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UNIVERSITE MOHAMED BOUDIAF - M'SILA

FACULTE DES SCIENCES **DOMAINE : Sciences de la matière**

DEPARTEMENT DE PHYSIQUE **FILIERE : Physique**

OPTION : physique énergétique

3rd year license energy physics

TP : 02 The Free Convection

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Description

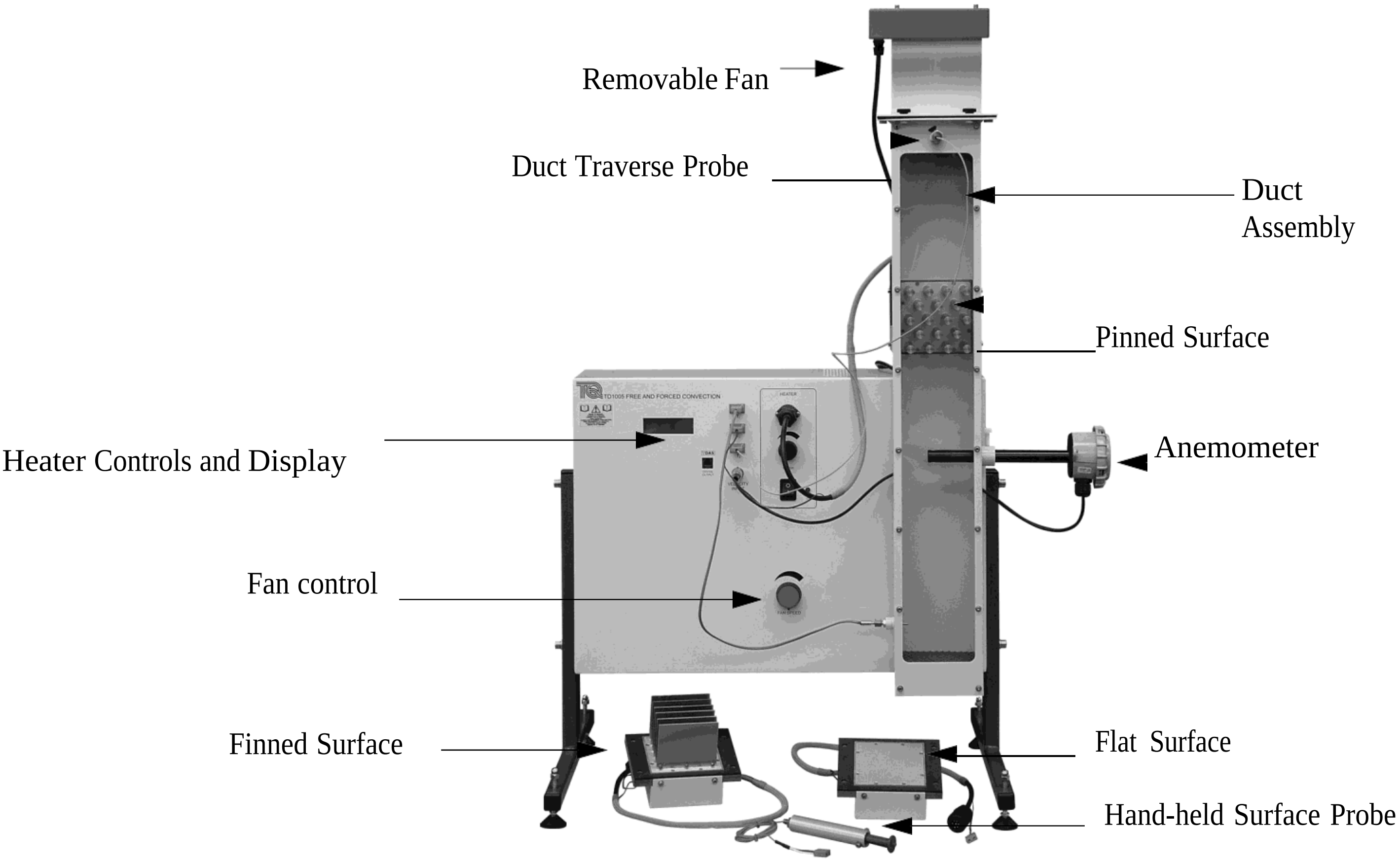

Figure 01 The Free Convection

The Main Unit

The Main Unit is a compact bench-mounting frame that connects to a suitable electrical supply. It has avertical duct assembly and a main 'Control Panel' with electrical controls and displays.
Each of the three heat transfer surfaces (supplied) fit into the back of the vertical duct, at just above half-way up the duct.
The vertical duct allows air to pass over the heat transfer surface, both by free convection, or by forced convection using a removable variable speed electric fan at the top of the duct. A fixed thermocouple probe measures the inlet (ambient) air temperature in the duct. A movable thermocouple probe in a traversing mechanism allows measurement of the temperature distribution across the duct at the outlet. This allows students to find the bulk outlet temperature for the more advanced calculations. An anemometer measures air velocity in the duct.

Each heat transfer surface includes a built-in thermocouple to measure its surface temperature. The equipment also includes a hand-held thermocouple probe for heat distribution measurement along the finned and pinned heat transfer surfaces. The user inserts the probe tip into a selection of six equally- spaced holes in the side of the duct (see Technical Details for distances). A magnetic cover allows you to cover the holes completely or so that you can only use one at a time, reducing stray convection caused by the other holes.

Figure 02 The Magnetic Cover

The Base Unit supplies safe, low-voltage electrical power to the heater (heat source) in each heat transfer surface and a variable supply for the fan at the top of the duct. The thermocouples in the duct and the thermocouple on the heat transfer surface connect to sockets on the front of the control panel. For heat distribution experiments with the hand-held probe, the user connects the probe to any unused thermocouple socket (not all are used for each experiment). A display on the control panel shows the electrical power supplied to the heater in the heat transfer surface, the air velocity in the duct and the temperature at each of the three thermocouples connected.

Flat Plate

Figure 03 The Flat Plate

This is simply a flat aluminium plate. This surface is unique from the other two, in that it fits completely flush with the inner wall of the duct and has no extra fins or pins that penetrate the duct airflow.

Finned Surface

Figure 04 The Finned Surface

This is a popular surface design used in for ‘heat sinks’ to transfer heat away from components in electrical and electronic circuits. It is also used on air-cooled combustion engines or compressors to help transfer heat away from the cylinder walls. It effectively increases the available heat transfer surface area to help transfer more heat into the surrounding air (or capture heat from the surrounding air if used inreverse). This surface is useful for a demonstration of free convection both vertically (up from the fins) and horizontally (with fins horizontal). The holes in the side of the duct allow the user to probe the temperature along a fin, to see the change in temperature (heat distribution) along it.

Pinned Surface

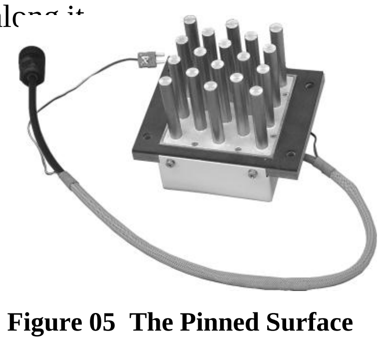

Figure 05 The Pinned Surface

This is a popular surface design used in ‘heat exchangers’, where one fluid flows along the pins (usually hollow tubes) at right angles to the flow of another fluid that passes around the pins. The heat energy in the hotter fluid passes through the surface of the pins or tubes into the colder fluid.

Again, as with the finned surface, this surface effectively increases the available heat transfer surface area to help transfer more heat into the surrounding fluid (or air as used in the experiment).

The holes in the side of the duct allow the user to probe the temperature along a pin, to see the change in temperature (heat distribution) along it.

Free Convection

This is when the heat transfers from the object under the influence of fluid (air) density changes. The heat energy around the object causes the air density around the surface of the object to decrease. The reduced density air is more buoyant than the surrounding air and rises, transporting the heat energy away naturally. In normal conditions gravity is the main force affecting buoyancy and therefore convection. However, where the object forms part of a rotating machine, centrifugal force can be a driving force for convection.

Heat Transfer Coefficient (Convective) (hc)

Heat transfer coefficient is a material's ability to conduct heat to another material.

Convective heat transfer occurs between the surface of a material and a moving fluid. Liquid boiling and condensing are examples of convective heat transfer.

Typical values of heat transfer to air are:

5 to 25 W/m^2K in ***free***

Nusselt Number (Nu)

A Nusselt number applies to heat transfer. It is a dimensionless value of the ratio of convective to conductive heat transfer across a boundary. It can also give an indication of convective flow - a lownumber (near to 1) shows that flow is laminar, while a high number (greater than 100) shows that flowis turbulent.

As with the velocity probe, a single point measurement of downstream temperature may not give anaccurate value for the bulk temperature of the air. The theory and experiments show that the extended surfaces give a thermal gradient along their length which you can see will transfer to the air passing over them and therefore up the duct. The geometry, thermal conduction of the extended surfaces and the air velocity all affect the temperature profile. However, the upper probe allows a traverse across the duct so you can use simple averaging or integration of the temperature values to give sensible values of T_{out}.

Experiment 1: Free Convection - Fixed Power

Power = 15 W			
Heat Transfer Surface	T 2	T 1	
	Surfa ceTs (°C)	Duct Inlet (ambien t)Tin (°C)	Differen ceT_S - T_{IN} (°C)
Flat Plate			
Pinned			
Finned			

Table 1 Blank Results Table

Results Analysis

For each set of results, subtract the inlet temperature from the heat transfer surface temperature to complete your results tables. The temperature difference gives a value with respect to ambient, helping to allow for changes in local conditions.

Compare the results. Which surface created the highest temperature difference in free convection? Whatdoes this say about this surface?

Experiment 2: Free Convection

Heat Transfer Surface: Power = 90 W			
	T_2	**T_1**	
Time (seconds)	**Surface T_S (°C)**	**Duct Inlet (ambient) T_{IN} (°C)**	**Difference T_S - T_{IN} (°C)**
0			
10			
20			
30			
40			
50			
60			
70			
80			
90			
100			
110			
120			
130			
140			
150			
160			
170			
180			
190			
200			

Table 2 Blank Results Table

Results Analysis

For each table of results, subtract the inlet temperature from the heat transfer surface temperature to complete your results tables. The temperature difference gives a value with respect to ambient, helping to allow for changes in local conditions.

Create a chart of temperature difference (vertical axis) against time. Add to this chart your results fromall three surfaces to see the relationship and compare results. Do not use the first line (zero seconds) results in your chart, as this is only for reference.

Which surface took the most time to reach 70°C? Look at the **Technical Details** for the surfaces andcompare the different masses. Each surface is made of the same material and the back side of each is ofidentical construction and mass, so do the results confirm the thermal inertia theory?

Why can you only use this test as a general comparison?

What does this test tell you about the importance of waiting for equilibrium (as in the earlier experiment)?

Experiment 3: Free Convection - Power and TemperatureRelationship

Heat Transfer Surface: Pinned/Finned			
Power (W)	**T2** Surface T_S (°C)	**T1** Duct Inlet (ambient) T_{IN} (°C)	**Differen ceT_S - T_{IN} (°C)**
0			
5			
10			
15			
20			
25			
30			
35			
40			
45			
50			

Table 3 Blank Results Table

1. For reference only, take readings of the surface and inlet temperatures with no power applied.
2. Switch on the heater and set to 5 Watts power.
3. ***Wait for the temperatures to stabilise*** and then record surface and inlet temperatures.
4. Repeat for several more heater powers as shown in the results table, stopping before the

surfacereaches 95°C.

5. Switch off the heater and allow the surface to cool down to near ambient temperature.
6. If you have time, repeat the experiment for the other heat transfer surface (Pinned or Finned).

Results Analysis

For each table of results, subtract the inlet temperature from the heat transfer surface temperature to complete your results tables. The temperature difference gives a value with respect to ambient, helping to allow for changes in local conditions.

Create a chart of power (vertical axis) against temperature difference. Add to this chart your results fromboth surfaces to see the relationship and compare results.