P.A. HILTON LTD.

EXPERIMENTAL

OPERATING

AND

MAINTENANCE MANUAL

FREE AND FORCED CONVECTION

H920

H920M/E/3/043

MAR 90 (3a)

SAFETY IN THE USE OF EQUIPMENT

Before proceeding to install, commission or operate the equipment described in this instruction manual, we request you to read the following notes to alert you to potential hazards so that they may be avoided.

Although designed for safe operation, any laboratory equipment may involve processes or procedures which are potentially hazardous. The major potential hazards are listed below. Those particularly relevant to this item of equipment are highlighted for your information by the following symbol - ●

- ● INJURY THROUGH MISUSE
- ● INJURY FROM ELECTRIC SHOCK
- ○ FIRE OR EXPLOSION FROM HIGHLY INFLAMMABLE LIQUIDS OR VAPOURS (e.g. KEROSENE)
- ○ POISONING FROM TOXIC MATERIALS (e.g. MERCURY)
- ○ INJURY FROM HANDLING LARGE OR HEAVY COMPONENTS
- ● INJURY FROM ROTATING COMPONENTS
- ● BURNS FROM COMPONENTS AT HIGH TEMPERATURES
- ○ SCALDING FROM BOILING LIQUIDS OR HOT VAPOURS (e.g. STEAM)
- ○ INJURY FROM FAST MOVING AIR STREAMS OR HIGH PRESSURE AIR HOSES
- ○ INJURY FROM CORROSIVE LIQUIDS
- ○ DAMAGE TO EYESIGHT
- ○ DAMAGE TO HEARING
- ○ DAMAGE TO CLOTHING

ACCIDENTS CAN BE AVOIDED provided that equipment is regularly maintained and staff and students are made aware of potential hazards. A list of general safety rules is included on Page 2 to assist staff and students in this regard.

The list is not intended to be fully comprehensive, but for guidance only.

H920 FREE AND FORCED CONVECTION HEAT TRANSFER UNIT

INTRODUCTION

Heat transfer by simultaneous conduction and convection, whether free or forced, forms the basis of most industrial heat exchangers and related equipment. The measurement and prediction of heat transfer coefficients for such circumstances is achieved in the Hilton unit by studying the temperature profiles and heat flux in an air duct with associated flat and extended transfer surfaces. The vertical duct is so constructed that the air temperature and velocity can be readily measured, and a variety of "plug-in" modules of heated solid surfaces of known dimensions can be presented to the air stream for detailed study. A fan situated at the top of the duct provides the air stream for forced convection experiments.

An independent bench-mounted console contains temperature measurement, power control, and fan speed control circuits with appropriate instrumentation. Temperature measurement, to a resolution of 0.1°C, is effected using thermistor sensors with direct digital read-out in °C.

Air velocity is measured with a portable anemometer mounted on the duct.

The power control circuit provides a continuously variable, electrical output of 0-100 Watts with a direct read-out in Watts.

Using the instrumentation provided, free and forced convective heat transfer coefficients may be determined for:

A flat surface
An array of cylinders (pinned heat sink)
An array of fins (finned heat sink)

Each module may be used independently, on the bench, to establish free convection coefficients for horizontal orientation.

The apparatus is fully self-contained.

RECEIPT OF EQUIPMENT

Sales in the United Kingdom
The apparatus should be carefully unpacked and the components checked against the Packing List.

Any omissions or breakages should be notified to P.A. Hilton Limited within three days of receipt.

Sales Overseas
The apparatus should be carefully unpacked and the components checked against the Packing List.

Any omissions or breakages should be notified immediately to the Insurance Agent stated on the Insurance Certificate if the goods were insured by P.A. Hilton Limited.

Your own insurers should be notified immediately if insurance was arranged by yourselves.

DESCRIPTION

(Refer to Fig.1, Page 8)

The apparatus consists of a vertical rectangular duct supported by a bench mounted stand (1). A flat plate (3), pinned (4), or finned (5) exchanger may be installed in the duct and secured by a quick-release catch (18) on each side. Each exchanger incorporates an electric heating element with thermostatic protection against overheating. The temperature at the base of each exchanger is monitored by a thermistor sensor (19) with connecting lead (7).

The exchanger in use may be viewed through an acrylic window (14) in the wall of the duct.

An upward flow of air may be generated in the duct with a variable speed fan (21) mounted at the top.

Air velocity in the duct, whether natural or forced, is indicated on a portable anemometer (2) held in a bracket (15) on the duct wall. The anemometer sensor (16) is inserted through the wall of the duct.

A thermistor probe (6) permits measurement of the in-going and out-going air temperatures, together with surface temperatures of exchanger pins and fins.

These temperatures are determined by inserting the probe through access holes (20) in the duct wall.

An electric console (8) incorporates a solid state power regulator with a digital read-out to control and indicate power supplied to the exchanger on test. The exchanger is connected to the console via the supply lead (10). A variable low voltage D.C. supply is provided for the fan via the supply lead (17). A digital read-out indicates the temperature using a thermistor probe connected to a flexible lead (6).

Power is supplied to the equipment via a supply lead (9) connected to the rear of the console.

INSTALLATION REQUIREMENTS

The equipment should be installed on a firm, level work surface.

A single phase electrical supply is required.

No other services are necessary.

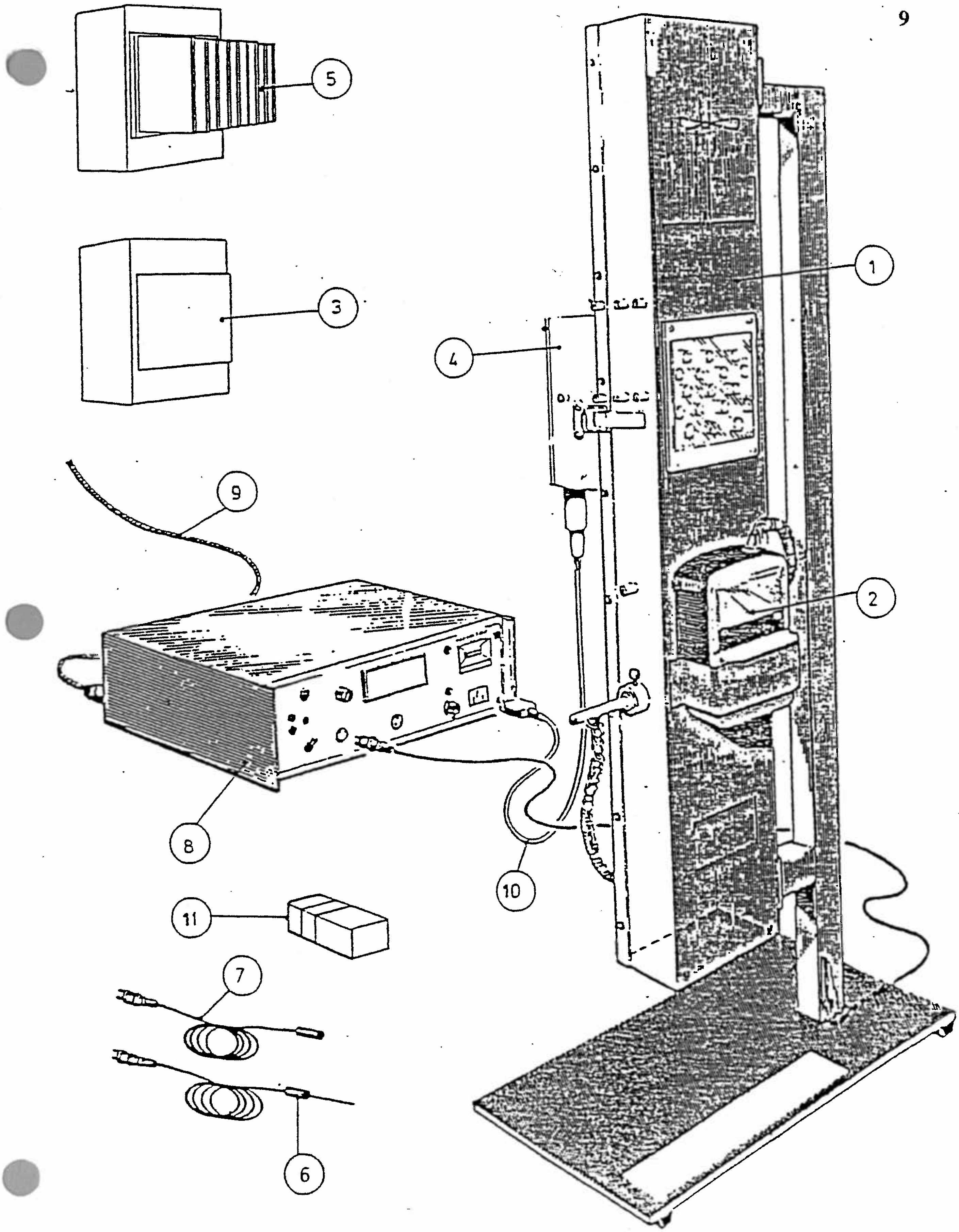


FIG 2 IDENTIFICATION DIAGRAM

H920 FREE AND FORCED CONVECTION HEAT TRANSFER UNIT

Experiments:

1. To demonstrate the relationship between power input and surface temperature in free convection.
2. To demonstrate the relationship between power input and surface temperature in forced convection.
3. To demonstrate the use of extended surfaces to improve heat transfer from the surface.
4. To determine the temperature distribution along an extended surface.
5. Comparison of a horizontal and flat plate in free convection.

NOTES

This instruction manual refers to 5 experiments which can be performed with the unit:

1. Free convection from a vertical flat surface
2. Forced convection from a vertical flat surface
3. Free/forced convection - Constant cross section (Pins)
4. Free/forced convection - Varying cross section (Fins)

E. Free convection from a horizontal flat surface

With the flat surface experiments (1, 2 and 5) it may be found difficult to achieve stable temperature conditions due to thermal inertia and the inherently low convective heat transfer coefficient. Because of the sensitivity of the heater power control, care is required to achieve stable temperatures.

N.B. (a) Current production models are fitted with a 10 turn potentiometer to reduce sensitivity.

(b) Power input required for steady state conditions between $50^\circ C < t_H > 90^\circ C$ will be found to vary between approximately 10W and 20W. Very delicate adjustment is required of the power control, especially at the lower temperatures.

(c) The heaters in the experimental modules have a temperature limit device which interrupts the power supply at 100°C and remakes it when the temperature has fallen to about 85°C.

(d) Current production models are fitted with a wattmeter with a 3 digit display indicating 00.0 to 99.9 Watts. The display will indicate 00.0 at zero or 100W which may be distinguished by the position of the potentiometer control knob. With the knob turned fully clockwise, the meter will measure between 110 and 120 Watts (indicated by 10.0 to 20.0)

The general procedure enumerated below should be found helpful in the rapid establishment of steady temperature conditions.

General Experimental Procedure

1. Note ambient air temperature (t_a).
2. Set fan control and note velocity.
3. Set heater power control so that the Wattmeter indicates about 80 to 90W.
4. Observe the rise of heater temperature (t_H) indicated by the digital thermometer and when this reads approximately 45°C, reduce power input to zero. It will be seen that the rate of temperature rise will reduce to zero at a heater temperature of approximately 50°C.
5. Carefully adjust the heater control to stabilise the temperature at about 50°C and note Input Power, Q Watts, and heater temperature, t_H, when the readings are steady.
6. Repeat this procedure for increments of heater temperature up to a maximum of 90°C.

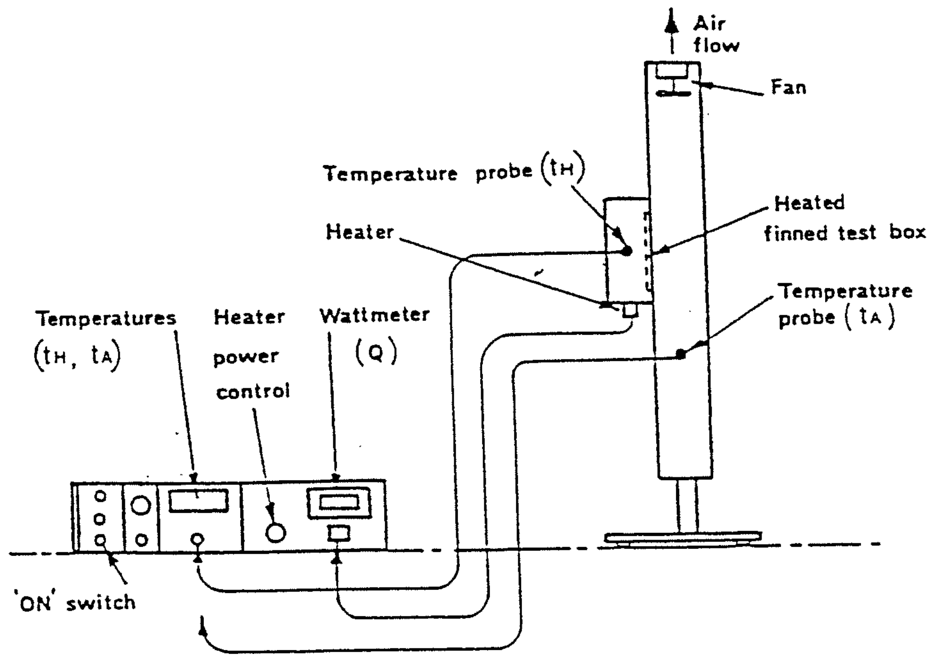
Free Convection
In this case the fan should be switched off. Check that the anemometer indicates zero velocity.

Forced Convection
Fan speed may be controlled to provide a range of readings for increments of air velocity. The readings may be of temperature against a power setting, or power required to achieve a steady temperature condition. Increments of velocity between about 1.0 m/s and maximum (approximately 2.5 m/s) are recommended.

Temperature Probe
The probe is intended for the measurement of temperature within the duct and may be inserted through the tapping points on the left-hand side. The probe tip should be smeared with a little heat conducting paste from the tube provided if surface temperatures are to be measured.

1. TO DEMONSTRATE THE RELATIONSHIP BETWEEN POWER INPUT AND SURFACE TEMPERATURE IN FREE CONVECTION.

Equipment Set-Up:



Summary of Theory:
A heated surface dissipates heat primarily through a process called convection. Heat is also dissipated by conduction and radiation, however these effects are not considered in this experiment. Air in contact with the hot surface is heated by the surface and rises due to a reduction in density. The heated air is replaced by cooler air which is in turn heated by the surface and rises. This process is called free convection.

The hotter the temperature of the surface, the greater the convective currents and the more heat (power) will be dissipated.

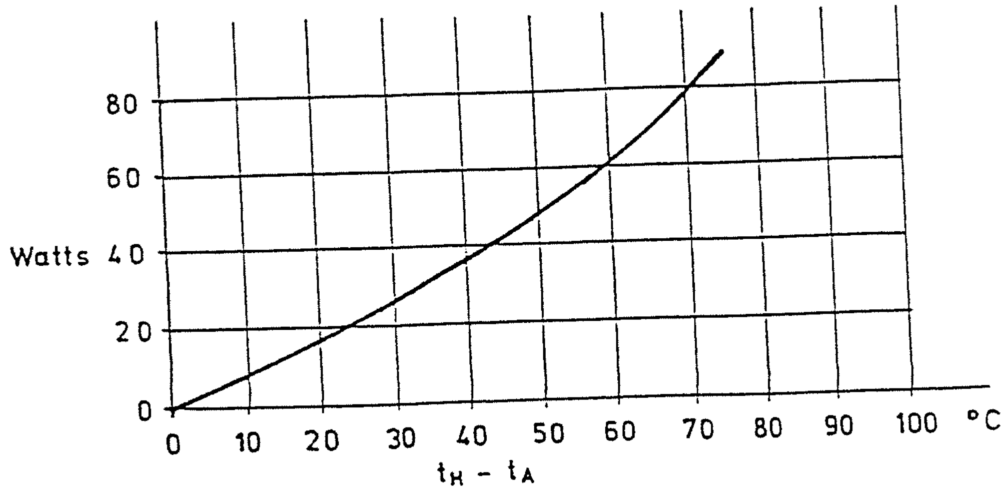
If more power is supplied to a surface, the temperature of the surface must rise to dissipate this power.

Readings to be taken:
Place the finned heat exchanger into the test duct. Record the ambient air temperature (t_A). Set the heater power control to 20 Watts. Allow sufficient time to achieve steady state conditions before noting the heated plate temperature (t_H). Repeat this procedure at 40, 60 and 80 Watts.

Results: Ambient air temperature (t_A) = °C

Input Power W	Heater Temp. (t_H) °C	t_H - t_A °C
20		
40		
60		
80		

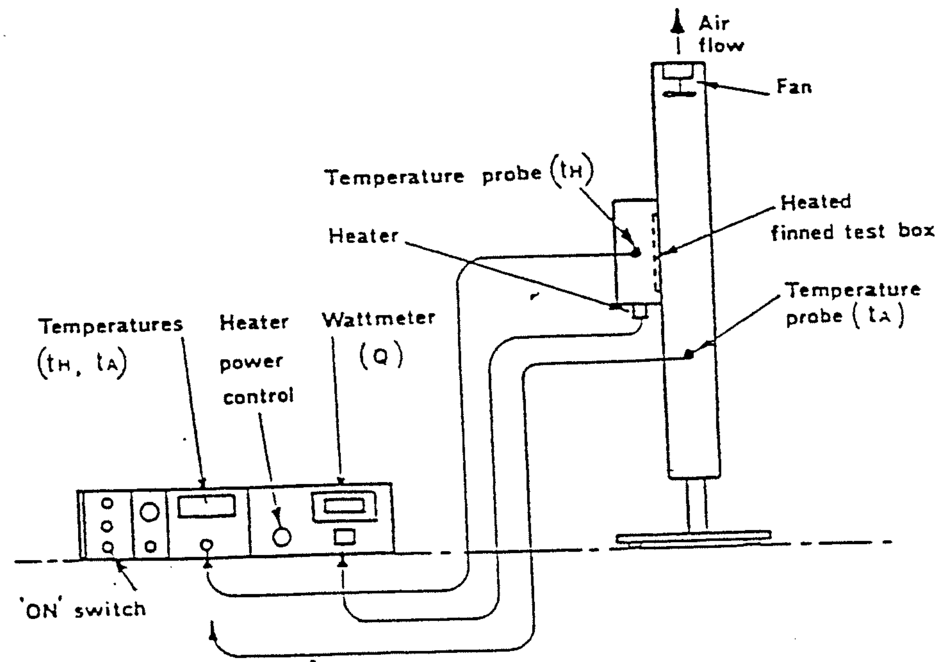
Plot a graph of power against surface temperature ($t_H - t_A$).



TYPICAL GRAPH OF POWER AGAINST SURFACE TEMPERATURE

2. TO DEMONSTRATE THE RELATIONSHIP BETWEEN POWER INPUT AND SURFACE TEMPERATURE IN FORCED CONVECTION.

Equipment Set-Up:



Summary of Theory:
In free convection the heat transfer rate from the surface is limited by the small movements of air generated by this heat. More heat is transferred if the air velocity is increased over the heated surface. This process of assisting the movement of air over the heated surface is called Forced Convection. Therefore a heated surface experiencing forced convection will have a lower surface temperature than that of the same surface in free convection for the same power input.

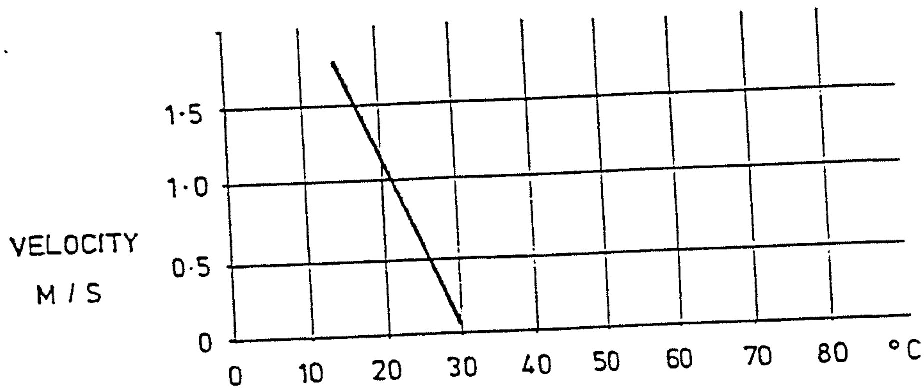
Readings to be taken:
Place the finned heat exchanger into the duct. Note the ambient air temperature (t_A). Set the heater power control to 50 Watts. Allow sufficient time to achieve steady state conditions before noting the heated plate temperature (t_H). Set the fan speed control to give a reading of 0.5 m/s on the thermal anemometer, allow sufficient time to achieve steady state conditions. Record heated plate temperature. Repeat this procedure at 1.0 m/s and 1.5 m/s.

Results: Ambient air temperature (t_A) = °C
Power input Watts = Watts

Air Velocity m/s	Heater Temp. (t_H) °C	t_H - t_A °C
0		
0.5		
1.0		
1.5		

18

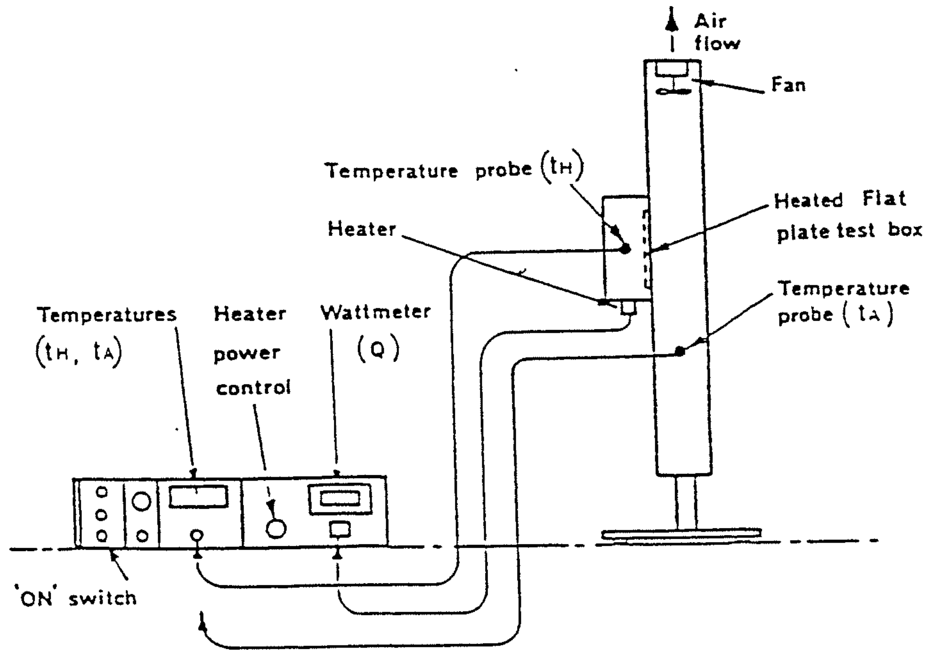
Plot a graph of air velocity against temperature.



TYPICAL GRAPH OF AIR VELOCITY AGAINST SURFACE TEMPERATURE

3. TO DEMONSTRATE THE USE OF EXTENDED SURFACES TO IMPROVE HEAT TRANSFER FROM THE SURFACE.

Equipment Set-Up:



Summary of Theory:
Heat transfer from an object can be improved by increasing the surface area in contact with the air. In practice it may be difficult to increase the size of the body to suit. In these circumstances the surface area in contact with the air may be increased by adding fins or pins normal to the surface. These features are called extended surfaces. A typical example is the use of fins on the cylinder and head of an air cooled petrol engine. The effect of extended surfaces can be demonstrated by comparing finned and pinned surfaces with a flat plate under the same conditions of power input and air flow.

Readings to be taken:
Place the flat plate heat exchanger into the duct. Record the ambient air temperature (t_A). Set the heater power control to 75 Watts. Allow the temperature to rise to 80°C, then adjust the heater power control to 20 Watts until a steady reading is obtained. Record heated plate temperature (t_H). Set the fan speed control to give 1 m/s using the thermal anemometer. Repeat this procedure at 2 and 2.5 m/s for the flat plate. Replace the flat plate with the finned plate and repeat experiment. Replace the finned plate with the pinned plate and repeat experiment.

Results: Ambient air temperature (t_A) = °C
Power input = 20 Watts

Air Velocity m/s	Heater Temp. (t_H) °C	t_H - t_A °C
0		
1.0		
2.0		
2.5		

Plot graphs of velocity against temperature for each of the plates.

Comment on the correlation between total surface area of the heat exchanger and the temperature achieved.

Further Experiments:
Increase power input and repeat experiments.