 8 The Standard Heat Exchanger

This heat exchanger has two 'tube bundles' of 16 tubes. The heated water path loops through the tubes from bottom to top across the working section and air passes through the tube bundles at right angles. This heat exchanger has the additional benefit of the two sets of tubes, which you can connect in series or parallel. In series mode, it allows the use of a third thermocouple at mid point in the water flow. The upstream bundle is that nearest the fan (see Figure 9).



NOTE

Do not confuse series and parallel connection with series and parallel flow. They are different terms.

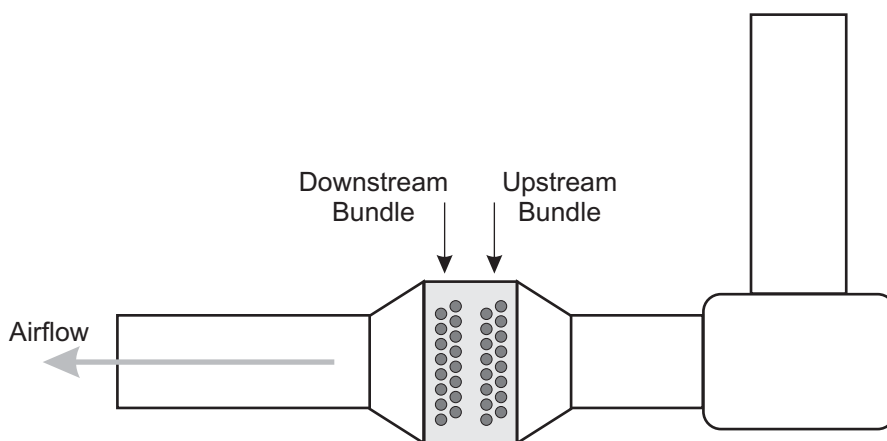


Figure 9 Upstream and Downstream Tube Bundles

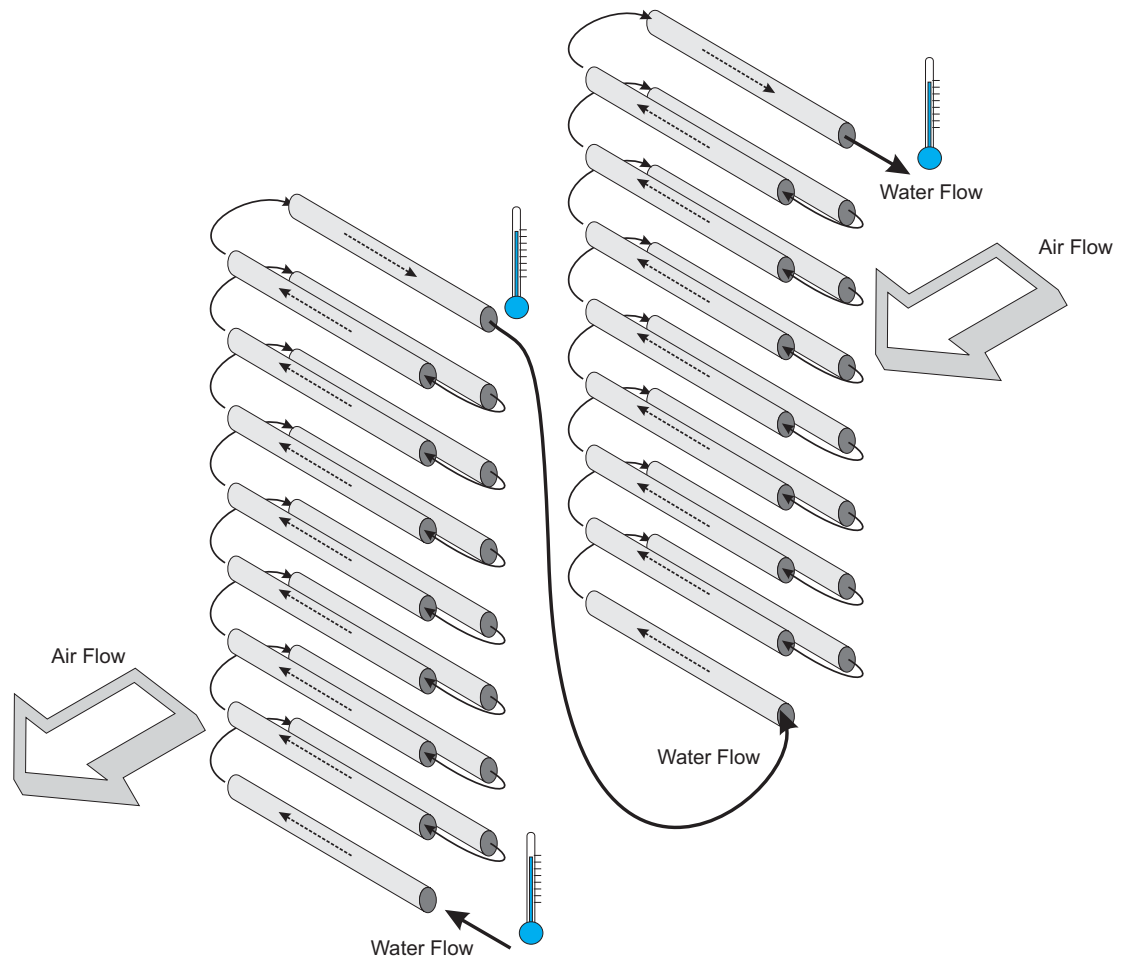


Figure 10 How the 32 Tube Heat Exchanger Works - Series Connection

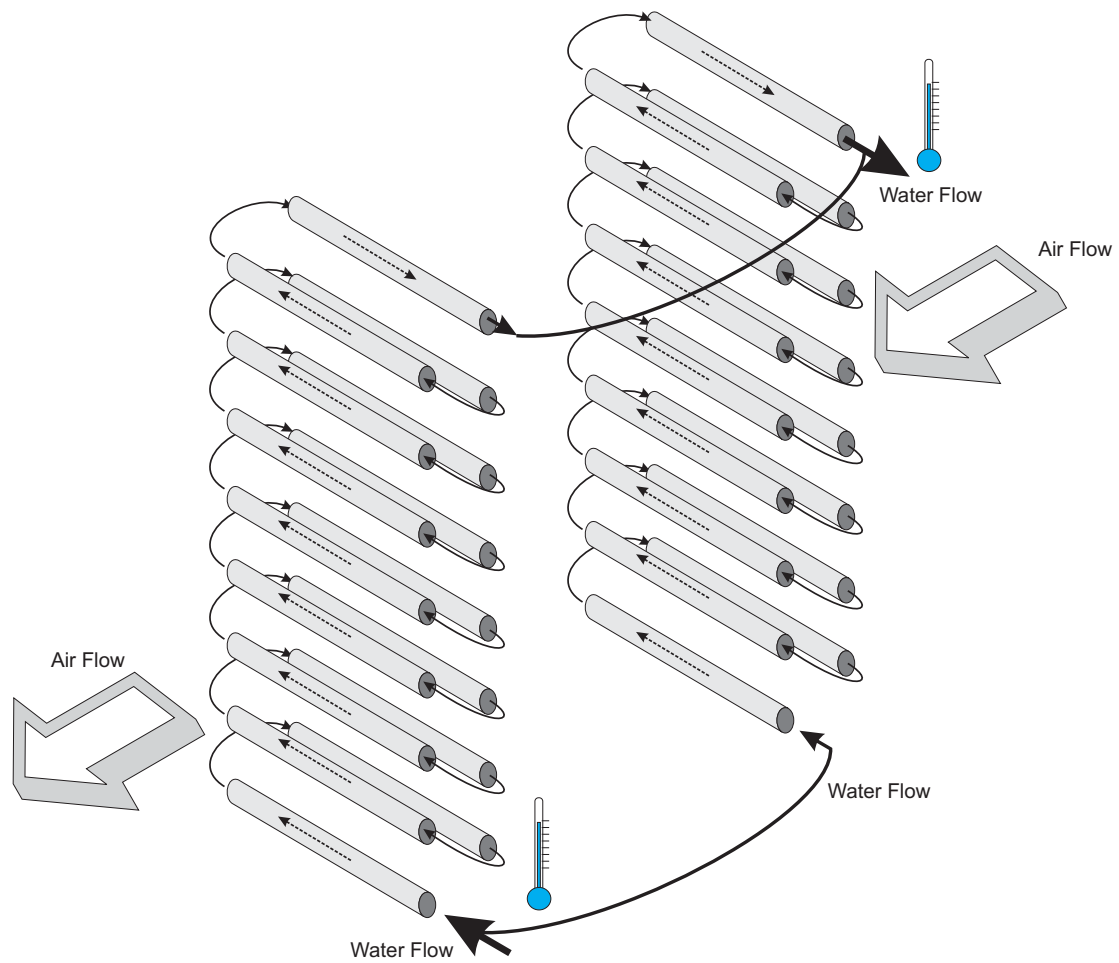


Figure 11 How the 32 Tube Heat Exchanger Works - Parallel Connection

Optional 16 Tube Heat Exchanger (TD1007a)

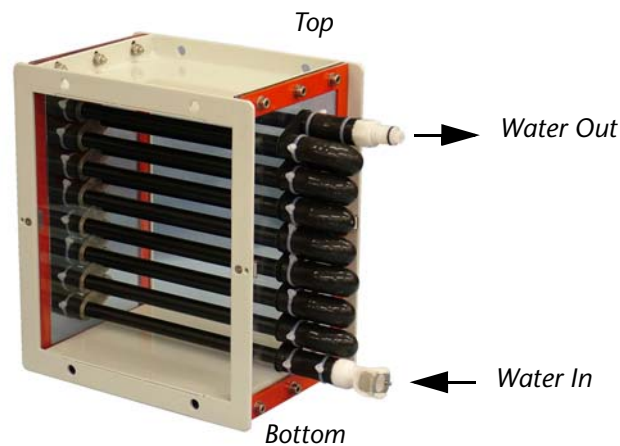


Figure 12 The 16 Tube Heat Exchanger (TD1007a)

This heat exchanger has a single 'tube bundle' of 16 tubes. The heated water path loops through the tubes forward and backward across the working section from bottom to top so the inlet and outlet are on the same side of the working section. Air passes through the tube bundle at right angles to the water flow, creating a 'cross-flow' heat exchanger. This heat exchanger has half the heat transfer area of the standard 32 tube unit.

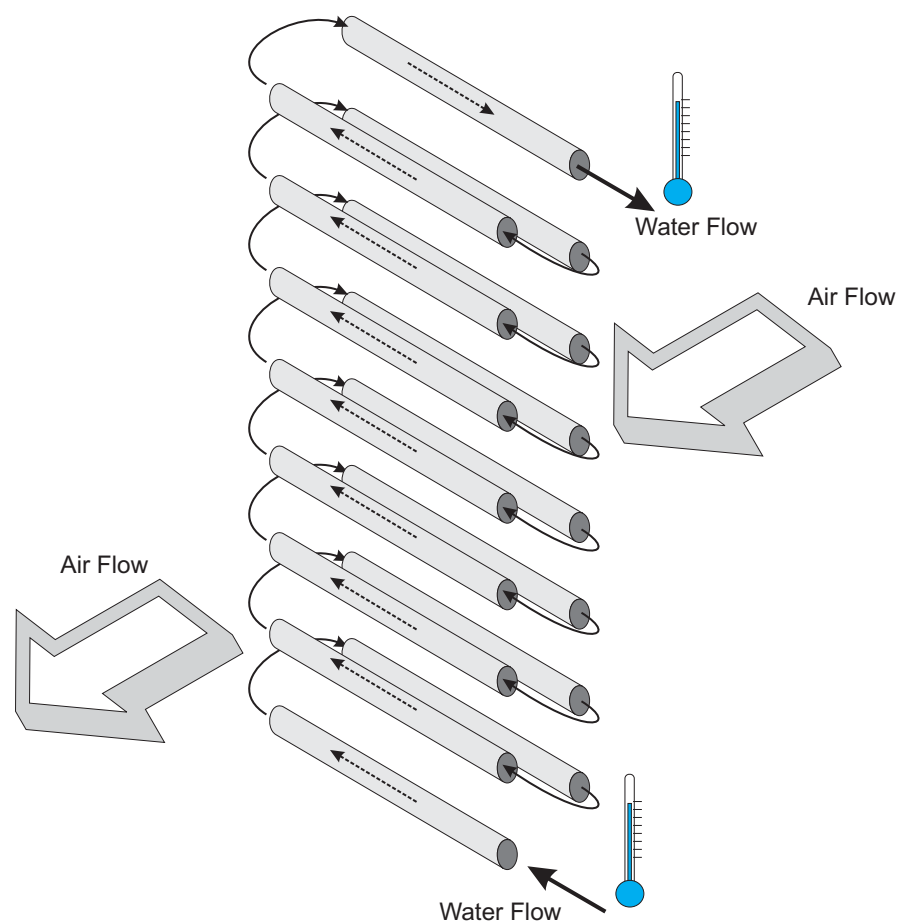


Figure 13 16 Tube Heat Exchanger Works

Optional 16 Tube Finned Heat Exchanger (TD1007b)

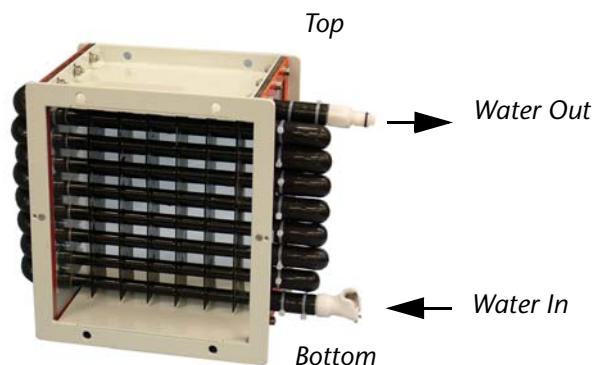


Figure 14 The 16 Tube Finned Heat Exchanger

This heat exchanger has a single 'tube bundle' of 16 tubes, identical to the 16 tube heat exchanger, but with added vertical 'fins'. The fins increase the heat transfer area of this single tube bundle to equal that of the 32 tube heat exchanger, for a direct comparison of performance.

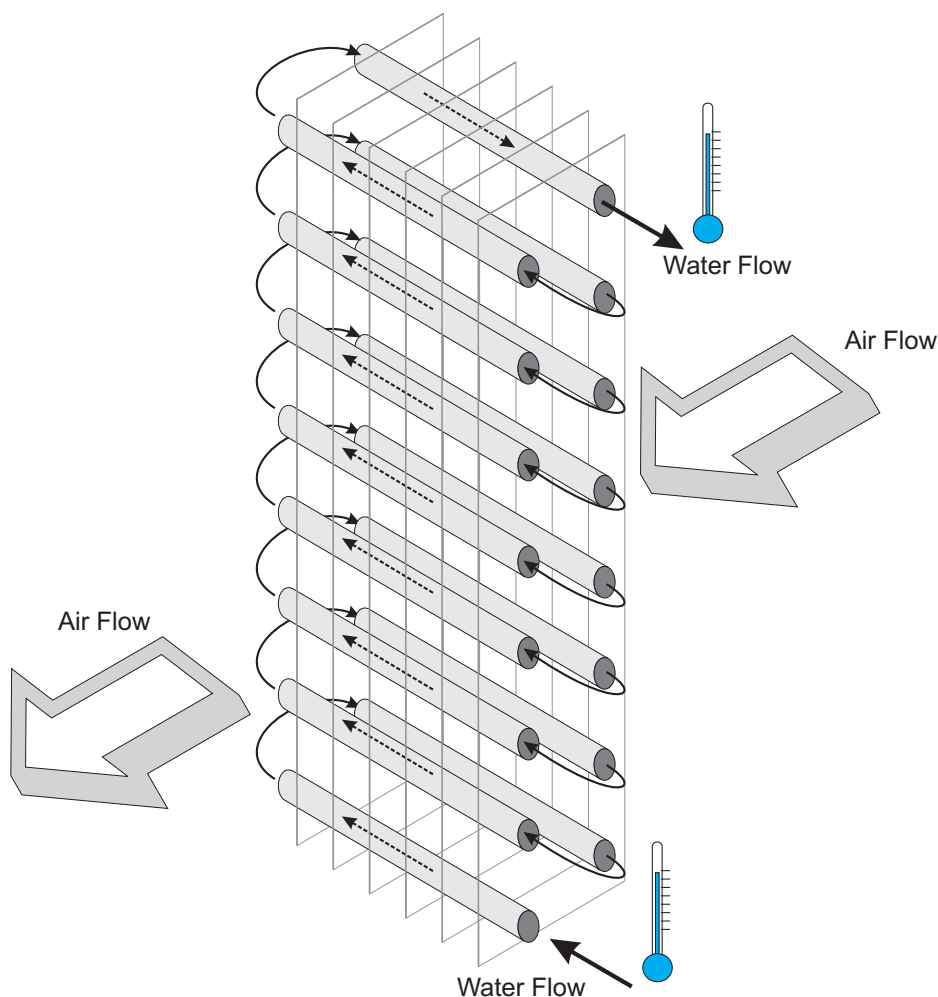


Figure 15 How the Sixteen Tube Finned Heat Exchanger Works

Versatile Data Acquisition System (VDAS)



Figure 16 The VDAS Hardware and Software

TecQuipment's VDAS is an optional extra. It is a two-part product (Hardware and Software) that will:

- automatically log data from your experiments
- automatically calculate data for you
- save you time
- reduce errors
- create charts and tables of your data
- export your data for processing in other software

NOTE



You need a suitable computer (not supplied) to use TecQuipment's VDAS.

Technical Details

Main Frame

Item	Details
Nett Dimensions	1250 mm long x 810 mm front to back x 620 mm high and 80 kg (with standard heat exchanger fitted)
Electrical Supply	220 VAC to 240 VAC Phase to Neutral or Phase to Phase* 50 Hz to 60 Hz at 13 A Nominal current 9 A.
Operating Environment	Altitude up to 2000 m Temperature range 5°C to 40°C* Maximum relative humidity 80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C Overvoltage category 2 (as specified in EN61010-1). Pollution degree 2 (as specified in EN61010-1). * Although the equipment will work in these conditions, its experiment results will not be useful. TecQuipment recommend that you use the equipment at an ambient temperature of around 20°C.
Electrical Circuit protection	Main switch - 13 A 2-pole circuit-breaker Miniature Circuit Breaker 4 A 2 pole type B Control circuits, water pump, fan and mains outlet to optional VDAS Interface. Note: Some units do not have the outlet for the optional VDAS interface. You must connect the interface to its own supply - refer to the VDAS User Guide for details.
Cold water supply needed	Clean cold water supply at minimum 1 bar and maximum 3 bar. Minimum Temperature 5°C. Note: The water supply does not need to be constant. It is only for refilling if water has been drained or used during earlier experiments.
External Connections	VDAS sockets - Extra Low Voltage (less than 25 VDC) communications. K - type Thermocouple sockets - Extra Low Voltage (less than 25 VDC). Ancillary Experiment Socket - 12 VDC Mains supply output socket for VDAS (where fitted) - 220 VAC to 240 VAC
Orifice	Nominal diameter 100 mm. Actual value stamped on orifice. $C_d = 0.6$ Maximum pressure drop 250 Pa Note: the display may show a higher value than this, but the reading becomes inaccurate above 250 Pa. The optional VDAS software may display an error.

NOTE



**The main circuits and displays of the equipment will operate at lower voltages, but the pump, fan and heater performance will drop.*

If you intend to use the equipment at lower voltages, your maximum experiment air and water flows may be slightly lower than expected.

Heat Exchangers

Heat Exchanger	Details
Standard 32 Tube Heat Exchanger	Nett Dimensions: 130 mm wide x 280 mm front to back x 210 mm high and 3.2 kg 2 x Tube bundle of 16 copper tubes. Mean Heat Transfer Area = $2 \times 0.0779 = 0.1558 \text{ m}^2$
Optional 16 Tube Heat Exchanger (TD1007a)	Nett Dimensions: 130 mm wide x 280 mm front to back x 210 mm high and 3 kg 1 x Tube bundle of 16 copper tubes. Mean Heat Transfer Area = 0.0779 m^2
Optional 16 Tube Finned Heat Exchanger (TD1007b)	Nett Dimensions: 130 mm wide x 280 mm front to back x 210 mm high and 3 kg 1 x Tube bundle of 16 copper tubes and 7 x vertical fins. Mean Heat Transfer Area = 0.1558 m^2

Noise Levels

The noise levels recorded at this apparatus are less than 70 dB (A).

Assembly and Installation

The terms **left**, **right**, **front** and **rear** of the apparatus refer to the operators' position, facing the unit.



- A wax coating may have been applied to parts of this apparatus to prevent corrosion during transport. Remove the wax coating by using paraffin or white spirit, applied with either a soft brush or a cloth.
- Follow any regulations that affect the installation, operation and maintenance of this apparatus in the country where it is to be used.

Location and Assembly

Use the Water to Air Heat Exchanger in a clean, well-lit laboratory or classroom type area. Put the Main Frame on top of a solid, level workbench, near to a water supply.

The Main Frame uses a bench area of 1300 mm x 900 mm. If you are to use the optional VDAS, allow room nearby for a computer.

Main Frame Assembly

The Main Frame is supplied already assembled, except for the air inlet thermocouple and the orifice air pressure pipe (see Figure 17). Fit the thermocouple to its position at the air inlet and use a spanner (not supplied) to tighten its fixing. Connect the orifice air pressure pipe to the orifice pressure tapping on the front panel.

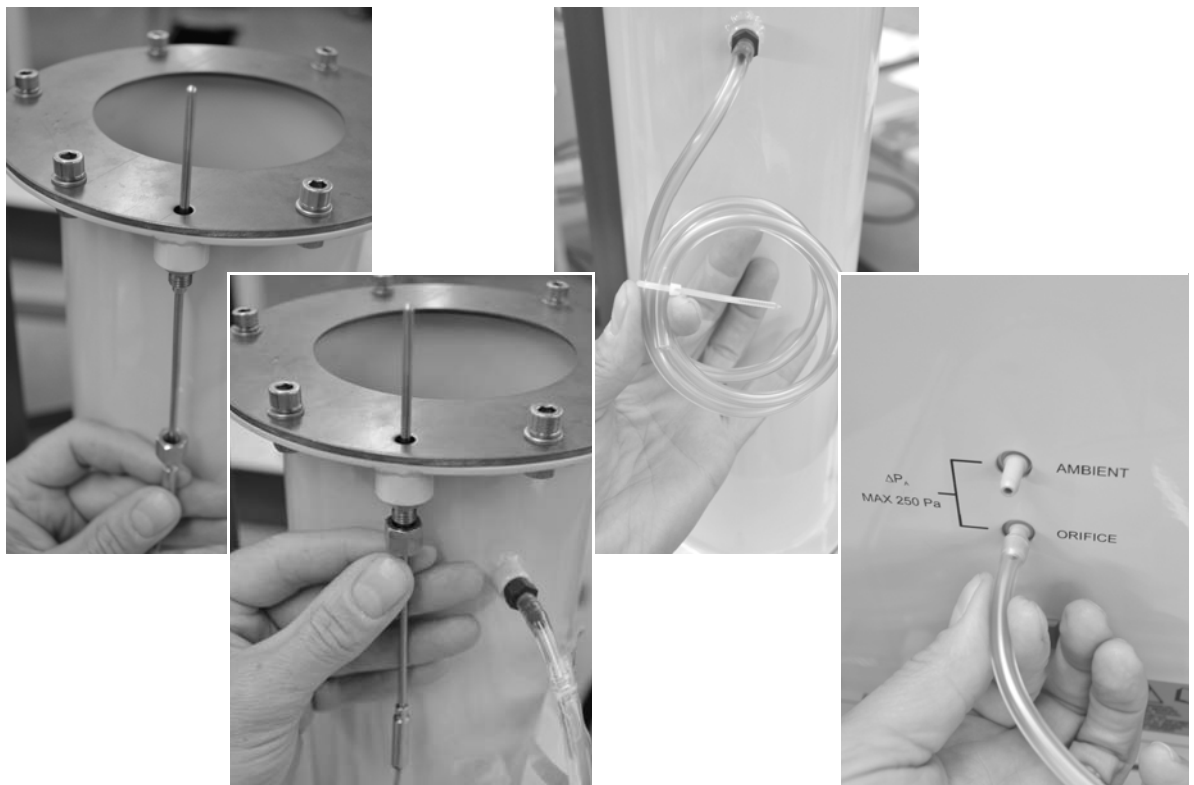


Figure 17 Fitting the Thermocouple and Orifice Air Pipe

Heat Exchanger Assembly



Figure 18 Heat Exchanger Fitted Backwards for Transport

NOTE



To help prevent damage during transport, the equipment may be supplied with the standard heat exchanger fitted backwards. The connection pipes will face the back of the equipment. Remove the heat exchanger and refit it correctly as shown later in this guide.

Refer to '**Experiments**' for details on how to fit the Heat Exchangers.

Lifting and Carrying

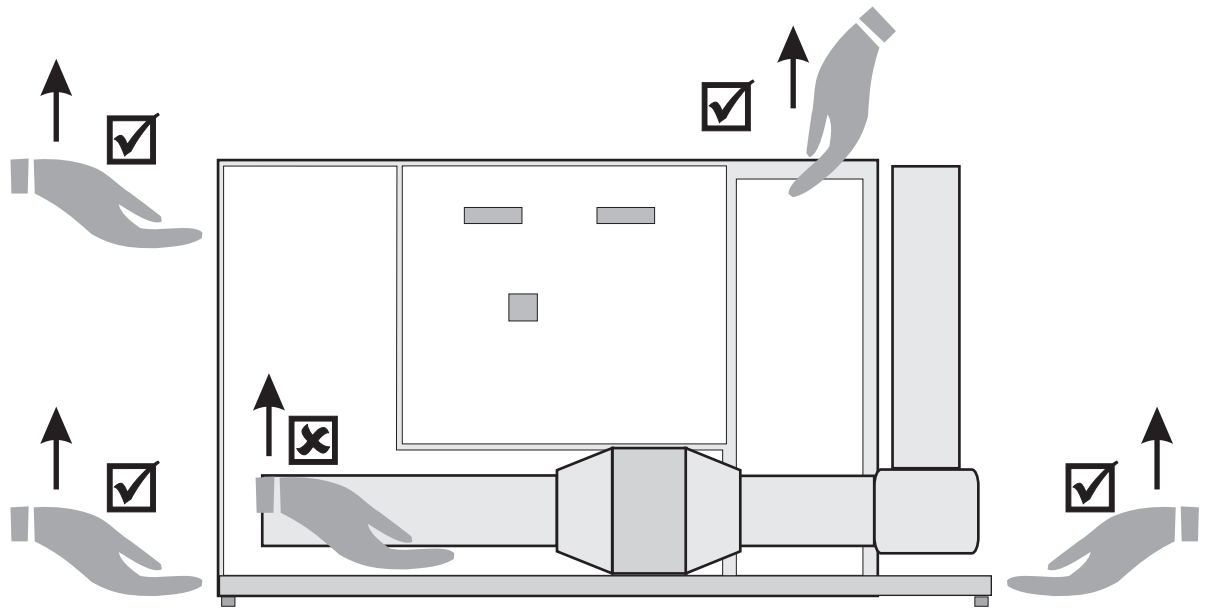


Figure 19 Lifting

Lift the equipment using the bottom or sides of the steel frame.

CAUTION



*Do not use any part of the duct to lift the equipment
Always drain the equipment before moving.*

WARNING



The TD1007 is heavy (> 80 kg). Use assistance and suitable lifting equipment to lift, carry or move it around.

Installation

1. Use assistance to put the equipment on your workbench. Make sure that the air duct exit (left of the equipment) has free space to allow it to vent easily. It must be at least one metre away from opposing walls or other furniture.
2. Connect your cold water supply to the inlet pipe at the back of the equipment (see Figure 20).



CAUTION

You must use clean water, or your experiment results will be wrong and you may break the equipment. For best results, make sure that your water supply has a filter and has a low mineral content.

3. If you are to use the optional VDAS, hook the VDAS-F Hardware into the frame and connect as shown in '**Connection to VDAS**'.
4. Connect the electrical supply cable from the back of the equipment to your electrical supply (see **Electrical Connection**).



Figure 20 Connect the Cold Water Supply

5. Switch on the electrical supply and the cold water supply. Fix any leaks immediately.
6. On the front panel, **switch off** the pump and the heater. Press and hold the button that fills the heater tank, until all three lamps are lit, showing that the tank is full.



Figure 21 Press and Hold the 'Press to fill tank' Button until all three lamps are on

7. Fit your heat exchanger as shown in '**Experiments**'.
8. The equipment is now ready for your experiments.

Electrical Connection

Use the cable supplied to connect the equipment to the electrical supply.

WARNING



Connect the equipment to the electrical supply through a plug and socket. The apparatus must be connected to earth.

Your plug and socket form the mains isolator. Make sure you can easily reach them.

These are the colours of each individual conductor:

Phase to Neutral Supply:

GREEN AND YELLOW:

EARTH E OR

BROWN:

LIVE

BLUE:

NEUTRAL

Phase to Phase Supply:

GREEN AND YELLOW:

EARTH E OR

BROWN:

PHASE 1 OR L1 or Hot 1

BLACK:

PHASE 2 OR L2 or Hot 2

GREY:

Do not use

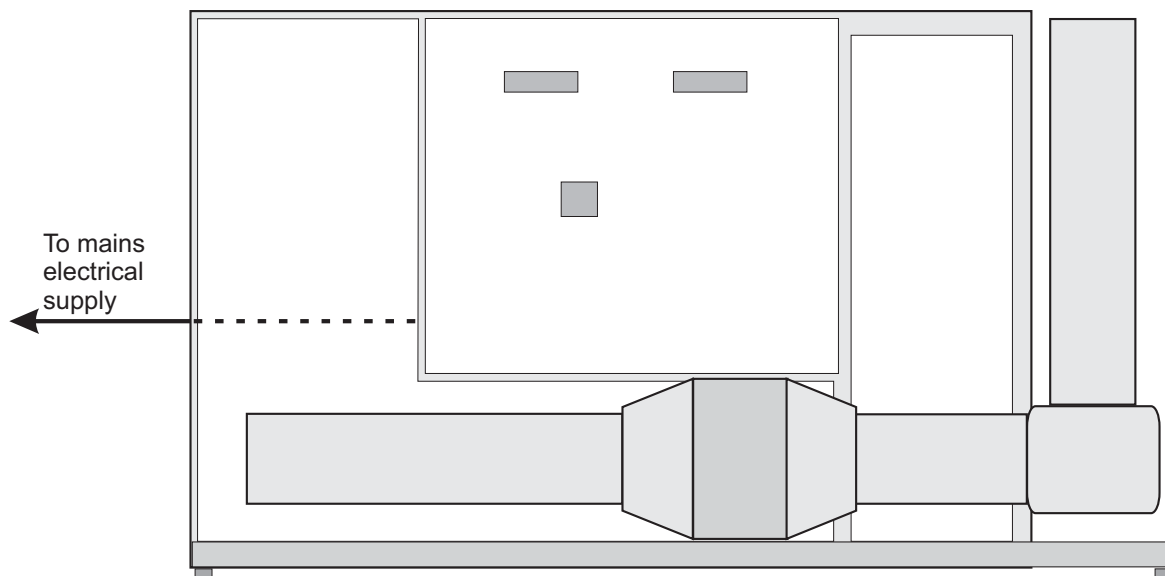


Figure 22 Connect to Mains Supply

Connection to VDAS

If you are to use the optional VDAS, read the VDAS User Guide and connect the VDAS-F Interface and computer as shown in Figure 23.

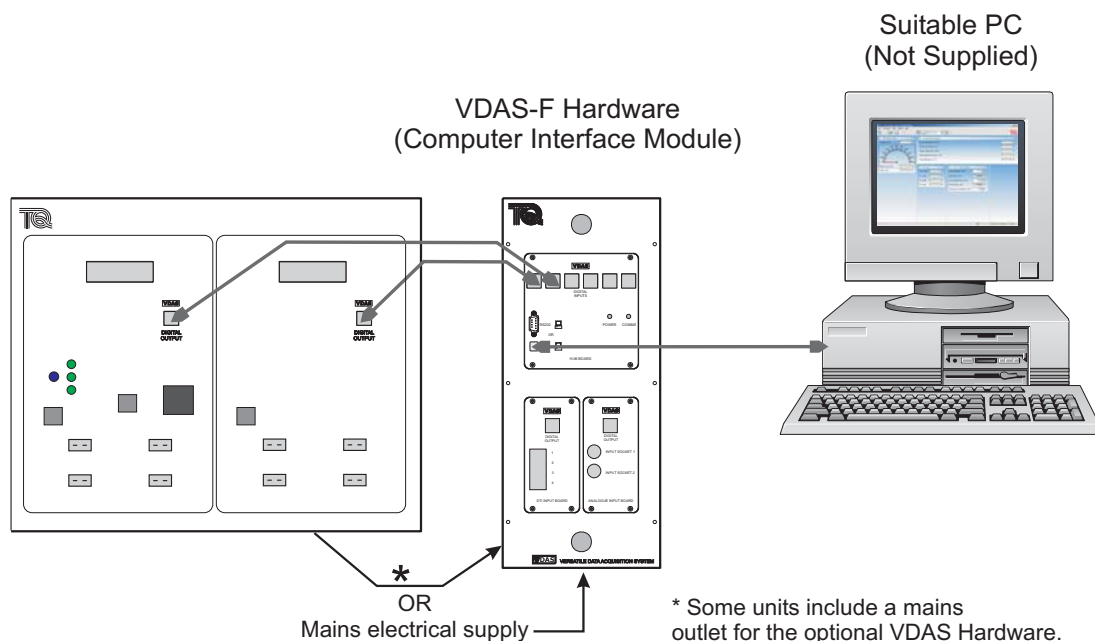


Figure 23 Connection to VDAS

Notation, Useful Equations and Theory

This section only gives the basic information needed to do the experiments. For full theory, refer to the textbooks listed in **Maintenance, Spare Parts and Customer Care** on page 71.

Notation

Symbol	Definition	Units
A	Heat Transfer Area	m^2
A_O	Orifice Area	m^2
C	Heat capacity	J.K^{-1}
C_d	Coefficient of discharge (orifice)	-
c_p and c_{pA} and c_{pW}	Specific Heat Capacity, of air and water at Constant Pressure (atmospheric pressure for air)	$\text{J.kg}^{-1}\text{K}^{-1}$
$LMTD$	Logarithmic Mean Temperature Difference	K or $^{\circ}\text{C}$ where shown
ρ and ρ_A and ρ_W	Density, of air and water	kg.m^{-3}
η_o	Overall Efficiency	%
C_{EB}	Energy Balance Coefficient	-
$\bar{\eta}_A$ and $\bar{\eta}_W$	Mean Temperature Efficiencies	%
Δp	Orifice pressure drop	Pa
Q	Heat energy transferred for a unit mass	J.kg^{-1}
$\dot{Q}$	Heat energy transferred for a unit time (heat transfer rate - or power)	W
$\dot{Q}_A$ and $\dot{Q}_W$	Heat energy (power) absorbed by the air and emitted by the water in a unit time	W
R	Specific gas constant for dry air	287 J/kg.K
T, T_W, T_A	Temperature, of water and air	K or $^{\circ}\text{C}$ where shown
ΔT	Change in Temperature	K or $^{\circ}\text{C}$ where shown
$\bar{T}$	Mean Temperature	K or $^{\circ}\text{C}$ where shown
U	Heat Transfer Coefficient	$\text{W.m}^{-2}\text{K}^{-1}$
$\dot{m}_W$ and $\dot{m}_A$	Mass Flow Rate (hot water circuit and air circuit)	kg.s^{-1}

Water Flow Conversion

The equipment measures volumetric water flow in litres per minute ($\text{L}\cdot\text{min}^{-1}$), but your calculations need mass flow in kilograms per second ($\text{kg}\cdot\text{s}^{-1}$).

$$\text{Mass flow (kg}\cdot\text{s}^{-1}) \dot{m}_W = \text{Volume flow (L}\cdot\text{min}^{-1})/60000 \times \text{Water density (kg}\cdot\text{m}^{-3})$$

Airflow

The equipment measures the pressure drop across the inlet orifice. If you use this pressure drop with the orifice discharge coefficient (C_d), its area and local air conditions, you can calculate the air flow through the duct.

$$\dot{m}_A = C_d \times A_{O\sqrt{\Delta p \times 2 \times \rho_A}} \quad (1)$$

Average Temperatures in Heat Exchangers

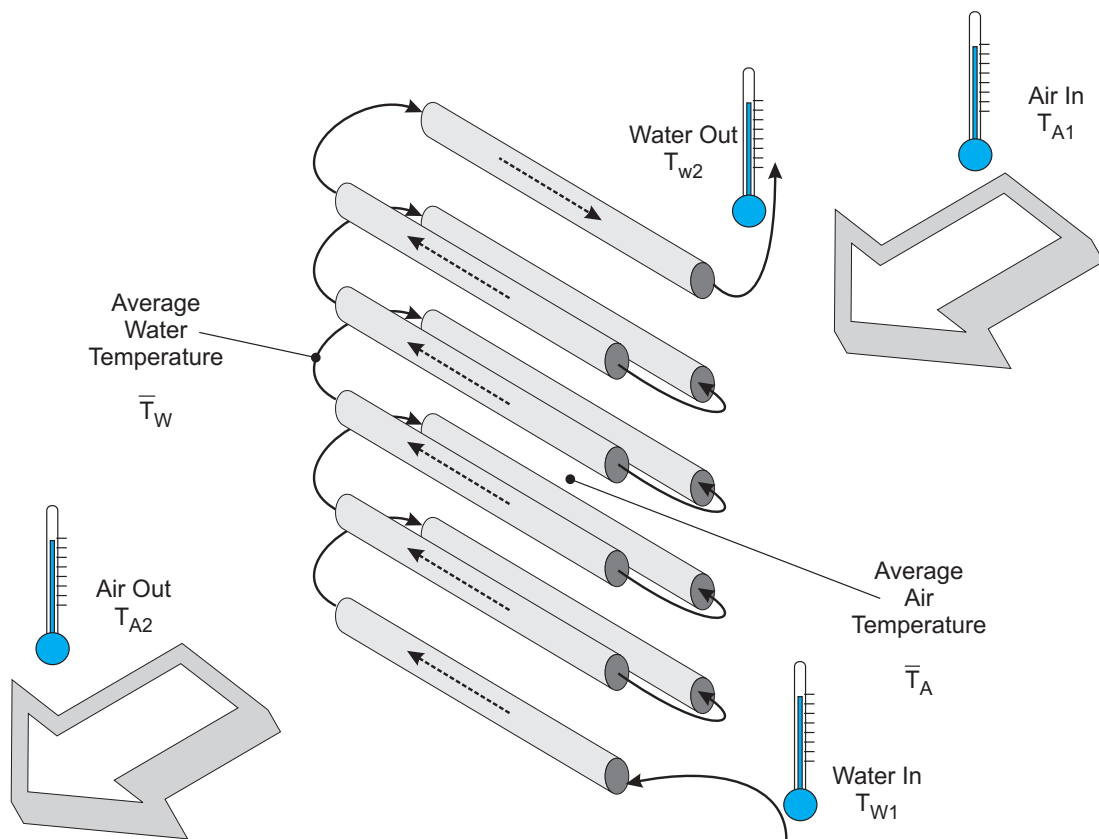


Figure 24 Average Temperatures Around the Heat Exchangers

For most heat transfer equations, and calculations of specific heat capacity and density of water, you must find the average temperature for the water and air circuits around your heat exchanger. This is the calculated value of the temperature at a mid-point between the inlet and outlet of the circuit (see Figure 24).

To find the average temperature of the **water** circuit:

$$\bar{T}_W = \frac{T_{W1} + T_{W2}}{2} \quad (2)$$

To find the average temperature of the **air** circuit:

$$\bar{T}_A = \frac{T_{A1} + T_{A2}}{2} \quad (3)$$

Useful Equations

Heat Capacity (C)

This is a measure of the heat needed to increase the temperature of a given mass of material by 1 degree (Kelvin or Celsius).

It is a product of the mass of a material (m) and its specific heat capacity (c).

$$C = m \times c \quad (4)$$

Specific Heat Capacity at Constant Pressure (c_p)

Specific Heat Capacity of Water at Constant Pressure

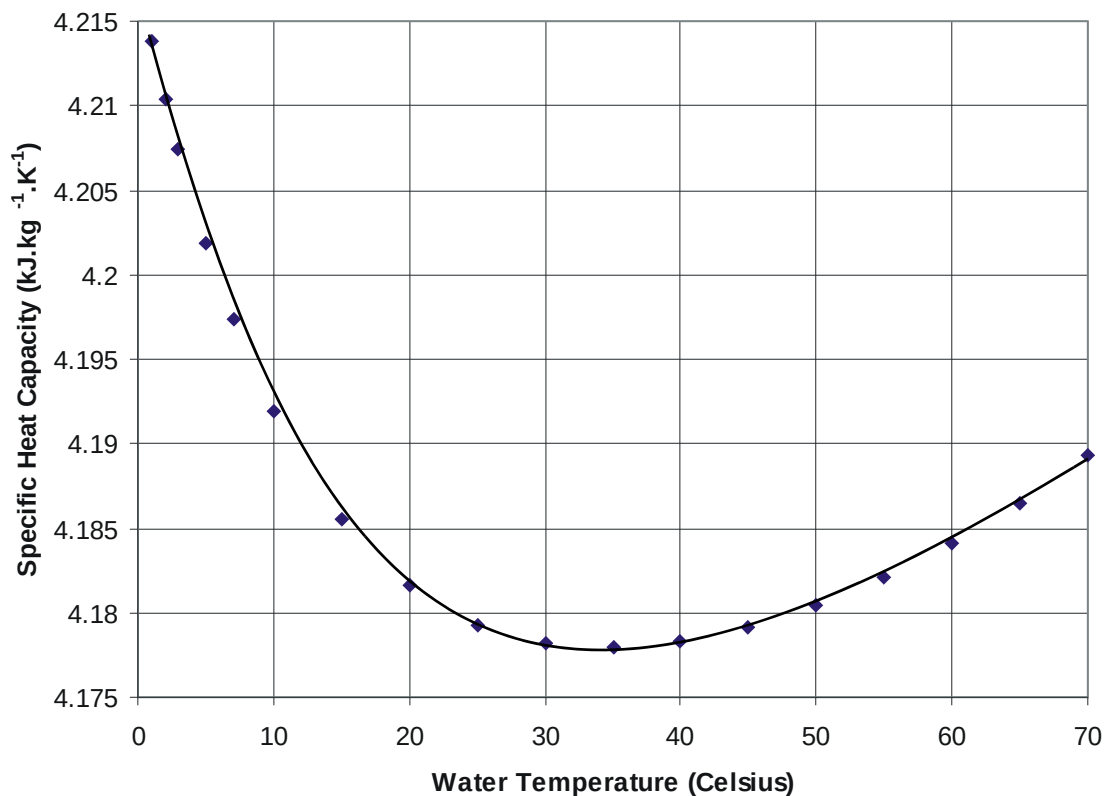


Figure 25 Specific Heat Capacity of Water at Constant Pressure

Specific heat capacity is the amount of heat energy needed to raise the temperature of exactly 1 kg of material by 1 degree (Celsius). It is a ratio of the change in heat energy and the change in temperature.

$$c = \frac{\Delta Q}{\Delta T} \quad (5)$$

Pressure and temperature affects specific heat capacity, so equation 6 assumes constant pressure over a known range of temperature. It is the 'isobaric' (equal pressure) specific heat capacity.

$$c_p = \frac{Q}{\Delta T} \quad (6)$$

For air, the specific heat capacity remains reasonably constant at around $1005 \text{ J.kg}^{-1}.\text{K}^{-1}$ at normal atmospheric pressure and for the temperature ranges used in the heat exchangers.

For water, you may use Figure 25 to find the specific heat capacity. Alternatively, Equation 7 (based on data from tests) will give you an accurate answer (where your temperature T is in Celsius):

$$\frac{c_{pw}(\text{at } T^\circ\text{C})}{c_{pw}(\text{at } 15^\circ\text{C})} = 0.996185 + 0.0002874 \left(\frac{T + 100}{100} \right)^{5.26} + 0.011160 \times 10^{-0.036T} \quad (7)$$

From tests, the specific heat capacity of water at 15°C is $4185.5 \text{ J.kg}^{-1}.\text{K}^{-1}$

NOTE



You must use the mean (or average) temperature of your flow circuit in this equation.

Density (ρ)

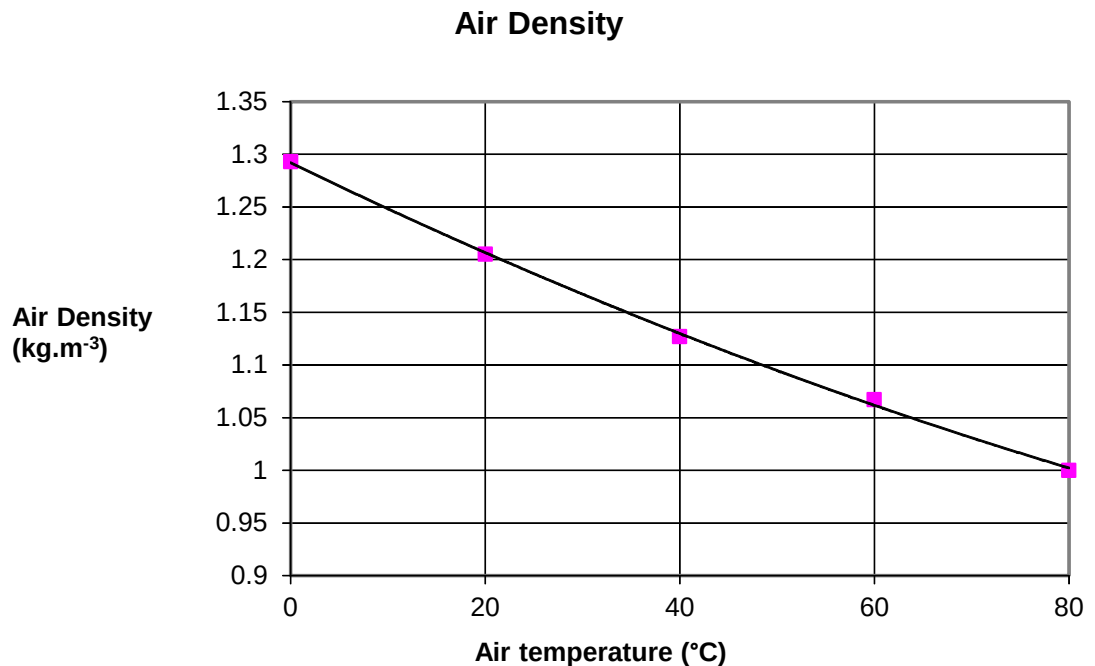


Figure 26 Air Density

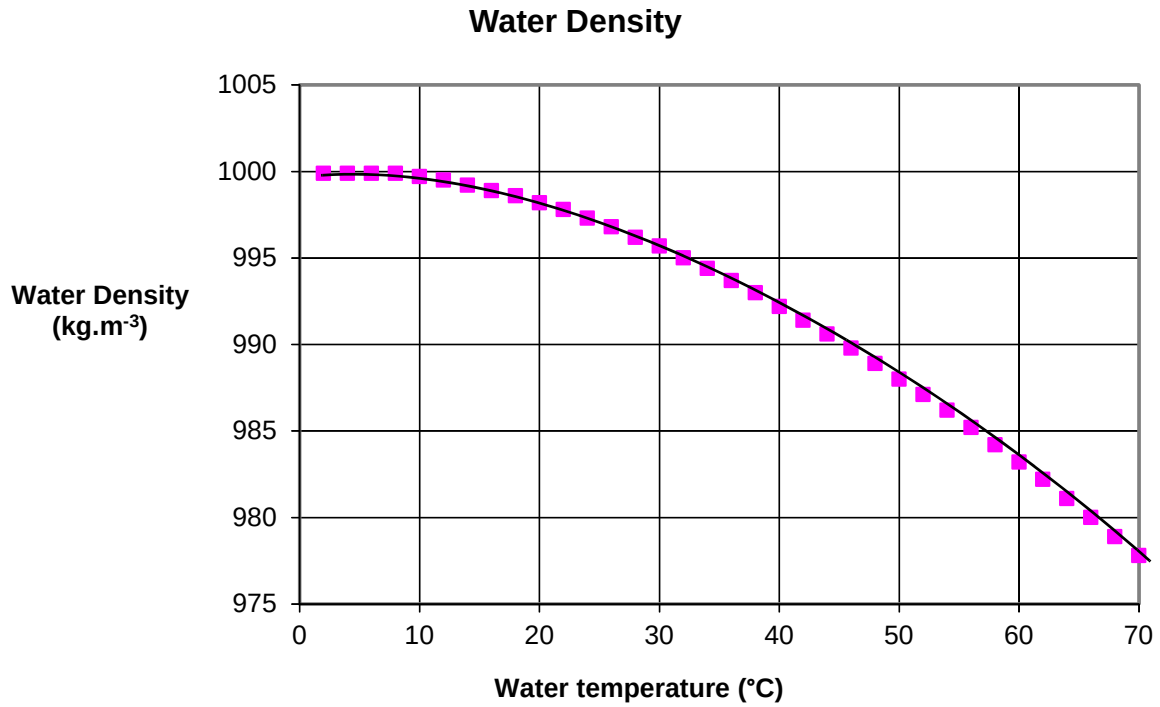


Figure 27 Water Density

Air has a maximum density at absolute zero, decreasing as temperature increases. You can use Figure 26 to determine its value over the range of temperatures used with the heat exchangers. Note that local air pressure affects air density, so the chart is relevant for normal atmospheric pressures. If you need more accuracy, Equation 8 allows you calculate the air density at a given pressure and temperature.

$$\rho_A = \frac{p}{RT} \quad (8)$$

Water has a maximum density at approximately 4 degrees celsius, decreasing as temperature increases or decreases from this value. This affects all your calculations. You can use Figure 27 to find water density over the range of temperatures used with the heat exchangers, for a unit mass and a constant pressure. If you need more accuracy, Equation 9 allows you calculate the water density (where T is your average water temperature in degrees centigrade).

$$\rho_w = \frac{\left(999.839 + 16.952T - 7.990 \times 10^{-3}T^2 - 46.241 \times 10^{-6}T^3 + 105.846 \times 10^{-9}T^4 - 281.030 \times 10^{-12}T^5 \right)}{\left(1 + 16.887 \times 10^{-3}T \right)} \quad (9)$$

Heat Energy (Power) Transfer, Energy Balance and Efficiencies

In heat exchangers, heat energy transfers or 'flows' from the hotter circuit to the cooler circuit. Power is the rate of heat energy or heat energy transferred or used per unit time.

The heat transfer rate $\dot{Q}$ is a function of the fluid (or air) mass flow rate, the temperature change and the specific heat capacity of the fluid or air (at mean temperature). Because the calculation is based on a mass flow rate, the heat transfer is also a rate (or power).

$$\dot{Q} = \dot{m} \times c_p \times \Delta T \quad (10)$$

The heat (power) emitted from the hot water is:

$$\dot{Q}_W = \dot{m}_W \times c_{pW} \times \Delta T_W \quad (11)$$



The temperature change of the water is negative, giving a negative heat transfer (emission).

The heat (power) absorbed by the air is:

$$\dot{Q}_A = \dot{m}_A \times c_{pA} \times \Delta T_A \quad (12)$$

In an ideal heat water to air heat exchanger, that does not lose or absorb heat from its surroundings, the cooler air absorbs all the heat from the hot fluid. So the heat transfer rate is:

$$\dot{Q} = \dot{Q}_W = \dot{Q}_A = \dot{m}_W \times c_{pW} \times \Delta T_W = \dot{m}_A \times c_{pA} \times \Delta T_A \quad (13)$$

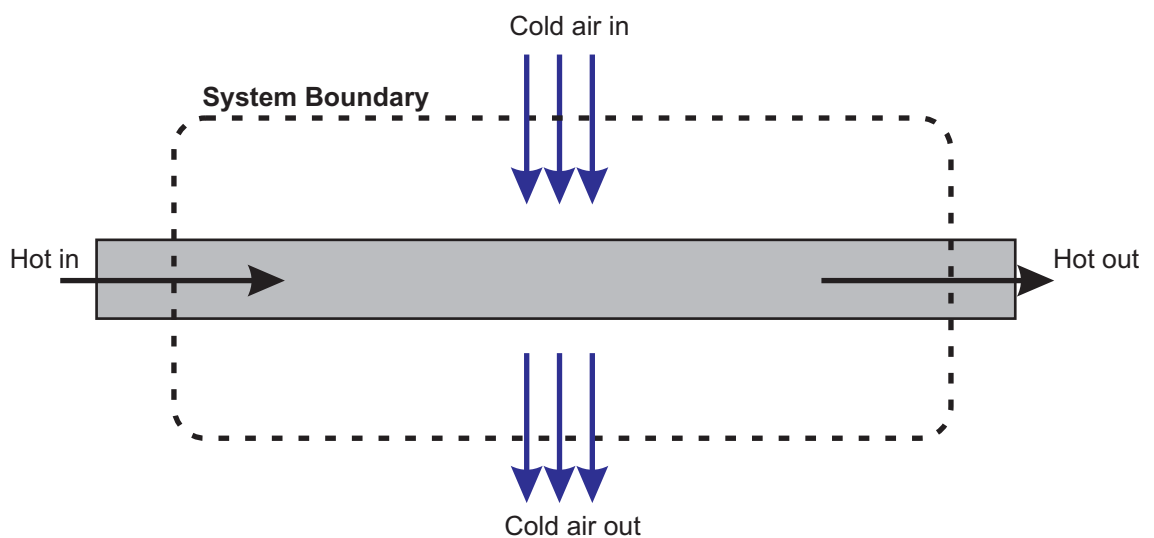


Figure 28 System Boundary

To better understand the heat transfer in a heat exchanger, you must assume it is a 'system' with the hot water and cooler air flows as its input and outputs (see Figure 28).

As mentioned earlier, there is no heat transfer across the 'system boundary' in an ideal heat exchanger. But, in reality the hot water is usually at a different temperature to the surroundings or duct work, so some heat transfers across the system boundary. For example, the heat from the warm water tubes or the heated air would transfer to the cooler air duct. Figure 29 shows the input, outputs and losses in diagram form as relative quantities.

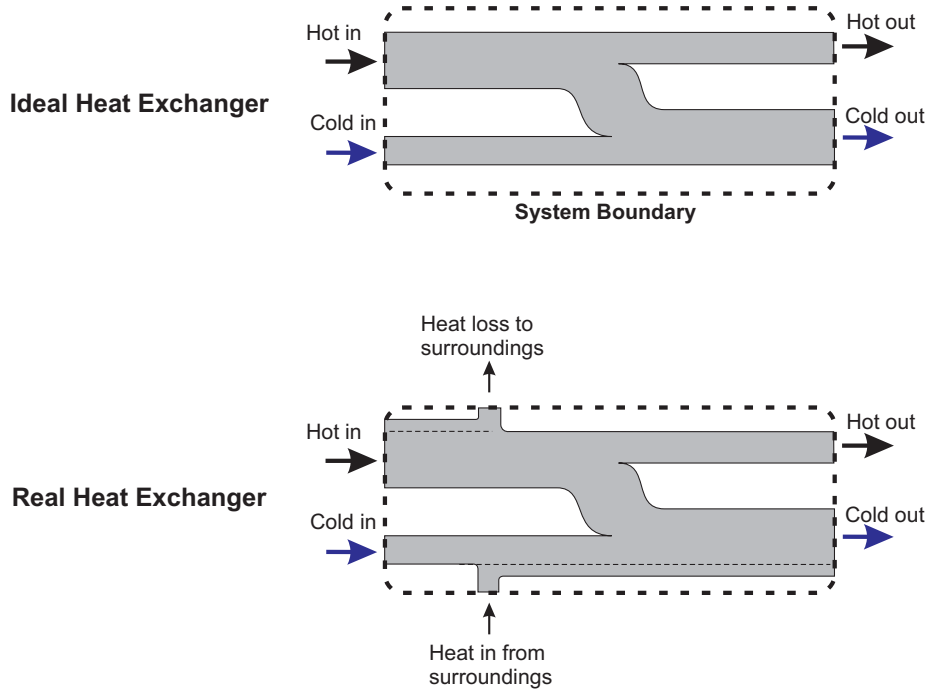


Figure 29 Ideal and Real Heat Exchangers

The energy balance coefficient (C_{EB}) shows the relationship between the energy absorbed and emitted, where:

$$C_{EB} = \frac{\dot{Q}_A}{\dot{Q}_W}$$

But, as shown, because of the possible heat flow into or out of the system, the energy balance coefficient can give answers of greater than 1 if the heat exchanger absorbs energy from its surroundings. So, it is only for guidance, because, in reality:

$$\dot{Q}_W = \dot{Q}_A \pm \text{Losses or gains from surroundings}$$

The mean temperature efficiency and heat transfer coefficient give more useful results for comparison between heat exchangers.

The **temperature efficiency** of the **hot water** circuit of the Heat Exchanger is the ratio of the temperature change in the hot water, divided by the difference between the maximum and minimum temperatures of the hot and cold circuits:

$$\eta_w = \frac{T_{W1} - T_{W2}}{T_{W1} - T_{A1}} \times 100 \quad (14)$$

The **temperature efficiency** of the **cooler air** circuit of the Heat Exchanger is the ratio of the temperature change in the cold circuit, divided by the difference between the maximum and minimum temperatures of the hot and cold circuits:

$$\eta_A = \frac{T_{A2} - T_{A1}}{T_{W1} - T_{A1}} \times 100 \quad (15)$$

The **mean temperature efficiency** of the two circuits is the average efficiency of them both:

$$\bar{\eta} = \frac{\eta_W + \eta_A}{2} \quad (16)$$

Logarithmic Mean Temperature Difference (LMTD)

This is a measure of the heat driving force that creates the heat transfer. It is a logarithmic average of the temperature difference between the hot and cold circuits at each end of the heat exchanger:

$$LMTD = \frac{(T_{W2} - T_{A2}) - (T_{W1} - T_{A1})}{\ln\left(\frac{T_{W2} - T_{A2}}{T_{W1} - T_{A1}}\right)} \quad (17)$$

Heat Transfer Coefficient (U)

This is the heat transfer coefficient for the wall and boundary layers. It is a measure of how well the heat exchanger works. A good heat exchanger will give a high coefficient, therefore this value is important to engineers.

$$U = \frac{\dot{Q}_W}{A \times LMTD} \quad (18)$$

Experiments

Safety

WARNING



Always clean up any water spills immediately. Never use any electrical switches when you have wet hands. Disconnect electrical supply before cleaning up water spills.

Keep hands and paperwork away from the air duct inlet and exhaust.

Never exceed a heater temperature of 60°C on the temperature controller.

If you do not use the equipment as described in these instructions, its protective parts may not operate correctly.

WARNING



Wear eye protection when using this equipment.

Useful Notes

CAUTION



The water connectors 'self-seal' but you will spill small amounts of water when you connect and disconnect your heat exchangers. Make sure your workbench can resist water and that you have some paper towels or clean cloth around to wipe up any spills.

Local Temperatures

Local ambient temperatures have a large affect on your results. Make sure that you do your experiments in a place that has a constant ambient temperature. TecQuipment's results are based on a standard room temperature of approximately 20°C.

Fan, Heater and Pump Performance

The fan, heater and pump may not reach the maximum values suggested in the experiment if you use lower voltages than recommended (see **Technical Details** on page 15). The equipment will still work but you may need to reduce the recommended experiment values.

At Least Two People

This equipment is simple to use, but you must record several readings while you do experiments. Unless you have TecQuipment's VDAS, TecQuipment recommend that you have at least one person to help you do experiments. One person can record the results, while the other controls the experiment.

Thermal Equilibrium for Accurate Results

Your results will be more accurate if you wait for the temperatures to stabilize before you take results. This is when the heat exchanger system reaches 'thermal equilibrium' and can take several minutes.

To Change a Heat Exchanger

1. Make sure the heat exchanger has cooled down.
2. Switch off the pump and heater switches. Fully shut the WATER SUPPLY valve.
3. Disconnect the WATER SUPPLY and WATER RETURN pipe connectors.
4. Undo the left hand toggle latches and slide the outlet duct left to give you room to change the heat exchanger.
5. Undo the right hand toggle latches and remove the heat exchanger.

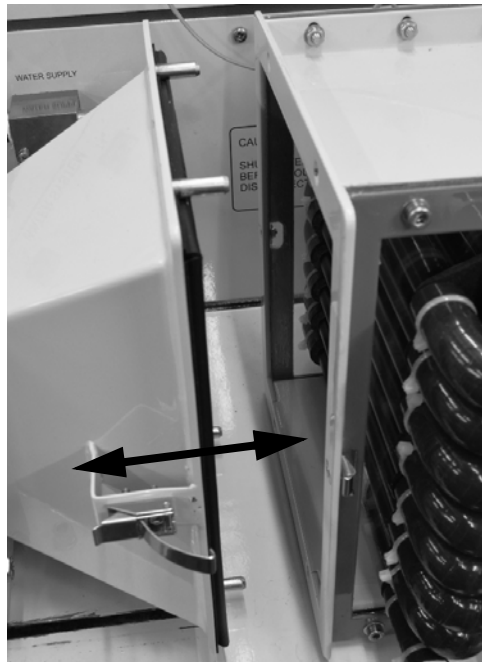


Figure 30 Slide the Duct Along

6. Fit the heat exchanger to the duct, using the toggle latches to hold it in position.
7. Fit the MIMIC diagram supplied with the heat exchanger to the blank panel of the main unit.



Figure 31 Use the Toggle Latches to Hold the Heat Exchanger

8. Connect the water pipes and thermocouples as shown in the experiment and on the MIMIC diagram.



Some experiments use all the pipe connections and some do not. Remember that the pipe connectors are self-sealing, so do not worry about the unconnected ends - they will not leak. For neatness and to reduce the stress on the heat exchanger connections you could put a gentle coil in the unconnected pipes (see Figure 32).



Figure 32 Some Pipe Connections are Not Used

9. Switch on the electrical power. Fully open the WATER SUPPLY valve.

10. Make sure the heater tank is full and switch on the pump and the heater, use the buttons on the controller to set the heater set point (SP) to the temperature shown in the experiment procedure. Figures 33 and 34 show how to use the controller.

NOTE



To protect the equipment, the pump and heater will not work until the heater tank is at least half full of water.

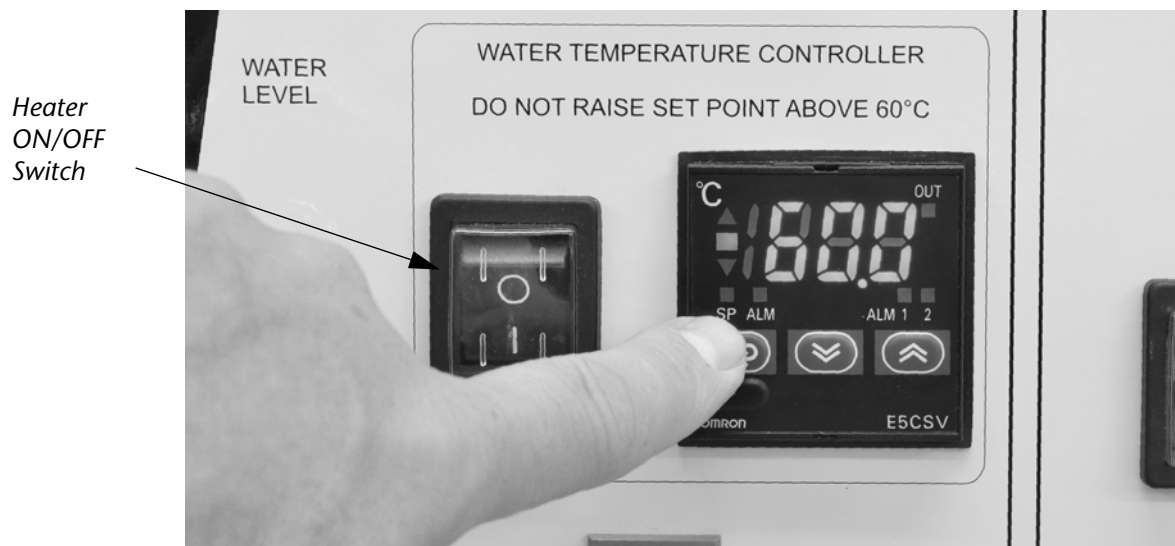


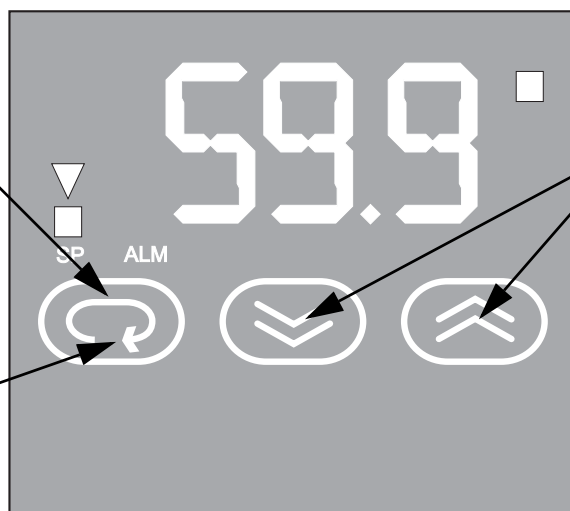
Figure 33 Setting the Controller

1. Use this button to display and set the setpoint (SP) temperature (hold the button to set).

The SP lamp will go on.

3. Then use this button again to show the actual temperature.

The SP lamp will go off.



2. Then use these buttons to change the setpoint (SP) temperature.

Figure 34 How to Use the Controller

WARNING



Never exceed a heater temperature of 60°C on the temperature controller.

11. Wait for at least a minute to allow any large trapped air bubbles to move out from the heat exchanger.
12. You are ready to do your experiment.

NOTE



The temperature controller continually updates its own PID (response) settings. If you find that it has become very slow to respond to changes in heater temperature, try resetting it by pressing the up and down arrowed buttons together for at least two seconds. This will force it to readjust itself.

Experiment 1 - The Effect of Varying Water Flow Rate



NOTE

This experiment gives best results with the standard heat exchanger.

Aim

To show how different water flow rates affect the performance of the heat exchanger for a given fixed air flow and water temperature.

Procedure

1. Connect and set up the standard 32 tube heat exchanger as shown in **To Change a Heat Exchanger** on page 35. Connect as for **parallel** flow (see Figure 35) and set a heater tank temperature of **60°C**. Water enters the bottom of the heat exchanger and exits from the top.

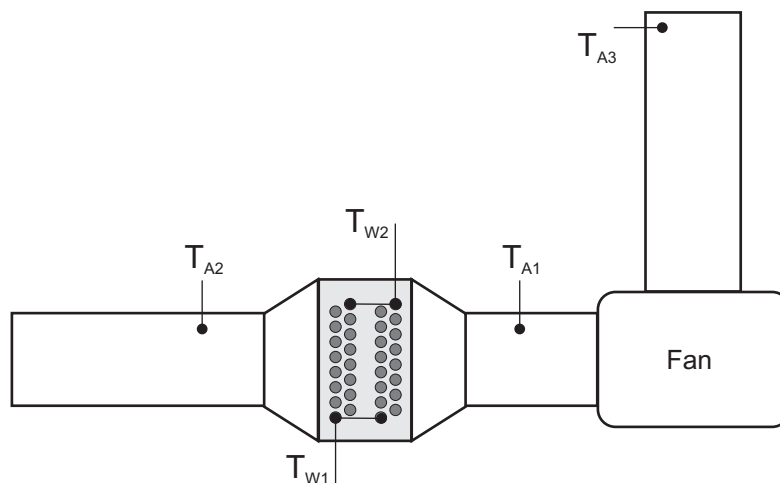


Figure 35 Heat Exchanger Connections

2. Create a blank results table, similar to Table 2. If you have VDAS, select the correct heat exchanger and experiment. The software will create a table for you automatically when you start taking readings.
3. Note the ambient air pressure.
4. Inspect the orifice and check its diameter - this is stamped on the surface of the orifice.
5. Switch on the fan and use the slide valve to set the airflow to give an orifice pressure drop of 250 Pa (+/- 5 Pa).
6. Switch on the pump and use the hand operated water supply valve to set the water flow to 2.25 L/minute (+/- 0.01 L/minute).

7. Allow at least five minutes for the heat exchanger temperatures to stabilize, then record all readings.



Your water and air flows may change slightly as you do the experiment, so regularly check and readjust them if necessary.

8. Repeat the procedure for lower water flow rates as shown in the table.
9. Switch off the heater, set air and water flow to maximum and allow the fan to cool the heat exchanger for roughly five minutes before switching off.

Results Analysis

Find the change in temperature (ΔT) for each circuit and the average temperature for each circuit.

Use the charts or the equations in the theory section to calculate the water and air densities at each temperature.

Calculate your air mass flowrate and convert your water flow to mass flow.

Find the specific heat capacity for the water at each flow rate (you can assume $1005 \text{ J.kg}^{-1}.\text{K}^{-1}$ for air).

Calculate the heat emitted, heat absorbed, and mean temperature efficiencies. Find the LMTD and use this to calculate the heat transfer coefficient (U) for each flow. From your results, comment on how the flow rate affects the heat exchanger performance.

Create three charts, each with a horizontal axis of water mass flow (kg.s^{-1}).

- On chart 1, plot the heat emitted by the heat exchanger and the power absorbed into the air (Watts). Note that one series gives negative numbers, so plot absolute values or use a second vertical axis to compare results.
- On chart 2, plot the air, water and mean temperature efficiencies (%).
- On chart 3, plot the heat transfer coefficient U . Note that because these values are based on a negative value, you may plot the absolute values (ignore the negative), or simply invert your vertical axis for neatness.

Experiment 1 Heater Temperature: Orifice $\Delta p =$										Ambient Pressure Orifice Diameter												
Hot Flow (L/min)	T_{W1}	T_{W2}	ΔT_W	Average T_W	T_{W3}	T_{A1}	T_{A2}	ΔT_A	Average T_A	T_{A3}	η_W	η_A	ρ_W	ρ_A	c_{pW}	c_{pA}	$\dot{Q}_e$	$\dot{Q}_a$	C_{EB}	$\bar{\eta}$	LMTD	U
2.25																						
1.75																						
1.25																						
0.75																						
0.25																						

Table 2 Blank Results Table

Experiment 2 - The Effect of Varying Air Flow Rate



NOTE

This experiment gives best results with the standard heat exchanger.

Aim

To show how different air flow rates affect the performance of the heat exchanger for a given fixed water flow and temperature.

Procedure

1. Connect and set up the standard 32 tube heat exchanger as shown in **To Change a Heat Exchanger** on page 35. Connect as for **parallel** flow and set a heater tank temperature of **60°C**. Water enters the bottom of the heat exchanger and exits from the top.

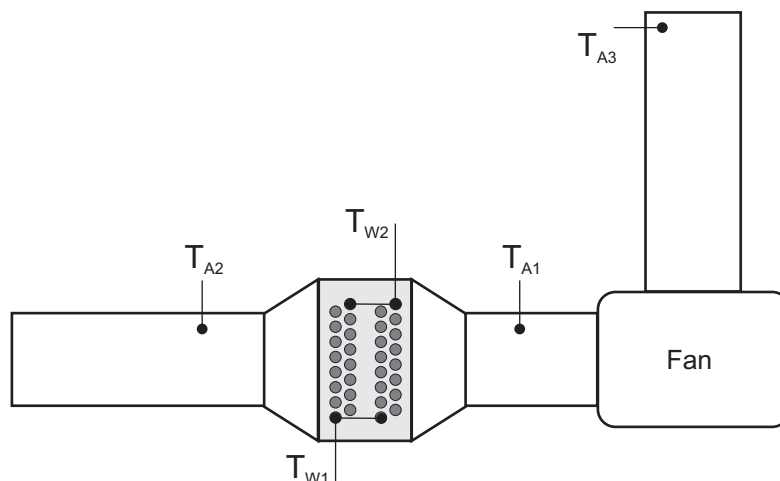


Figure 36 Heat Exchanger Connections

2. Create a blank results table, similar to Table 3. If you have VDAS, select the correct heat exchanger and experiment. The software will create a table for you automatically when you start taking readings.
3. Note the ambient air pressure.
4. Inspect the orifice and check its diameter - this is stamped on the surface of the orifice.
5. Switch on the fan and use the slide valve to set the airflow to give an orifice pressure drop of 250 Pa (+/- 5 Pa). Note that the pressure drop becomes more stable as air flow decreases.
6. Switch on the pump and use the hand operated water supply valve to set the water flow to 0.25 L/minute (+/- 0.01 L/minute).

7. Allow at least five minutes for the heat exchanger temperatures to stabilize, then record all readings.



Your water and air flows may change slightly as you do the experiment, so regularly check and readjust them if necessary.

8. Repeat the procedure for lower air flow rates as shown in the table.
9. Switch off the heater, set air and water flow to maximum and allow the fan to cool the heat exchanger for roughly five minutes before switching off.

Results Analysis

Find the change in temperature (ΔT) for each circuit and the average temperature for each circuit.

Use the charts or the equations in the theory section to calculate the water and air densities at each temperature.

Calculate your air mass flowrate and convert your water flow to mass flow.

Find the specific heat capacity for each circuit at each flow rate.

Calculate the heat emitted, heat absorbed, and mean temperature efficiencies. Find the LMTD and use this to calculate the heat transfer coefficient (U) for each flow. From your results, comment on how the flow rate affects the heat exchanger performance.

Create three charts, each with a horizontal axis of air mass flow ($\text{kg}\cdot\text{s}^{-1}$).

- On chart 1, plot the heat emitted by the heat exchanger and the power absorbed into the air (Watts). Note that one series gives negative numbers, so plot absolute values or use a second vertical axis to compare results.
- On chart 2, plot the air, water and mean temperature efficiencies (%).
- On chart 3, plot the heat transfer coefficient. Note that because these values are based on a negative value, you may plot the absolute values (ignore the negative) for neatness.

Experiment 2 Heat exchanger: Pipe Connection: Heater Temperature: Water Flow:										Ambient Pressure: Orifice Diameter:												
Air Pressure Δp (Pa)	T_{W1}	T_{W2}	ΔT_w	Average T_w	T_{W3}	T_{A1}	T_{A2}	ΔT_A	Average T_A	T_{A3}	η_W	η_A	ρ_W	ρ_A	ϵ_{pW}	ϵ_{pA}	$\dot{Q}_e$	$\dot{Q}_a$	C_{EB}	$\bar{\eta}$	LMTD	U
250																						
200																						
150																						
100																						
50																						
25																						

Table 3 Blank Results Table

Experiment 3 - Effect of Varying Temperature (Driving Force)



This experiment gives best results with the standard heat exchanger.

Aim

To show how different hot water supply temperatures affect the performance of the heat exchanger for a given fixed water flow.

Procedure

1. Connect and set up the standard 32 tube heat exchanger as shown in **To Change a Heat Exchanger** on page 35.
2. Connect as for **parallel** flow and set a heater tank temperature of **45°C**. Water enters the bottom of the heat exchanger and exits from the top.

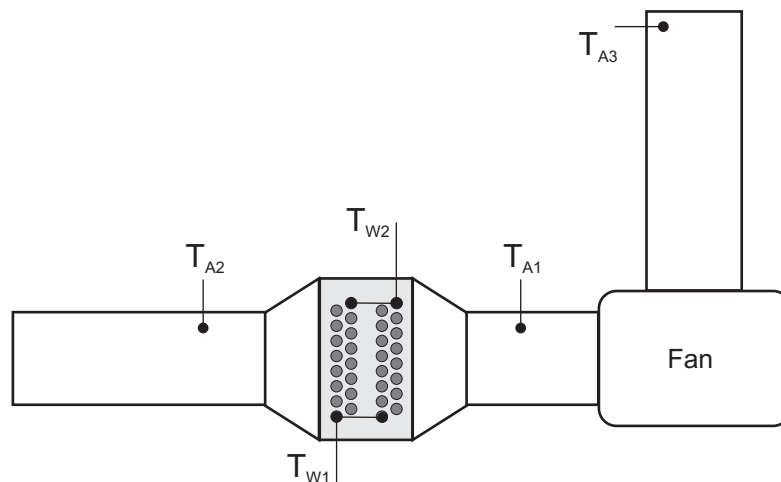


Figure 37 Heat Exchanger Connections

3. Repeat **Experiment 2 - The Effect of Varying Air Flow Rate**.

Results Analysis

Plot the same charts as described in **Experiment 2 - The Effect of Varying Air Flow Rate** to compare how the two water temperatures affect the heat exchanger performance.

Experiment 4 - Series Connection



This experiment is only for the standard heat exchanger.

Aims

To use the extra piping modes available on the 32 tube heat exchanger to show the difference in performance when connected in series.

The procedure tests the two bundles of 16 in series, with the third water thermocouple at mid-point, showing that the assumption of an average water temperature in a heat exchanger may not always be true.

Procedure

Connect and set up the standard 32 tube heat exchanger as shown in **To Change a Heat Exchanger** on page 35.

Use the SERIES ADAPTOR and connect as for **series** flow with the water flow to the downstream bundle first. Water enters the bottom of the heat exchanger and exits from the top.

Set a heater tank temperature of **60°C**.

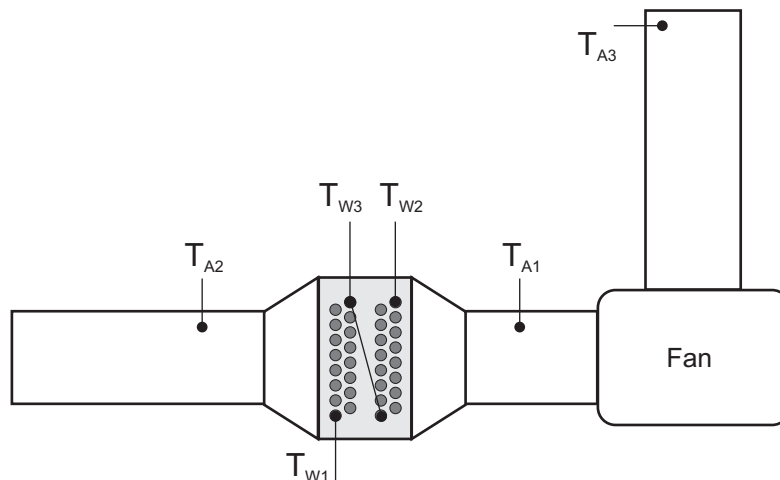


Figure 38 Heat Exchanger Connections

Repeat **Experiment 2 - The Effect of Varying Air Flow Rate**.

Results Analysis

Create a chart of heat transfer coefficient (vertical axis) against air flow rate. Compare the results with those of the parallel connection in experiment 2 to see the difference in performance between the two piping methods.

Can you explain the difference?

Create a chart of water temperature (vertical axis) against air flow. Add your results of average water temperature and TW3 temperature to compare them.

Can you explain why they are not the same?

Experiment 5 - Comparison of Heat Exchangers

NOTE



This experiment is for all TD1007 heat exchangers.

Aim

To compare the performance of the optional and standard heat exchangers.

Procedure

Repeat **Experiment 2 - The Effect of Varying Air Flow Rate**, using each heat exchanger.

Results Analysis

Compare all heat exchangers by plotting the charts as described in **Experiment 2 - The Effect of Varying Air Flow Rate**.

NOTE



You are comparing with the 32 tube standard heat exchanger in parallel connection.

Results

Note: These results are sample results only, actual results may be slightly different.

Experiment 1 - The Effect of Varying Water Flow Rate

Typical Calculation - Water

Volume water flow = 1.24 L/min

$T_{W1} = 60.9^{\circ}\text{C}$ and $T_{W2} = 53.8^{\circ}\text{C}$. $\Delta T_W = -7.1^{\circ}\text{C}$. Average $T_W = 57.4^{\circ}\text{C}$

Density at $57.4^{\circ}\text{C} = 984.5 \text{ kg.m}^{-3}$

Mass water flow = 0.0203 kg.s^{-1}

Water $c_{pW} = 4183 \text{ J.kg}^{-1}.\text{K}^{-1}$

Water power = $0.0203 \times 4183 \times -7.1 = -603 \text{ Watts}$

Water efficiency = $(7.1/38.4) \times 100 = 18.5\%$

Typical Calculation - Air

$T_{A1} = 22.5^{\circ}\text{C}$ $T_{A2} = 27.9^{\circ}\text{C}$. $\Delta T_A = 5.4^{\circ}\text{C}$. Average $T_A = 25.2^{\circ}\text{C}$. $T_{A3} = 21.6^{\circ}\text{C}$.

Density at $21.6^{\circ}\text{C} = 1.2 \text{ kg.m}^{-3}$

Orifice = 100.15 mm diameter = 0.007878 m^2 Area

$\Delta p = 250 \text{ Pa}$

Mass air flow = $0.6 \times 0.007878 \times \sqrt{250 \times 2 \times 1.2} = 0.004727 \times 24.5 = 0.1158 \text{ kg.s}^{-1}$

Air $c_{pA} = 1005 \text{ J.kg}^{-1}.\text{K}^{-1}$

Air power = $0.1158 \times 1005 \times 5.4 = 628 \text{ Watts}$

Air efficiency = $(5.4/38.4) \times 100 = 14.1\%$

Mean temperature efficiency = $(18.5 + 14.1)/2 = 16.3\%$

LMTD = $(25.9-38.4)/\ln(25.9/38.4) = -12.5/-0.394 = 31.74$

$U = -603/(0.1158 \times 31.74) = -603/4.945 = -121.8 \text{ W.m}^{-2}\text{K}^{-1}$

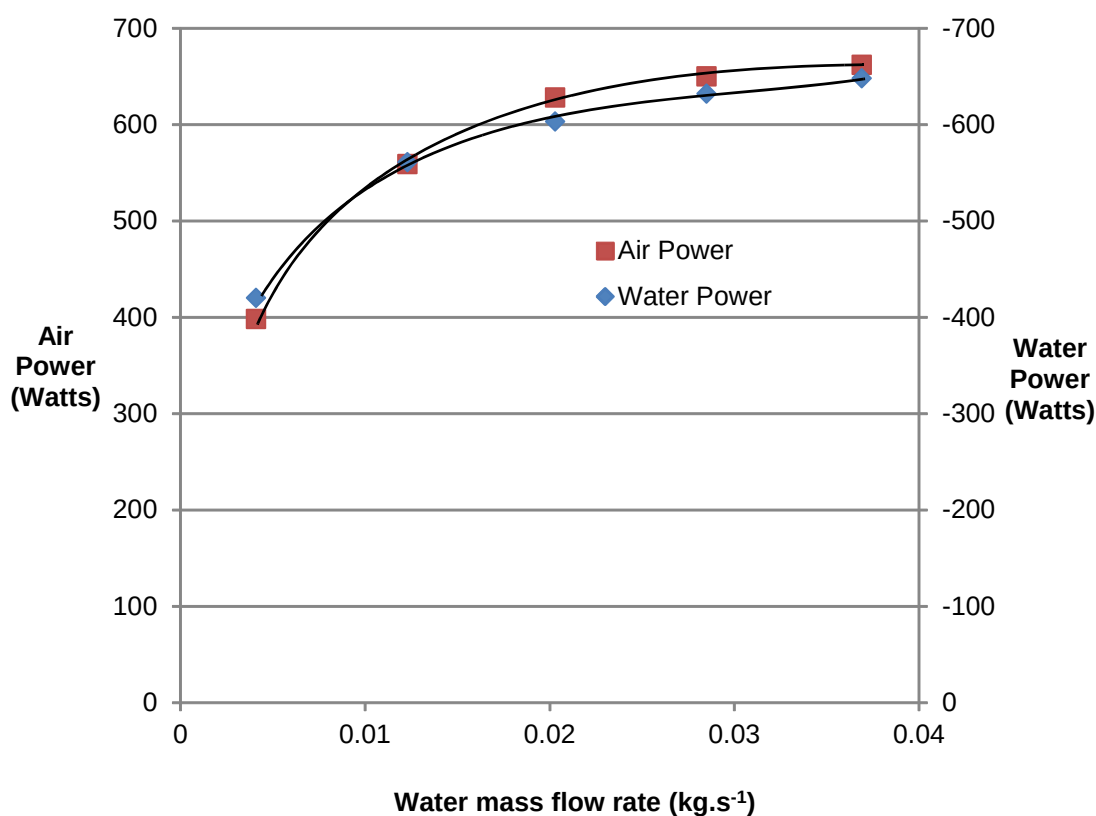


Figure 39 Typical Results For Experiment 1

The heat energy (power) results for the standard heat exchanger show that power transfer improves with water flow. The slope is not linear and starts to decrease, suggesting that there will be a maximum power transfer value at a mass flow of just above 0.04 kg.s⁻¹. The heat emitted from the water and absorbed by the air give similar values, showing a good energy balance coefficient (varying from around -0.95 to -1.02). As mentioned in the theory, slight variations in external conditions may cause the two values to separate.

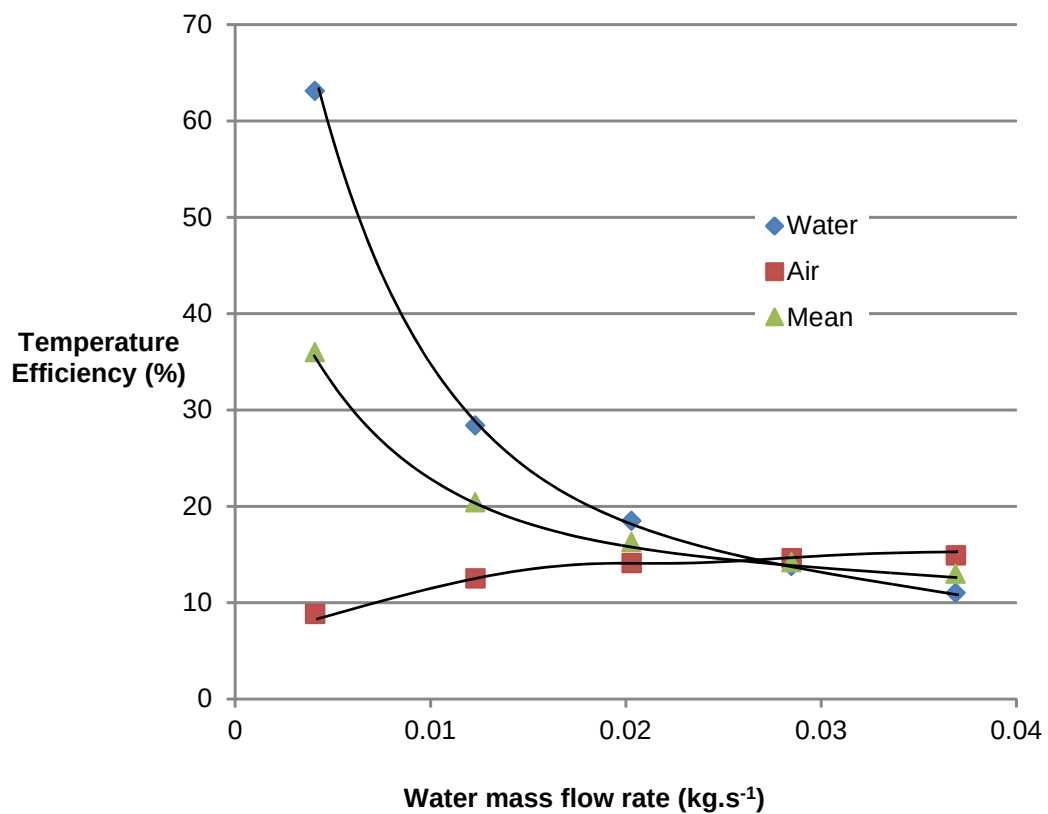


Figure 40 Typical Results For Experiment 1

The temperature efficiencies for the standard heat exchanger show that the water temperature efficiency decreases with water flow while air efficiency increases with water flow. But, the change in water efficiency is larger than the change in air efficiency over the range of flow rates. This is expected due to the higher temperature changes in the water compared with the air. The mean temperature efficiency therefore shows a gradual decrease with increasing flow.

At lower water flow rates, the heat exchanger produces a higher temperature drop for a given amount of emitted power. This gives a higher temperature efficiency for the water circuit. However, this higher temperature drop gives a lower temperature gradient between the water and air at the end of the water flow path within the heat exchanger. This gradient drives the heat exchange, so Figure 39 shows the reduction in power at the lower flows and Figure 40 shows this in the reducing air efficiency at lower flows.

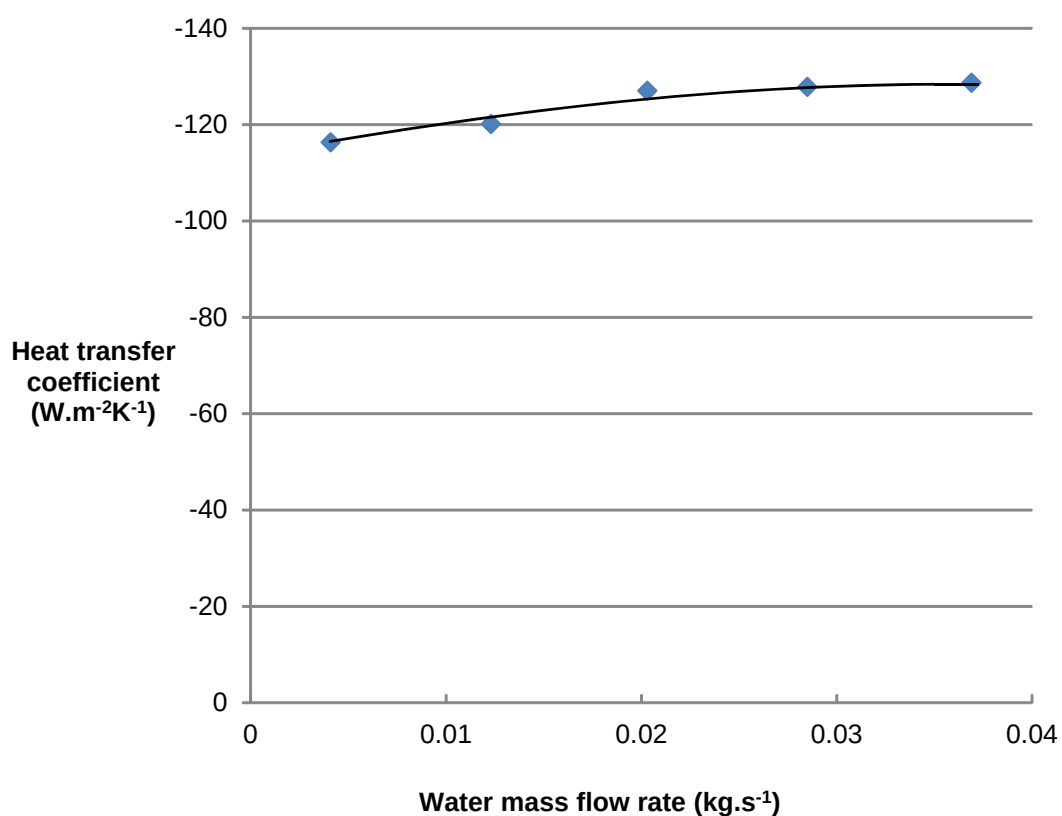


Figure 41 Typical Results For Experiment 1

The heat transfer coefficient for the standard heat exchanger tends to initially increase with water flow rate, then levels out. The initial rise and then levelling out suggests that increasing water flow past a certain optimum value makes no improvement to performance. This compares with the power curves of Figure 39.

Experiment 2 - The Effect of Varying Air Flow Rate

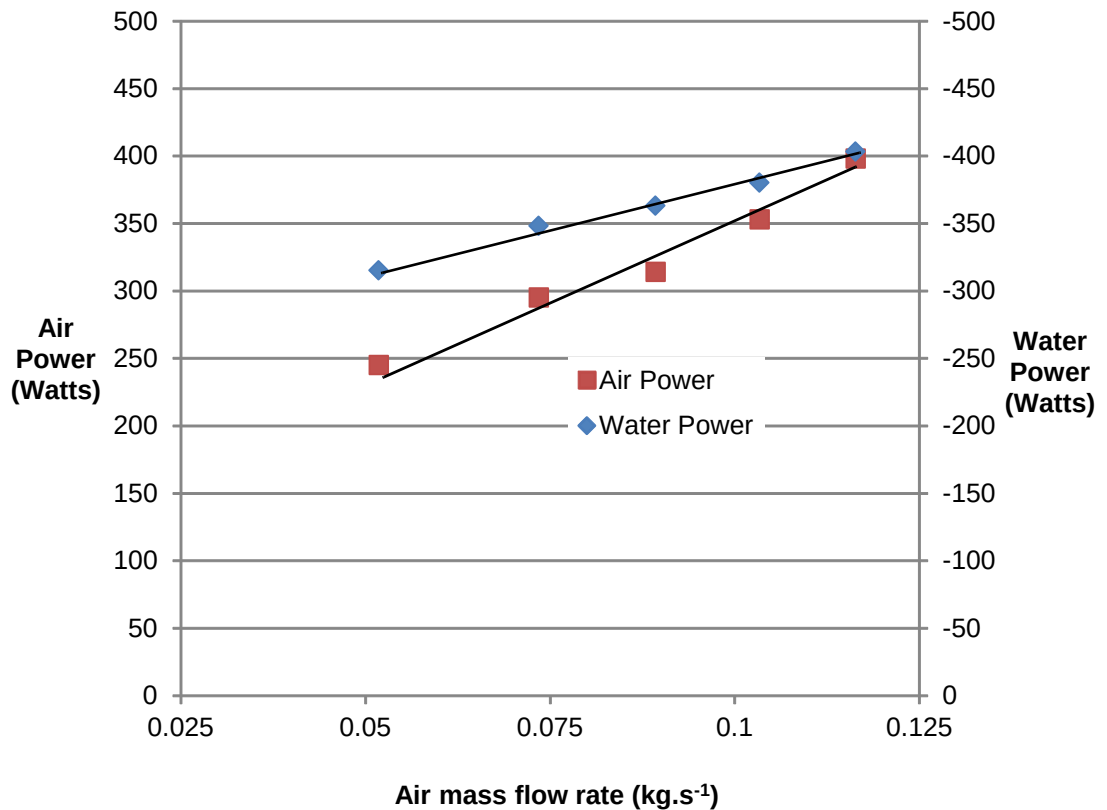


Figure 42 Typical Results

The heat energy (power) results for the standard heat exchanger show that power transfer improves with air flow, and gives reasonably linear results. At lower air flows, the heat emitted from the water is slightly greater than the heat absorbed by the air, suggesting that there are increased losses at low flow rates, possibly the duct or the heat exchanger metalwork tend to conduct some heat energy away. This has the effect of changing the energy balance coefficient from around -0.78 to -0.99 over the range of the experiment. Once air flow reaches at certain value, the external losses become less dominant and the two values start to converge.

The trend does not 'level out' as in experiment 1, suggesting that increasing the air flow rate could further increase the heat transfer.

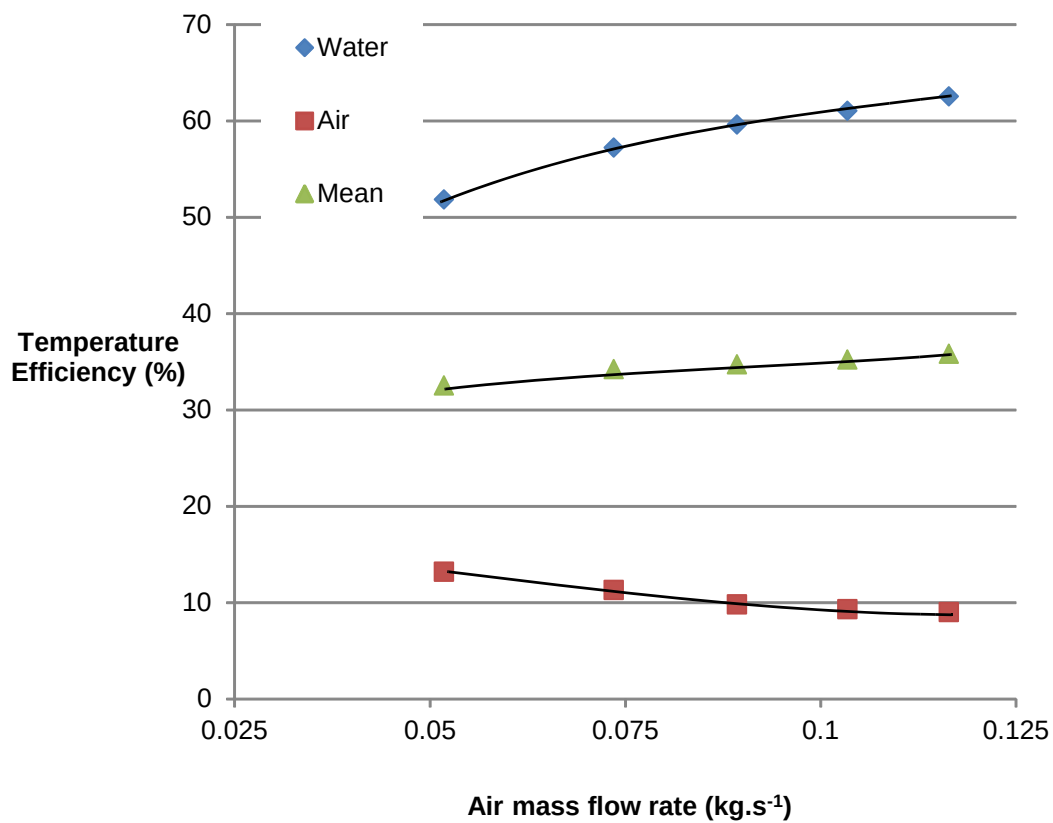


Figure 43 Typical Results for Experiment 2

The temperature efficiencies for the standard heat exchanger show that the water efficiency increases with air flow while air efficiency decreases with air flow. The change in efficiencies is similar over the range of air flow rates. The mean temperature efficiency shows a gradual increase with increasing air flow.

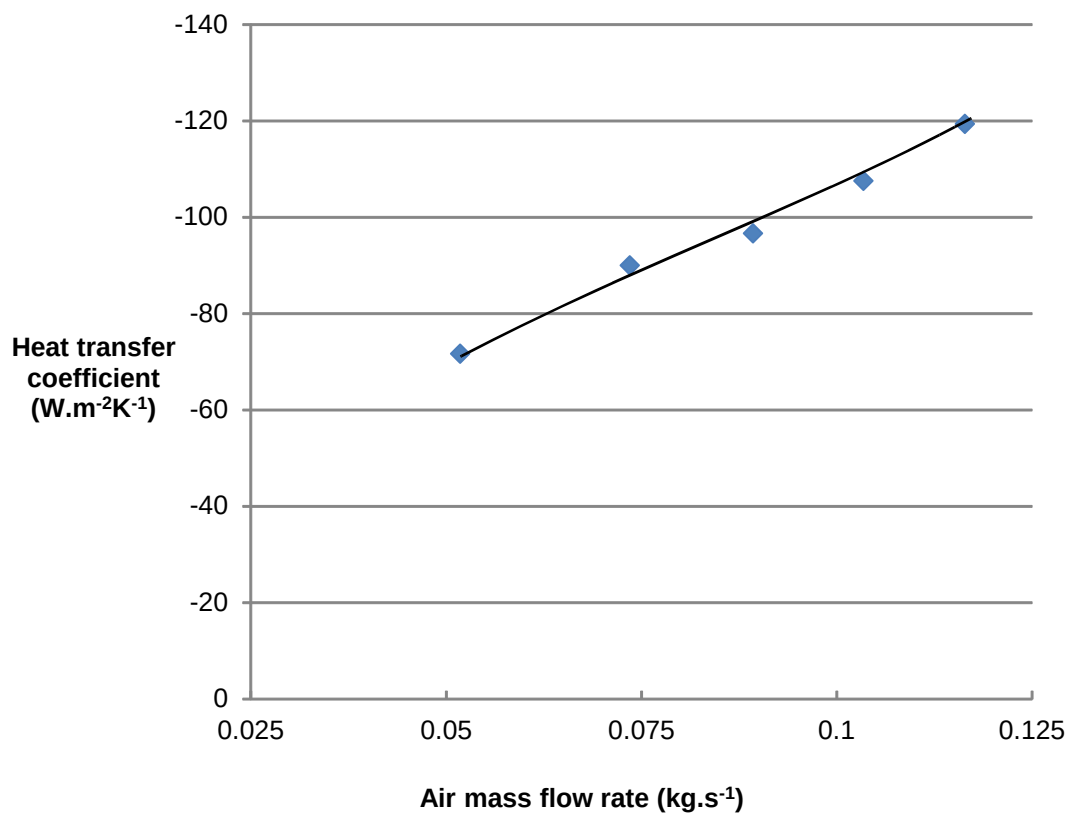


Figure 44 Typical Results for Experiment 2

The heat transfer coefficient results for the standard heat exchanger show a reasonably linear increase with air flow, showing that increased air flow improves the heat exchanger performance. Again, the trend suggests that increasing air flow rate could give increased heat transfer.

Experiment 3 - Effect of Varying Temperature (Driving Force)

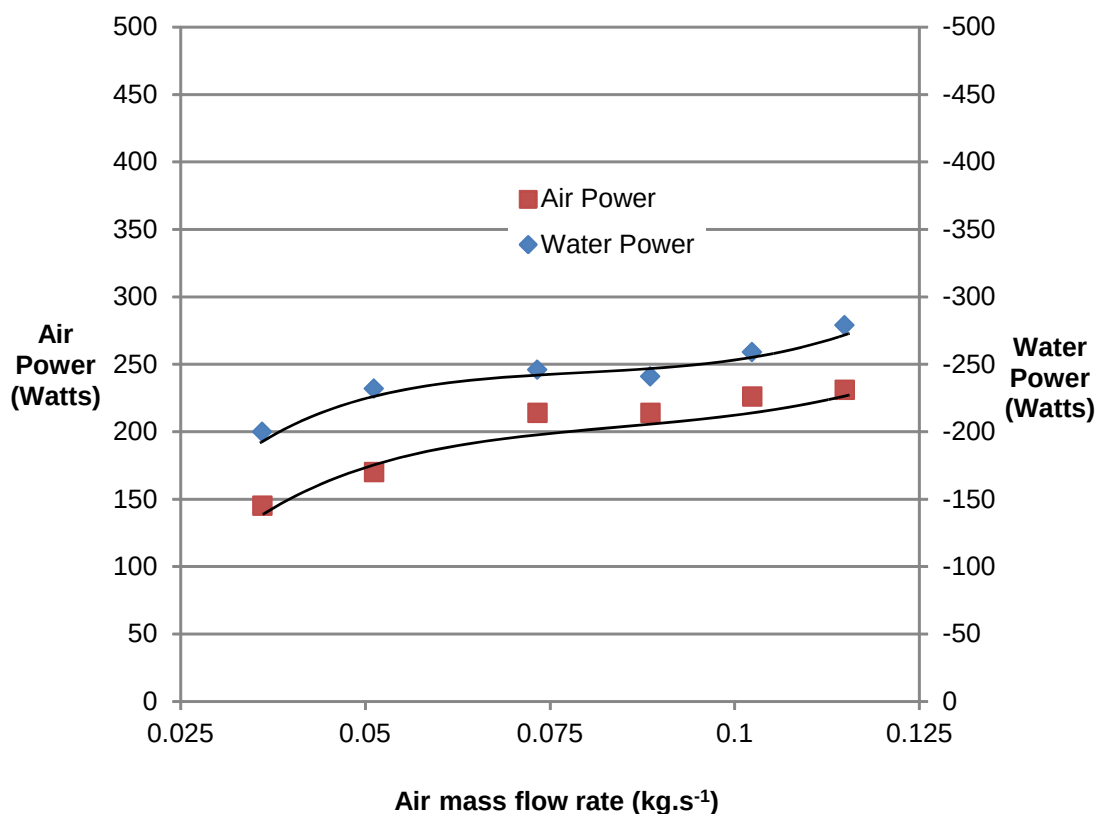


Figure 45 Typical Results - Tests at 45 Degrees

The 60°C tests gave a linear trend for both air and water power. The 45°C tests show that the power trend starts to trail off. This suggests that at this reduced driving force of 45°C, the heat transfer is near its limit for this configuration. You can see the difference between the two plots of water power becoming larger with increasing air flow rates.

At both 60°C and 45°C the temperature efficiencies and heat transfer plots show similar results. The effect of the lower 45°C temperature does not affect heat transfer coefficient as much as power because it allows for the starting temperature through the LMTD term. This factors in the available power, which is lower at the 45°C temperature.

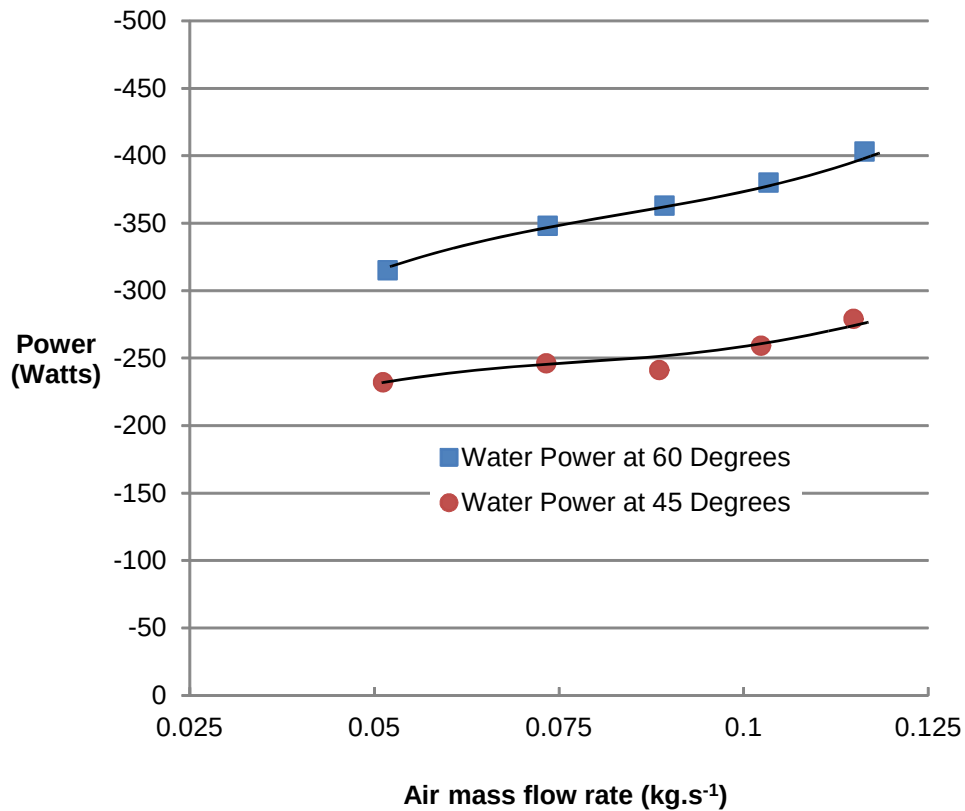


Figure 46 Comparison of Water Powers

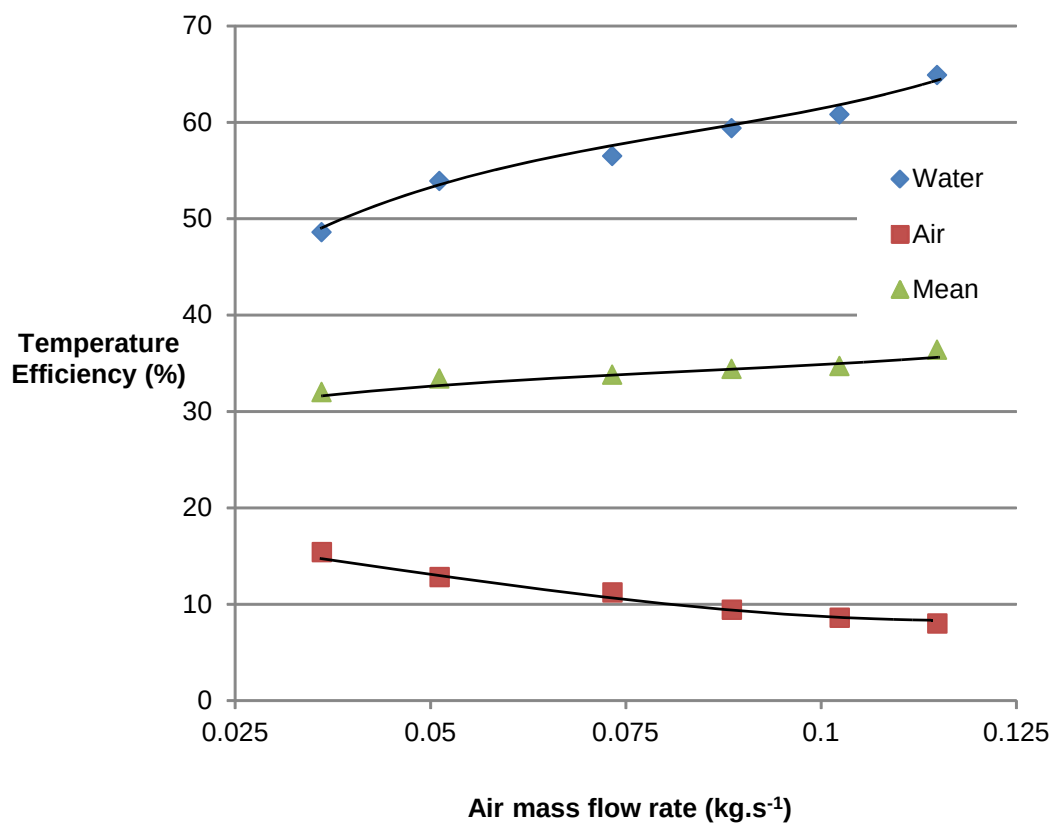


Figure 47 Typical Results - Tests at 45 Degrees

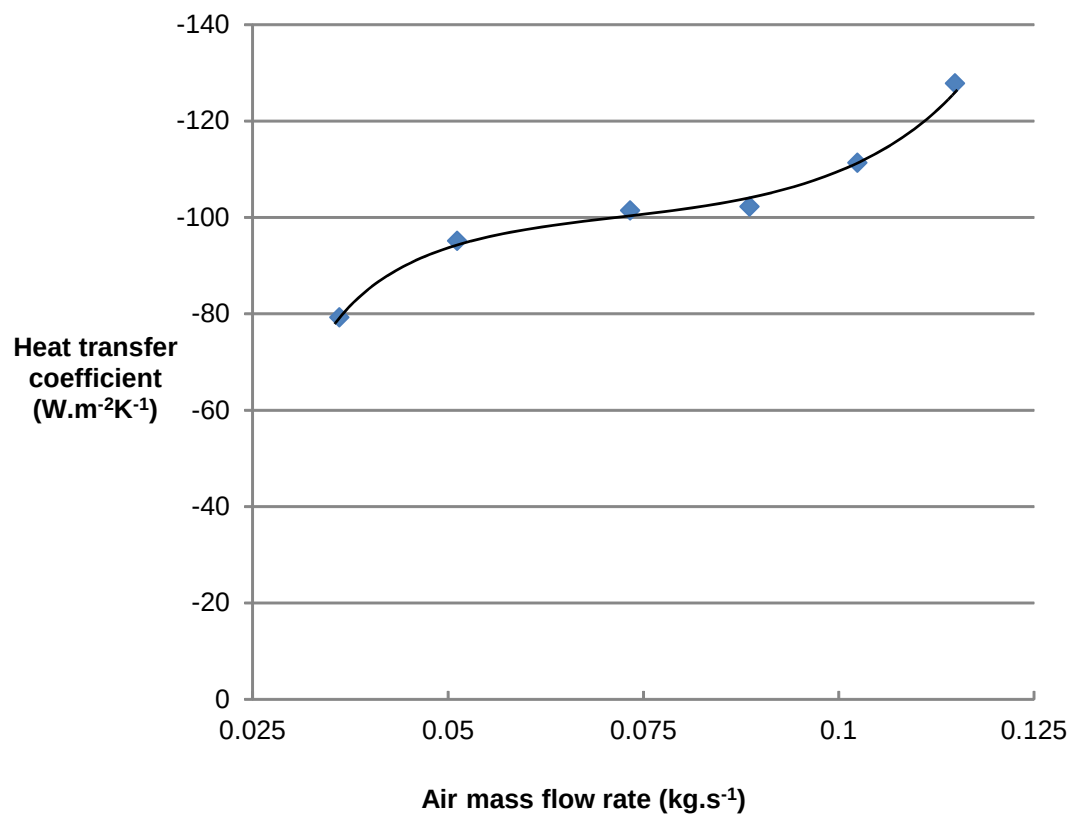


Figure 48 Typical Results - Tests at 45 Degrees

Experiment 4 - Series Connection

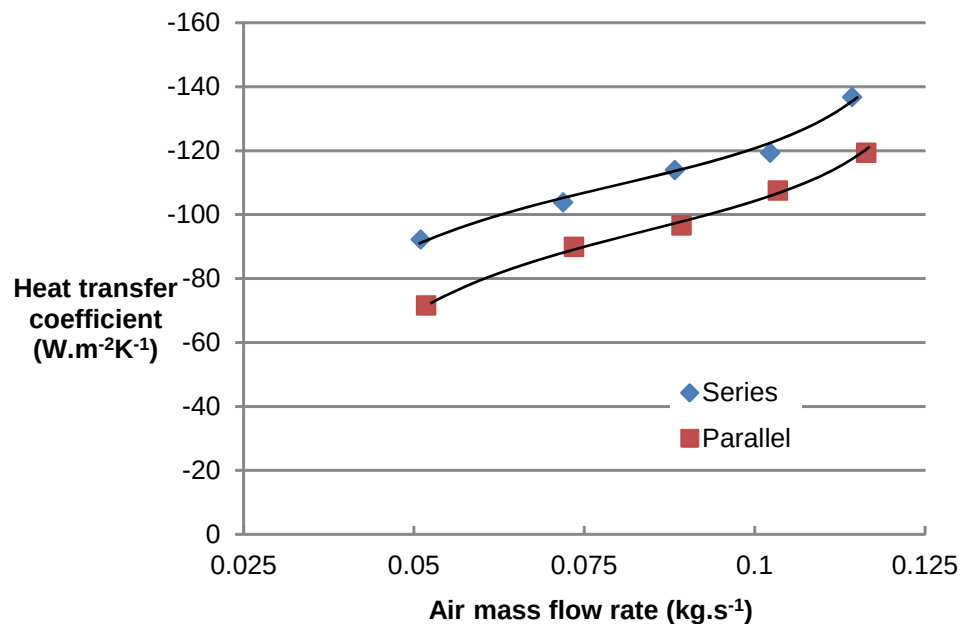


Figure 49 Comparison of Series and Parallel Connection

The series results show that heat transfer improves with air mass flow, just as with the other results. They also show that throughout the air flow range, the series heat exchanger connection gives a slightly improved heat transfer compared to the parallel flow of experiment 2.

Both parallel and series connections use the same water flow rate. When in parallel, the connection splits the flow equally between the two banks of 16 tubes, halving the flow in each bank. When in series, the connection allows full flow rate through all 32 tubes. However, this connection gives a higher resistance to the flow, and so the pump has to work harder to achieve the same flow rate through the heat exchanger. This is a problem that the designer has to allow for. An advantage of the higher velocity in the series connection is higher turbulence levels. This drives the heat transfer to the copper tubes at a higher rate and improves heat transfer to the air flow.

The series mode also allows the use of the mid point thermocouple to measure the water temperature between the two banks, (see Figures 50 and 51) showing that each bank does not transfer the same amount of heat. The temperature drop across each bank of 16 tubes shows that the downstream bank transfers 57% to 70% of the total heat transferred. If we were to switch which bank was connected first we would expect this to inverse. The results show that, although the air temperature is higher through the downstream bank, the mixture of the higher water temperature and the additional turbulence of the airflow gives better heat transfer.

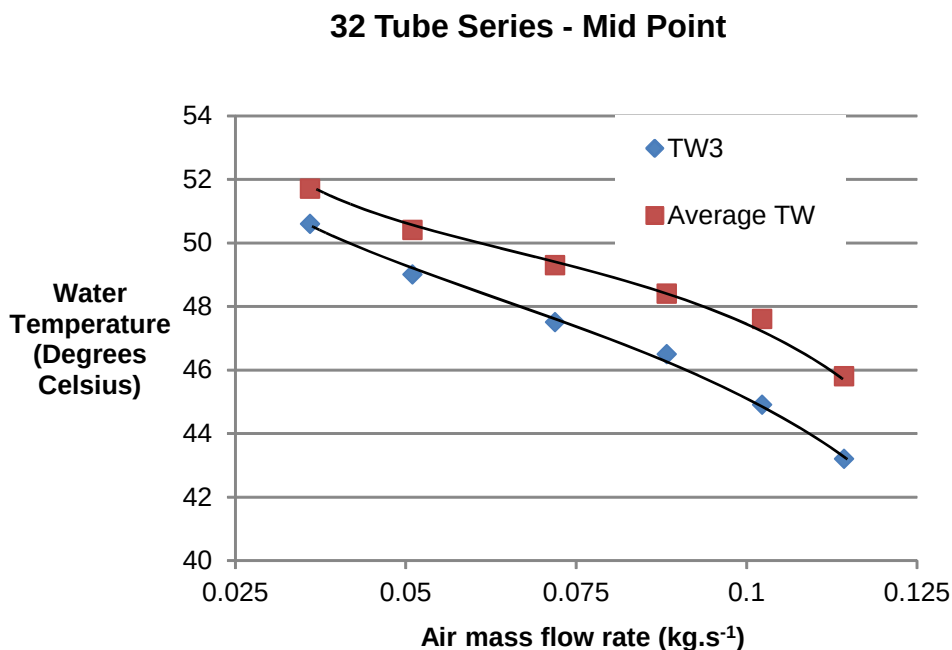


Figure 50 Typical Results for 32 Tube Heat Exchanger at 60 degrees

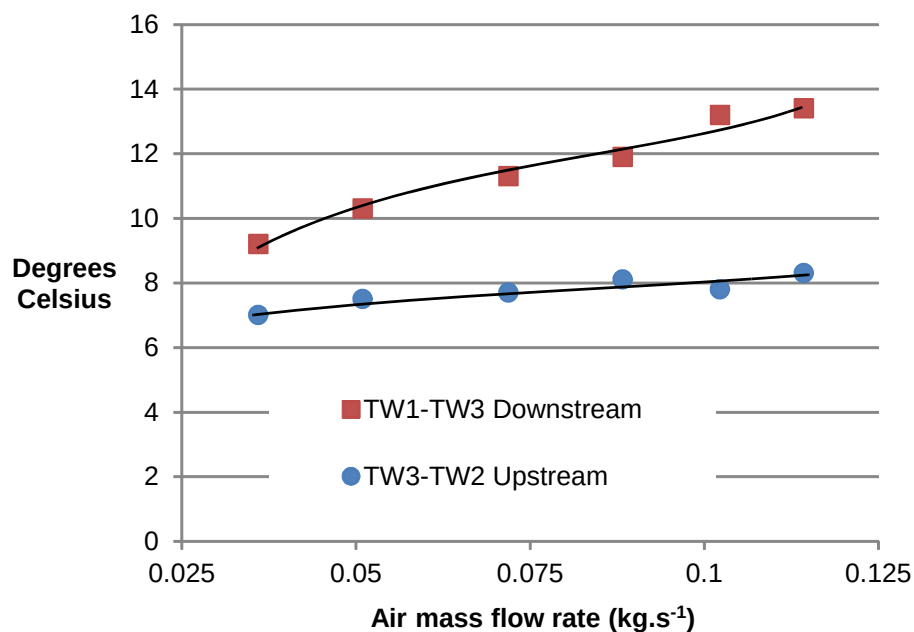


Figure 51 Comparison of Up and Downstream Temperature Differences

A complete analysis of the results extends into fluid dynamic engineering and leads to more complex equations. TecQuipment's Cross Flow Heat Exchanger (TE93) shows this in more detail.

You could connect the 32 tube heat exchanger in other ways, for example just the downstream or just the upstream banks; however any differences in heat transfer on this scale will be too small to reliably measure.

The results show that heat transfer is a complex topic and that heat exchanger designers must manage and optimise the temperature gradient through the entire heat exchanger rather than as a system as a whole. As mentioned earlier, the designer must also allow for other factors such as:

- resistance to the water flow (series or parallel connection)
- the available air flow rate to extract away the heat energy
- where to direct the heat removed?

The optional heat exchangers allow the user to explore other questions, such as:

- does having only half the surface area only give half the heat transfer?

if the same area is obtained by other mean (fins), does this achieve the same heat transfer?

Experiment 5 - Comparison of Heat Exchangers

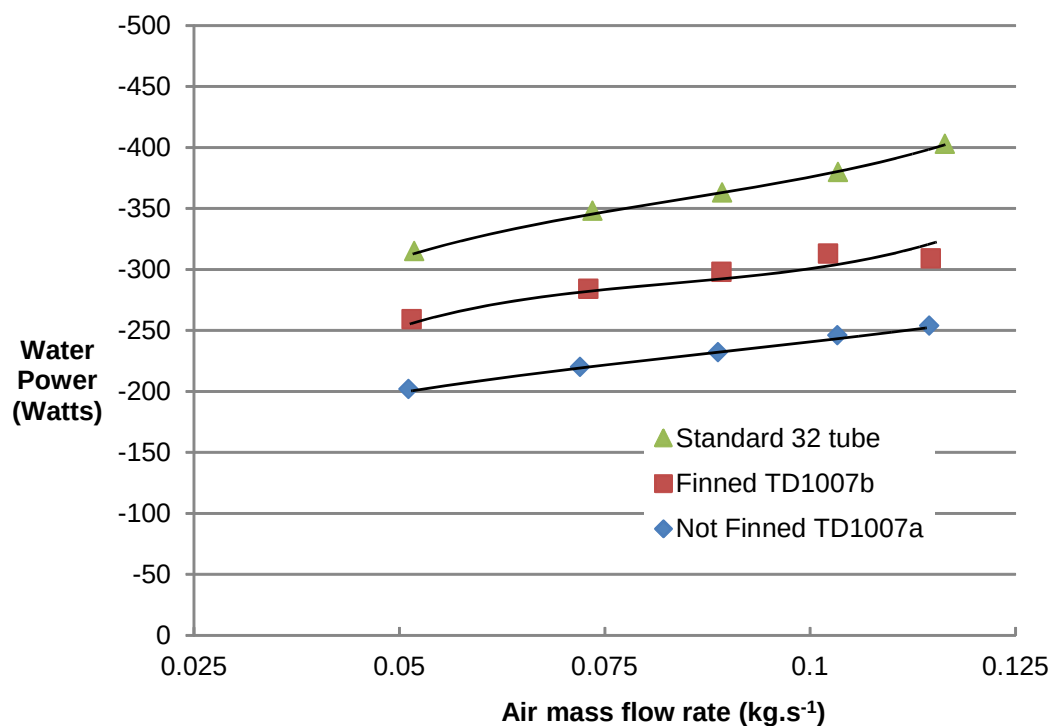


Figure 52 Comparison of Water Powers for all Three Heat Exchangers

A comparison of the water powers shows that the (non finned) TD1007a heat exchanger, with half the available heat transfer area, exchanges more than half the power of the standard heat exchanger. The (finned) TD1007b, with the same area as the standard heat exchanger, improves on the TD1007a but only exchanges around 75% of the heat transferred of the standard heat exchanger.

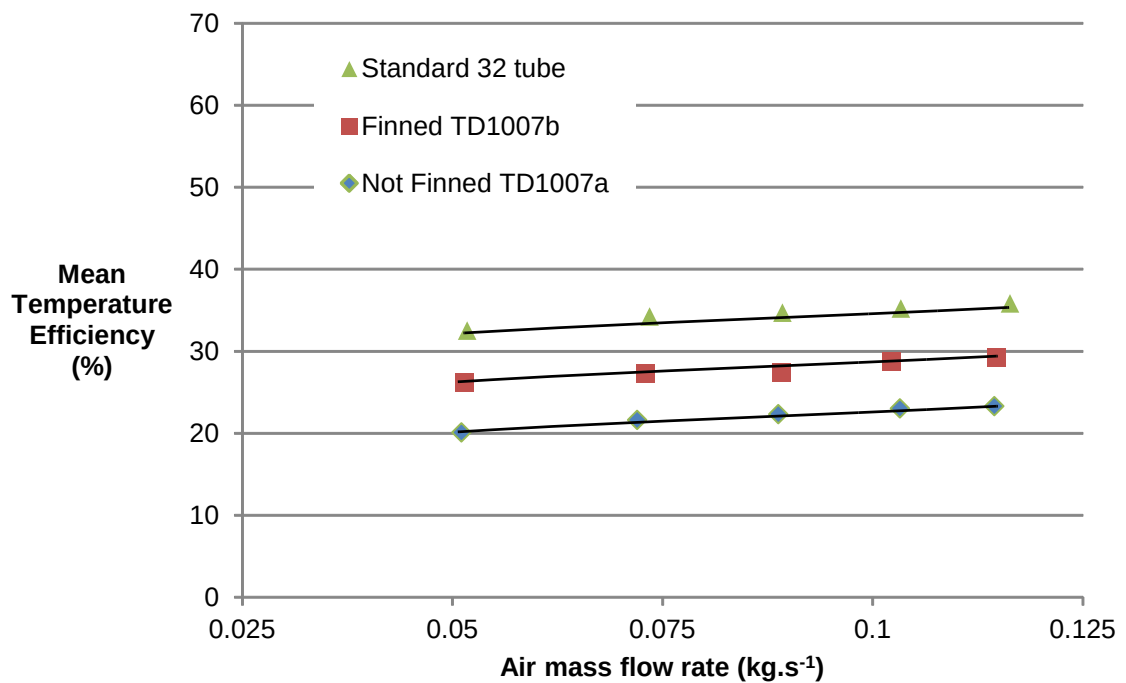


Figure 53 Comparison of Mean Temperature Efficiencies for all Three Heat Exchangers

The mean temperature efficiencies show a similar pattern to the power chart, with all three having the same trend with varying air flow rate.

If we look at the heat transfer coefficient, things have changed around with the TD1007a and b. We can see that the (not finned) TD1007a produces similar results to the standard heat exchanger but the (finned) TD1007b gives much lower results due to its relatively low heat transfer compared with the standard heat exchanger.

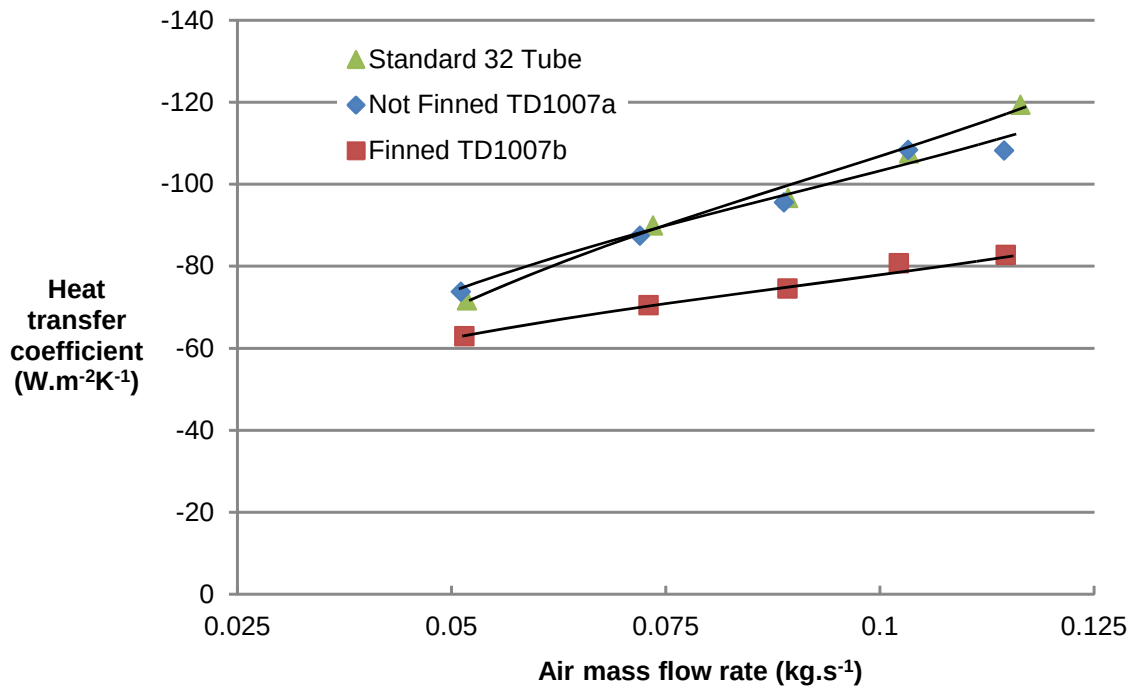


Figure 54 Comparison of Heat Transfer for all Three Heat Exchangers

As mentioned in experiment 4, heat exchanger design is complex, and as with all engineering applications, optimization is specific to the application at hand. The TD1007a has fewer parts and could be made more compact, but the standard unit can exchange more energy, or the same energy at a lower air flow rate. The TD1007b is a middle ground option. Many options are available, for example more fins could be used to greatly increase surface area for a more compact unit, but this would restrict the air flow.

Summary of Results

The results generally show that:

- More tubes (up to a practical limit) give better results.
- Finned tubes improve performance factors other than heat transfer coefficient.
- Fins improve performance without needing an increase in heat exchanger size, but are not a direct substitute for more tubes.
- Series connection may improve performance, but at the cost of increased flow resistance.
- The assumption of an average temperature at the middle of a heat exchanger may not be true.

Useful Textbooks

Basic Engineering Thermodynamics

By Rayner Joel

Published by Longman

ISBN0-582-25629-1

Engineering Thermodynamics

By G.F.C Rogers and Y.R Mayhew

Published by Longman

ISBN 0-582-02704-7

Maintenance, Spare Parts and Customer Care

Maintenance

General

If you are to leave the main frame or a heat exchanger unused for several weeks, drain out any water. This helps to reduce any corrosion or bacteria that may gather in the water. Refer to **To Drain the Water from the Main Unit** on page 74 and **To Drain the Heat Exchangers** on page 73 for more details.

CAUTION  *To prevent spills, drain the water from the main frame before you move it.*

- Regularly check all parts of the equipment for damage, renew if necessary.
- When not in use, store the equipment in a dry dust free area, preferably covered with a plastic sheet.
- If the equipment becomes dirty, wipe the surfaces with a damp, clean cloth. Do not use abrasive cleaners.
- Regularly check all fixings and fastenings for tightness; adjust where necessary.

NOTE  *Renew faulty or damaged parts with an equivalent item of the same type or rating.*

Faulty heater - or no heating

If the water heater appears not to work:

1. Check the water level. All three lamps should be on.
2. Check the controller is switched on and set.
3. Check the thermal switch on the heater tank. Disconnect your mains supply, then gently press its reset button (see Figure 55). Reconnect the mains supply and try the equipment again.

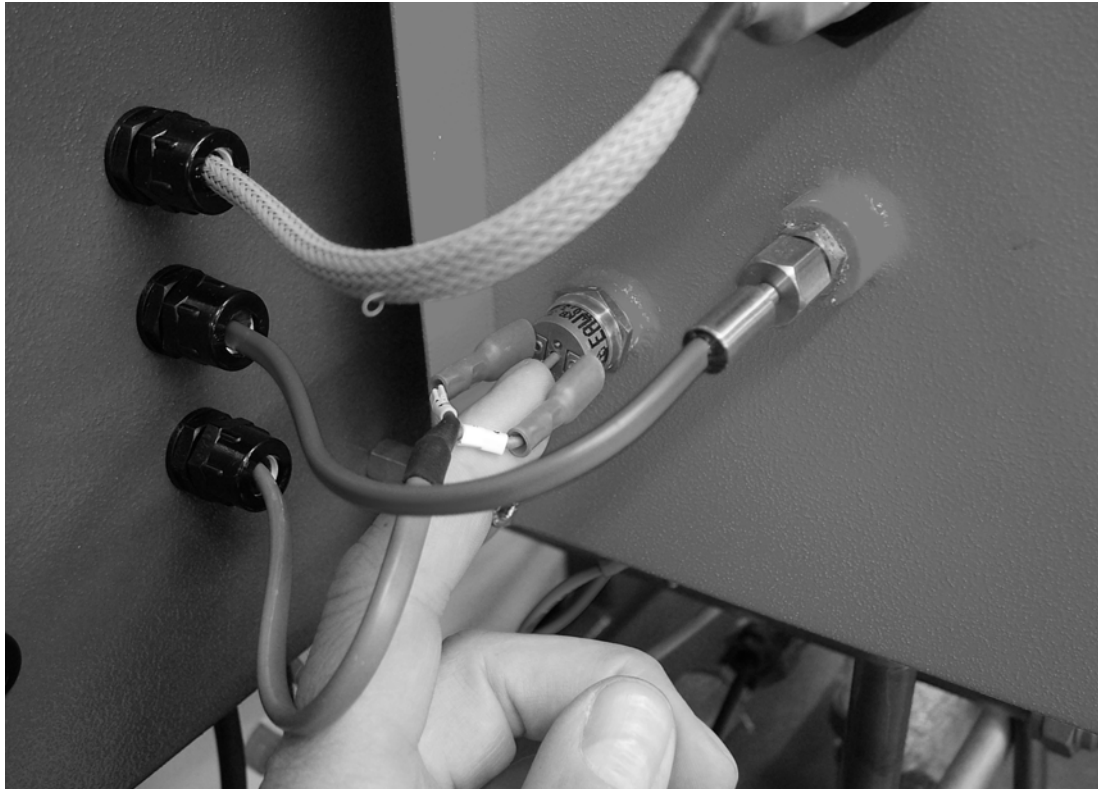


Figure 55 Thermal Switch on the Heater Tank

To Drain the Heat Exchangers

WARNING



Make sure the heat exchanger is cool before you drain it.

Always clean up any water spills immediately.

Supplied with the equipment is a short tube with a connector.

To drain a heat exchanger thoroughly, remove it from the duct, fit the short tube to the bottom connector and direct its end into a suitable container or drain. Gently press the top connector to allow air into the heat exchanger and water to drain out. See Figure 56. Finally, tilt the heat exchanger to completely empty it.

*Short tube with
connector
(supplied)*

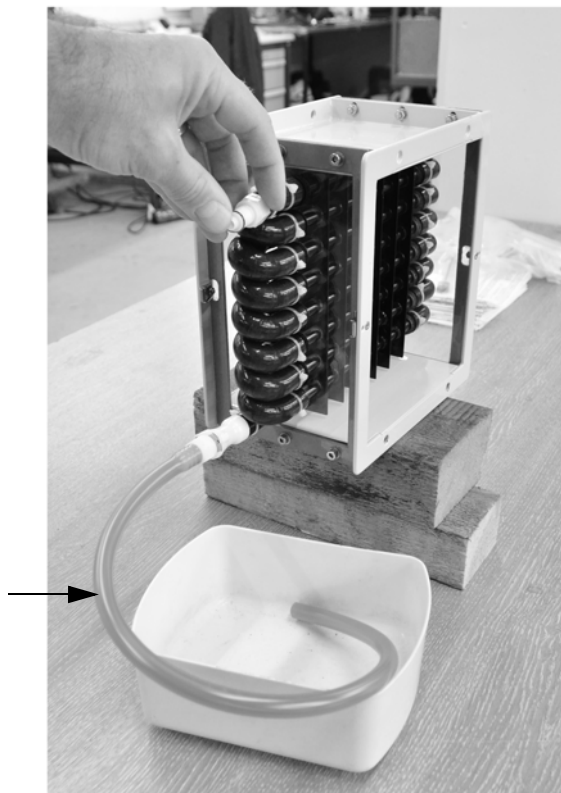


Figure 56 Draining a Heat Exchanger

To Drain the Water from the Main Unit



WARNING

Make sure the water has cooled down to less than about 40°C before you drain it.

1. Disconnect the Electrical Supply.
2. Disconnect the water pipes connecting to the heat exchanger.
3. Fully open the WATER SUPPLY valve.
4. See Figure 57. Direct the ends of the water pipes into a suitable container (not supplied). Fit the short pipe and female connector to drain one pipe, gently press on the connector of the other pipe. Wait until all the water has drained from the pipes.



Figure 57 Drain the Water Pipes

5. Some water will remain in the heater tank. To drain this, undo the small bolt at the bottom of the heater tank (see Figure 58) and hold a container underneath to catch the water. Refit the bolt.



Figure 58 To Drain the Heater Tank

To Clean the Water Filter

Once a year, or sooner if you notice a drop in water flow rates, check and clean the Water Filter.

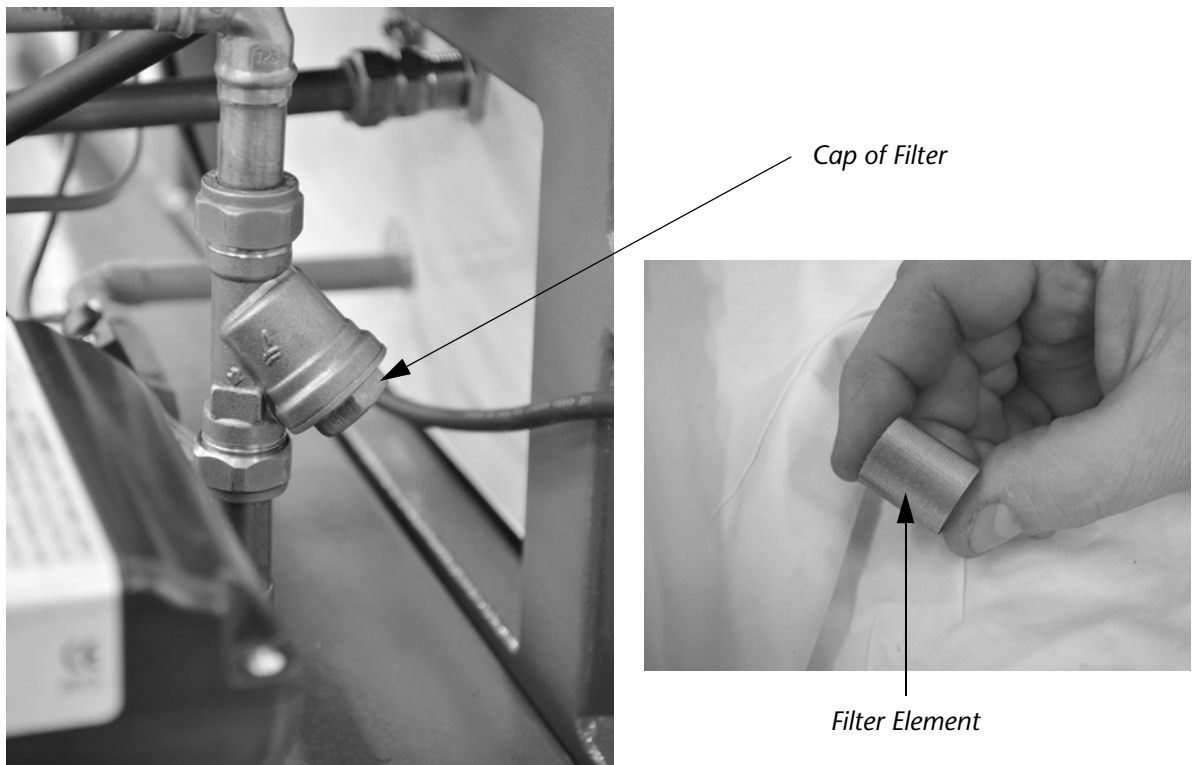


Figure 59 Remove the Filter Element and Clean it

To do this:

1. Disconnect the electrical supply.
2. Disconnect the water supply.
3. Drain the Main Part as shown earlier.
4. Use a spanner to undo the cap of the filter.
5. Gently remove the filter element and clean it inside and out with clean water and a soft brush. Make sure it is thoroughly clean before you refit it, or you may cause damage to the flow sensor.
6. If it is very dirty, check your mains water supply and correct any problems with dirt. Consider fitting your own filter to your mains water supply.
7. Replace the filter element and refit the cap of the filter.

Accidental Water Ingress from Misuse

WARNING



If someone has not used the equipment correctly and you suspect that water has accidentally entered the control panels, disconnect the electrical supply and ask a qualified electrician to check the equipment before you use it again.

Electrical

WARNING



Only a qualified person may carry out electrical maintenance. Obey these procedures:

- Assume the apparatus is energised until it is known to be isolated from the electrical supply.
- Use insulated tools where there are possible electrical hazards.
- Confirm that the apparatus earth circuit is complete.
- Identify the cause of a blown fuse or tripped circuit breaker before renewing.

To renew a broken fuse/reset a tripped circuit breaker

- Isolate the apparatus from the electrical supply.
- Renew the fuse or reset the circuit breaker.
- Reconnect the apparatus to the electrical supply and switch on.
- If the apparatus fails again, contact TecQuipment Ltd or your agent for advice.

NOTE



Renew faulty or damaged parts or detachable cables with an equivalent item of the same type or rating.

Circuit Protection Location

The main switch (circuit breaker) for the equipment is at its left-hand side, next to the mains cable inlet.

The internal circuit protection for the control circuits, pump and fan is inside the main cabinet. You must isolate the electrical supply and remove the front cover of the main cabinet. Push the circuit breaker up to reset it.

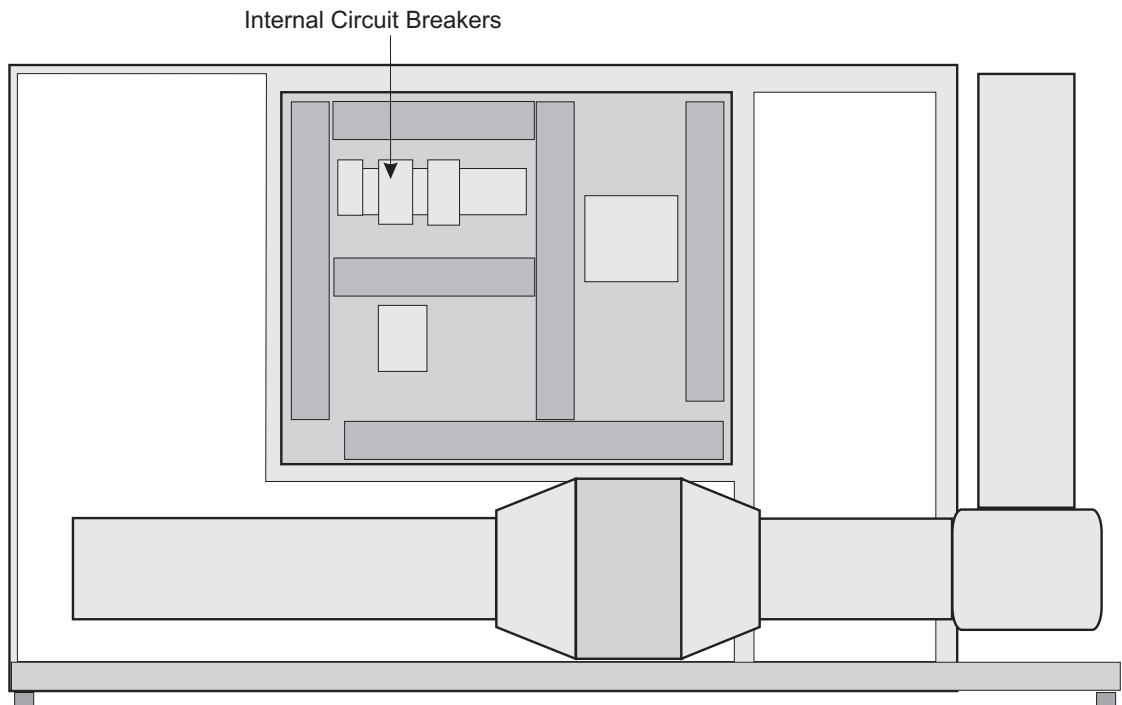


Figure 60 Internal Circuit Protection

Spare Parts

Check the Packing Contents List to see what spare parts we send with the apparatus.

If you need technical help or spares, please contact your local TecQuipment Agent, or contact TecQuipment direct.

When you ask for spares, please tell us:

- Your Name
- The full name and address of your college, company or institution
- Your email address
- The TecQuipment product name and product reference
- The TecQuipment part number (if you know it)
- The serial number
- The year it was bought (if you know it)

Please give us as much detail as possible about the parts you need and check the details carefully before you contact us.

If the product is out of warranty, TecQuipment will let you know the price of the spare parts.

Customer Care

We hope you like our products and manuals. If you have any questions, please contact our Customer Care department:

Telephone: +44 115 9722611

Fax: +44 115 973 1520

email: **customer.care@tecquipment.com**

For information about all TecQuipment Products and Services, visit:

www.tecquipment.com