**OLABISI ONABANJO UNIVERSITY**

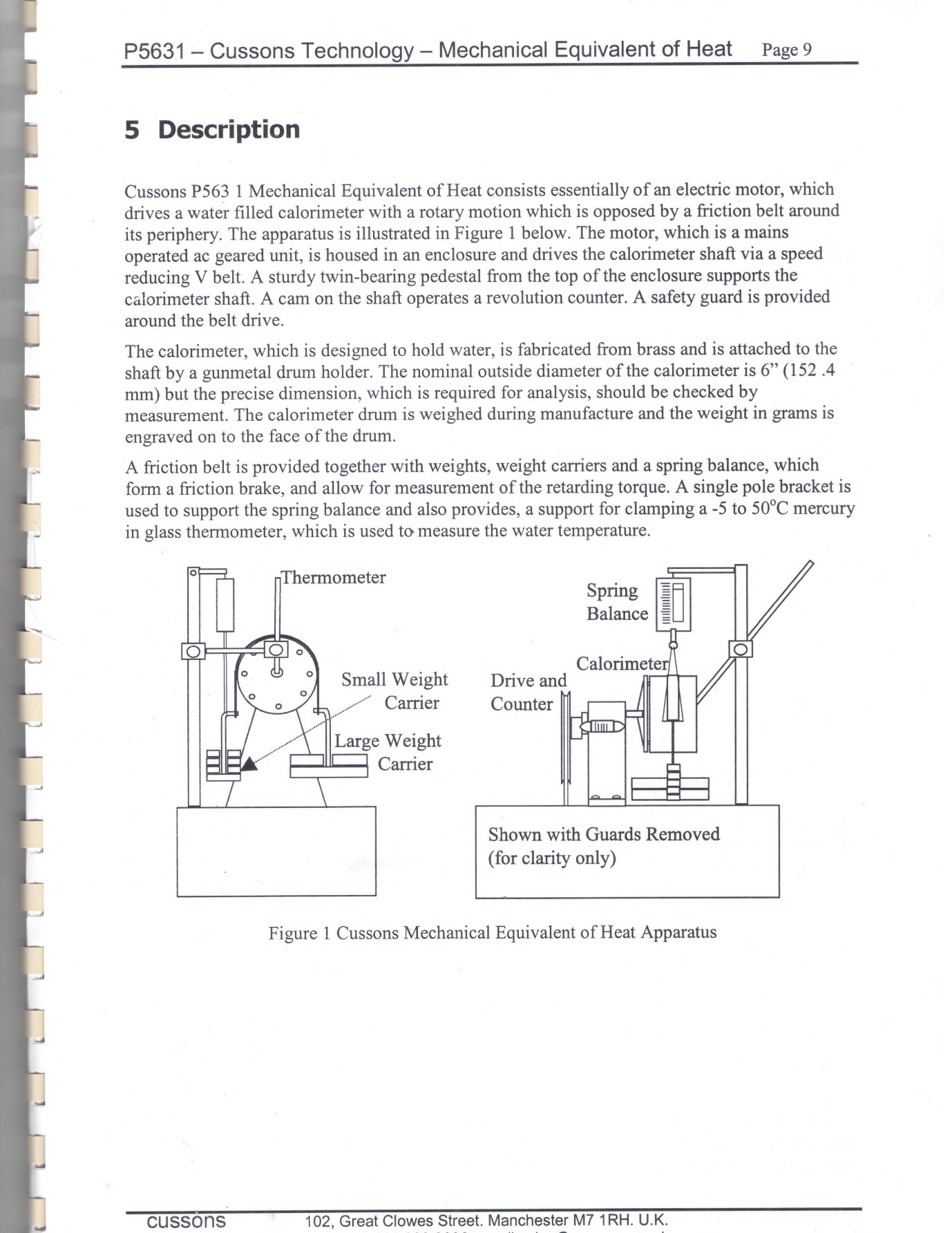
College of Engineering & Environmental Studies,

Faculty of Engineering

Ibogun Campus.

MECHANICAL ENGINEERING DEPARTMENT



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ENGINEERING THERMODYNAMICS

LABORATORY MANUAL

200 LEVEL

**NAMES……………………………………………………………………………………………………..**

**MATRIC. NO. :……………………………………… LEVEL: …………………………………………**

**DEPT.: ………………………………………………...GROUP NO: ……………………………………**

**COURSE:………………………………………………. CODE: ………………………………………..**

**DATE:…………………………… SESSION: ………………………SIGNATURE…………………….**

** OLABISI ONABANJO UNIVERSITY**

**COLLEGE OF ENGINEERIG & ENVIRONMENTAL STUDIES**

**DEPARTMENT OF MECHANICAL ENGINEERING**

**IBOGUN CAMPUS**

**THERMODYNAMICS PRACTICALS (200 LEVEL)**

**Introduction**

A calorimeter is a device that thermally isolates an experiment from its surroundings. Ideally, this means that the results of an experiment performed in a calorimeter are independent of the temperature of the surroundings, because no heat flows into or out of the calorimeter.

However, no calorimeter is perfect, and there is always some unwanted and unaccountable heat flow affecting the results of any calorimetric experiment. To minimize unwanted heat flow, always plan the experiment so that: *the time between the taking of initial and final temperatures is minimal.*

In other words, do the critical portion of the experiment quickly, so there is minimal time for unwanted heat flow between measurements. Don’t rush; just plan carefully.

**EXPERIMENT 1**

**Title:** Specific Heat Capacity

**Aim**: To Determine the Specific Heat Capacity of Solids

**Apparatus/Material**: Copper calorimeter, stirrer, weighing machine, water, thermometer

**Theory:**

The specific heat capacity of a solid substance in block is determined by this method. When the

solid is heated and introduced in to water in a calorimeter, the heat loss by the solid is equal to

heat gain by the water and calorimeter.

Mathematically:

Heat loss by solid = heat gain by water and calorimeter …………………….(1)

Heat loss by solid = yx(ts2-t2)

Heat gain by water = mwCw (t2-t1)

Heat gain by calorimeter = mcCc(t2-t1)

From equation (1)

yx(ts2-t2) = mwCw (t2-t1) + mcCc(t2-t1) ………………………(2)

The specific heat capacity of the solid is equal to the heat capacity of the solid per unit mass of

Solid i.e X = y/ms …………………………………….(3)

Where:

y = the specific heat capacity of the solid J/k

ms =mass of the solid, g

ts2 = temperature of the solid

t1 = initial temperature of water

mw = mass of water, g

mc = mass of copper calorimeter, g

Cw = the specific heat capacity of water = 4.2 J/gk

Cc = the specific heat capacity of copper calorimeter = 0.4 J/gk

Cs = specific heat capacity of the solid, J/gk

**Procedure**

a. Weigh the calorimeter empty.

b. Partly fill the calorimeter by 2/3 with cold water and reweigh.

c. Determine the mass of water.

d. Record water initial temperature.

e. Place the calorimeter in the lagged jacket.

f. Measure the mass of the solid by weighing.

g. Record initial solid temperature.

h. Heat solid as shown above and record its temperature.

i. Transfer the solid with of the string into the water in the calorimeter and stir note the maximum temperature after stirring.

**Result:**

Record your results as follows:

Mass of calorimeter =

Mass of water + calorimeter =

Mass of water =

Mass of substance =

Initial water temperature =

Final water temperature =

Temperature of hot solid =

**Exercises**

1 Determine solid heat capacity

2 Determine solid specific heat capacity

3 Why do you shake the solid on removal from the hot water?

4 Why do you cover the calorimeter with an insulating lid?

5 How is the calorimeter heat loss by radiation minimized?

6 How is heat loss by convection eliminated?

7 Compare your result with the generally accepted value for the specific heat capacity value of

the solid?

8. What are the precautions to be observed during your experiment?

**PRACTICAL REPORT NOTES**

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**Experiment 2**

**Title:** Specific Heat of Metals

**Objectives:** To determine thespecific heats of a number of metals

**Introduction**

The Specific Heat of a substance is the amount of heat required to raise the temperature of one gram of the substance by one degree centigrade, usually indicated by the symbol C.

From the definition of the calorie, it can be seen that the specific heat of water is 1.0 cal/g°C.

If an object is made of a substance with specific heat equal to csub, then the heat, ΔH, required to raise the temperature of that object by an amount ΔT is: ΔH = (mass of object) (csub) (ΔT).

In this experiment you will measure the specific heats of a number of metals given, including

aluminum, copper, mild steel and brass.

**Equipment/Materials required:**

Calorimeter

Thermometer

Metal Samples - aluminum, mild steel, copper and brass

Balance

Boiling water

Cool water

Thread

**Procedure**

**The Specific Heats of Aluminum, Copper or Lead**

a. Measure the mass Mcal,of the empty and dry calorimeter you will use. Record your result.

b. Measure the masses of the aluminum, mild steel, copper or brass samples. Record these masses in in the row labeled Msample.

c. Attach a thread to each of the metal samples and suspend each of the samples in boiling water. Allow a few minutes for the samples to heat thoroughly.

d. Perform steps (a) through (c) for each metal sample.

e. Fill the calorimeter approximately 1/2 full of cool water - use enough water to easily cover any one of the metal samples.

f. Measure Tcool, the temperature of the cool water, and record your measurement in the table.

g. Immediately following your temperature measurement, remove the metal sample from the

boiling water, quickly wipe it dry, then suspend it in the cool water in the calorimeter (the

sample should be completely covered but should not touch the bottom of the calorimeter).

h. Stir the water with your thermometer and record Tfinal, the highest temperature attained by

the water as it comes into thermal equilibrium with the metal sample.

i. Immediately after taking the temperature, measure and record Mtotal, the total mass of the

calorimeter, water, and metal sample.

**Table 2.1: Table of results and calculations**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Trial 1** | **Trial 2** | **Trial 3** |
| Mcal (g) |  |  |  |
| Msample (g) |  |  |  |
| Tcool (°C) |  |  |  |
| Tfinal (°C) |  |  |  |
| Mtotal (g) |  |  |  |
| MH2O |  |  |  |
| ΔTH2O |  |  |  |
| c (cal/gm°C) |  |  |  |

For each metal tested, use the equations shown below to determine MH2O, the mass of the water used, ΔTH2O, the temperature change of the water when it came into contact with each metal sample, and ΔTsample, the temperature change of the metal sample when it came into contact with the water.

Record your results in table.

**M**H2O = **M**final - (**Mcal** + **Msample**);

Δ**T**H2O = **T**final - **T**cool;

Δ**Tsample = 100** °**C - T**final

From the law of conservation of energy, the heat lost by the metal sample must equal the heat gained by the water:

Heat lost by sample = (**Msample**) (**csample**) (Δ**Tsample**) **=** (**M**H2O) (CH2O) (Δ**T**H2O) = Heat gained by water (**C**H2O is the specific heat of water, which is **1.0 cal/g**°**C**.)

Use the above equation, and your data collected, to solve for the specific heats of each metal samples.

**NOTE:** This experiment involves the use of boiling water and the handling of **HOT** metal objects. Work carefully. **SAFETY FIRST.**

**PRACTICAL REPORT NOTES**

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**Experiment 3**

**Title:** Heat Energy

**Objectives: To** determine the amount of heat energy transferred and heat energy conserved

**Equipment/Materials:** Calorimeter, Weigh Balance, Thermometer, Hot and cold water

**Introduction**

When two systems or objects of different temperature come into contact, energy in the form of heat is transferred from the warmer system into the cooler. This transfer of heat raises the temperature of the cooler system and lowers the temperature of the warmer system. Eventually the two systems reach some common, midway temperature, moreover the heat transfer stops.

The standard unit for measuring heat transfer is the calorie. A calorie is the amount of energy required to raise the temperature of one gram of water by 1°C (one degree Celsius).

In this experiment, you will combine hot and cold water of known temperature and mass. Using the definition of the calorie, you will be able to determine the amount of heat energy that is transferred in bringing the hot and cold water to their final common temperature, and thereby determine if heat energy is conserved in this process.

**Procedure**

a. Determine the mass of the empty calorimeter, Mcal. and record your result in table

b. Fill the first calorimeter to about 1/3 full with cold water. Weigh the calorimeter and cold water together to determine Mcal + H2O,cold. Record your result.

c. Fill a second calorimeter to approximately 1/3 full of hot water. The water should be at least

20°C above room temperature. Weigh the calorimeter and hot water together to determine

Mcal + H2O, hot. Record your result

d. Measure the temperatures in degrees Celsius of the hot and cold water, Thot and Tcold, and

record your results.

e. Add the hot water to the cold water immediately after measuring the temperatures, and stir with the thermometer until the temperature stabilizes.

f. Record the final temperature of the mixture, Tfinal.

g. Repeat the experiment twice with different masses of water at different temperatures.

(You could try adding cold water to hot instead of hot to cold.)

Table 3.1: Table of results

|  |  |  |  |
| --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 |
| Mcal |  |  |  |
| Mcal + H2O, cold |  |  |  |
| Mcal + H2O, hot |  |  |  |
| Thot |  |  |  |
| Tcold |  |  |  |
| Tfinal |  |  |  |
| Mfinal |  |  |  |
|  |  |  |  |

**Calculations**

From your data,

a. determine the mass of the combined hot and cold water

b. the temperature changes (ΔT) undergone by each.

c. using the equations shown below, calculate ΔHcold and ΔHhot, the heat gained by the cold

and hot water, respectively. Enter your results in the table.

**d.** Δ**H**cold **=** (**M**H2O, cold) (Δ**T**cold) (**1 cal/gm**°**C**);

Δ**H**hot = (**M**H2O, hot) (Δ**T**hot) (**1 cal/gm**°**C**

**Table 3.2: Table of Calculations**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 |
| MH2O, cold |  |  |  |
| MH2O, hot |  |  |  |
| ΔThot |  |  |  |
| ΔTcold |  |  |  |
| ΔHcold |  |  |  |
| ΔHhot |  |  |  |

**Questions**

1. Which one had more thermal energy between the two cups of water before they were mixed together or after they were mixed? Was energy conserved?

2. Discuss any unwanted sources of heat loss or gain that might have had an effect on the

experiment.

3 If 150 grams of water at 75°C were added to 100 grams of water at 10°C, what would be the

final equilibrium temperature of the mixture?

4. What are the precautions to be observed during the experiment?

**PRACTICAL REPORT NOTES**

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EXPERIMENT 4

TITLE: MECHANICAL EQUIVALENT OF HEAT

AIM/OBJECTIVE: To determine the mechanical equivalent of heat and verify the first law of thermodynamics.

EQUIPMENT/APPARATUS: Electric motor, Calorimeter, friction belt, revolution counter, weight hanger, weight, spring balance, glass Thermometer.

INTRODUCTION:

Mechanical equivalent of heat essentially consists of an electric motor, which drives a water filled calorimeter with a rotary motion which is opposed by a friction belt around its periphery. The apparatus is shown in figure below. The motor is a main operated ac geared unit, which is housed in an enclosure and drives with the calorimeter shaft through a speed reducing V belt. A sturdy twin bearing pedestal from the top of the enclosure support the calorimeter shaft. A cam on the shaft operates a revolution counter. A safety guard is provided around the belt drive.

The calorimeter which is design to hold water is fabricated from brass and is attached to the shaft by a gunmetal drum holder. The nominal outside diameter of the calorimeter is 6” (152.4 mm), but the precise dimension, which is required for analysis, should be checked by measurement. The calorimeter drum is weighed during manufacture and the weight in grams is engraved on to the face of the drum.

A friction belt is provided together with weights, weight carriers and a spring balance, which form a friction brake, and allow for measurement of the retarding torque. A single pole bracket is used to support the spring balance and also provides a support for clamping a -5 to 500C mercury in glass thermometer, which is used to measure the water temperature.

THEORY:

First law of thermodynamics is the principle of the conservation of energy when applied to a closed system in which only energy in the form heat or work can cross the boundary of the system. i.e Q = W

If, a system does not follow a cycle but undergoes a process, then a corollary of the first law is that: Q γ W

Which state as “There exists a property of a closed system such that a change in its value is equal to the difference between the heat received and the work done during any change of state.”

The property is called an Internal Energy U and it is represented with equation

Q –W = ∆U (called Non Flow Energy Equation NFEE)

APPLICATION:

Appling the first law of thermodynamics to Mechanical Equivalent of Heat requires a number of definitions to be made and some assumptions simplifying.

System- Let the system be defined as the calorimeter drum, the band brake and the water contained in the drum.

Work Done- Work is done on the system by the electric motor which impart relative movement between the calorimeter drum and the band brake. The band brake grips the drum and the motor has to overcome the friction force, which is measured by the force that has to be applied to restrain the band brake from rotating.

Restraining Force, F = WL – WS + S

The product of the restrain force and circumference of the drum gives the work done per revolution i.e the restrain force x circumference of the drum = the work done per revolution

W = πDF = πD (WL – WS + S)

And the total work done during the time period is

W = πDFN = πD (WL – WS + S)N

Where N is the number of revolutions.

Heat Transfer- If heat transfer provided the temperature difference between the system is very small, then the heat transfer to the surrounding will also be very small.

Diagram

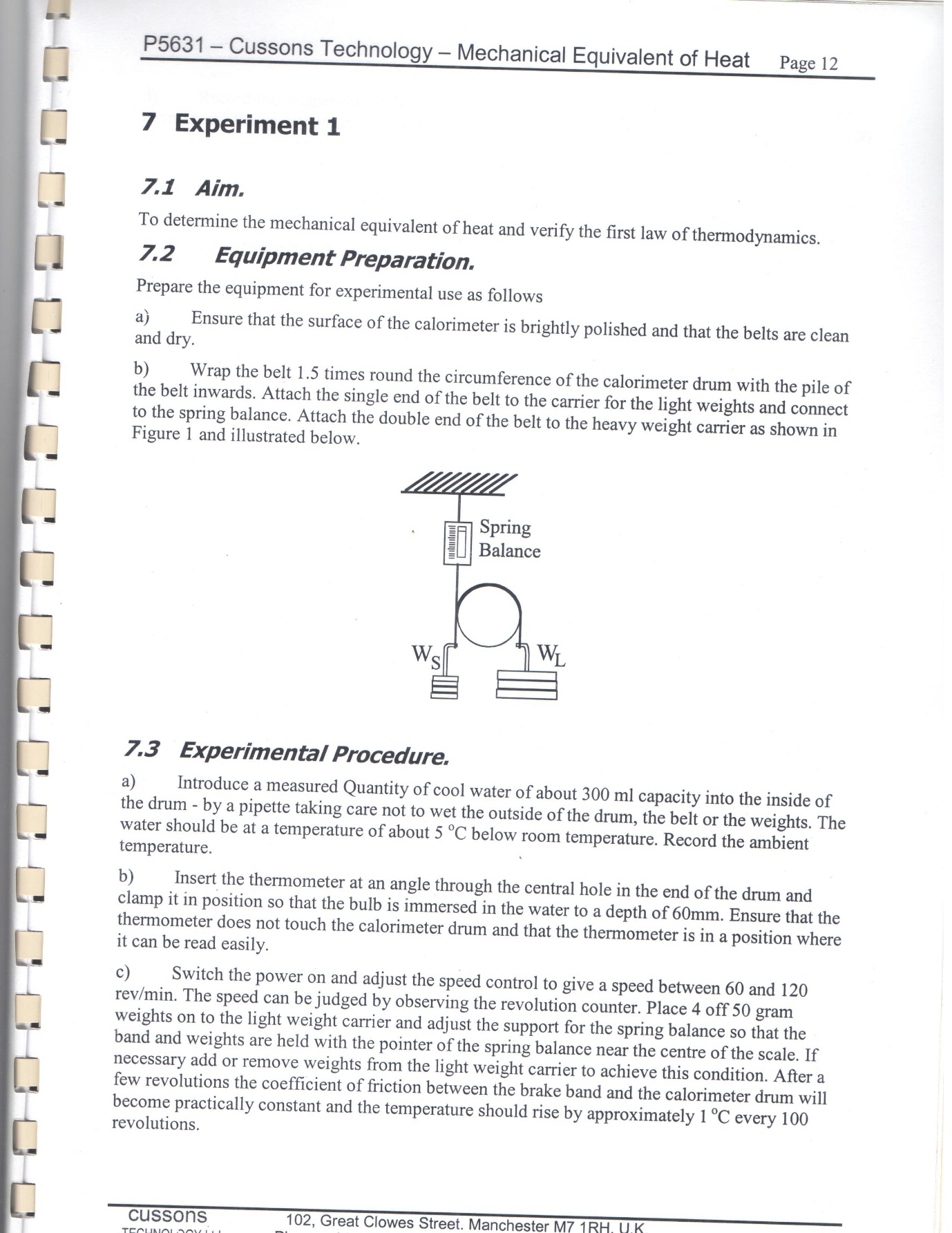
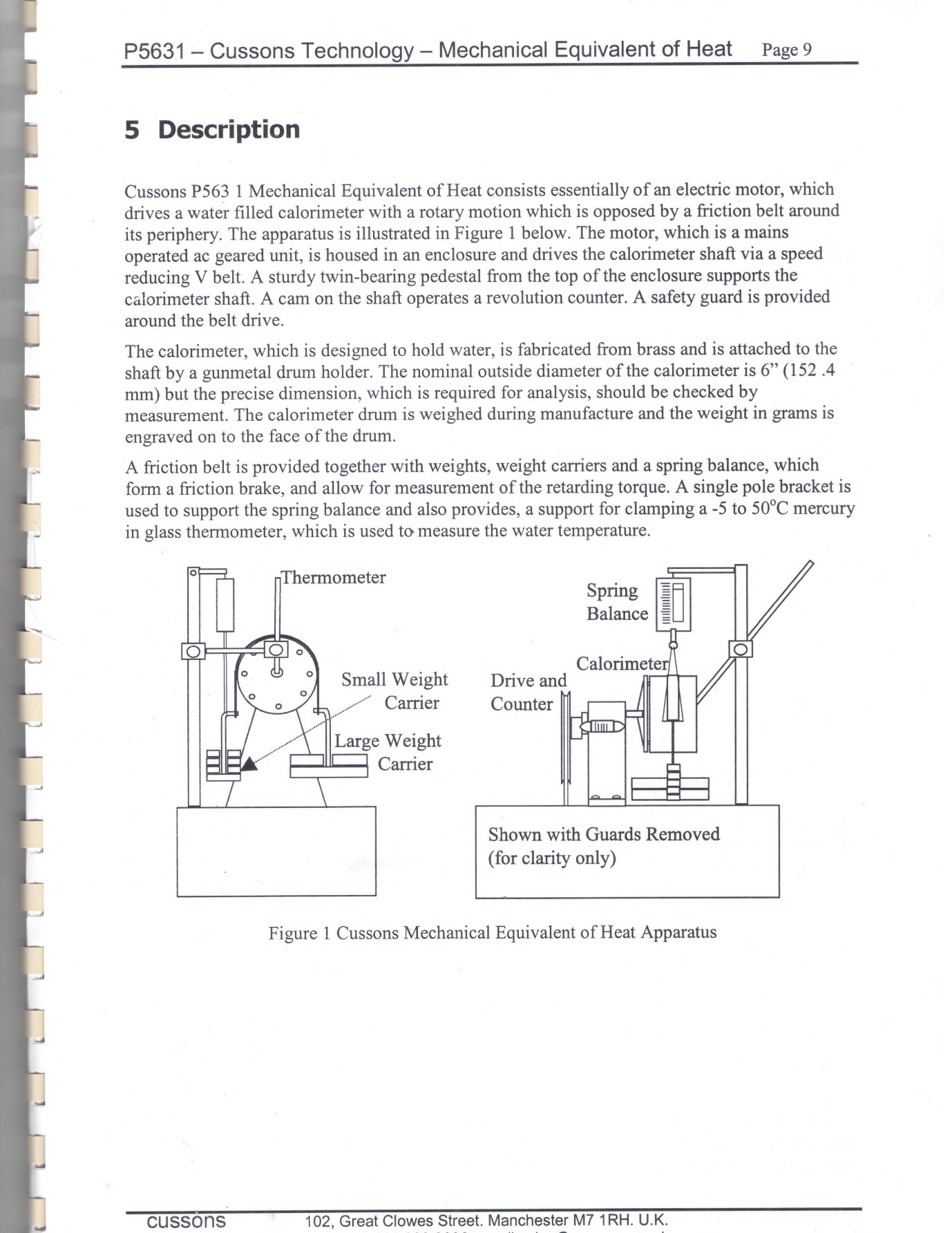


Figure 4.1: Mechanical Equivalent of Heat Apparatus

PROCEDURE:

Equipment preparation:

(a) Ensure that the surface of the calorimeter is brightly polished and that the belts are clean and dry.

(b) Wrap the belt 1.5times round the circumference of the calorimeter drum with the pile of the belt inwards. Attach the single end of the belt to the carrier for the light weights and connect the spring balance. Attach the double end of the belt to the heavy weight carrier as shown in the diagram below.

(i) Introduce a measured quantity of cool water of about 300ml capacity into the inside of the drum by a pipette taking care not to wet the outside of the drum, the belt or the weights. The water should be at a temperature of about 50C below room temperature. Record the ambient temperature.

(ii) Insert the thermometer at an angle through the central hole in the end of the drum and clamp it in position so that the bulb is immersed in the water to a depth of 60mm. Ensure that the thermometer does not touch the calorimeter drum and that the thermometer is in a position where it can be read easily.

(iii) Switch the power on and adjust the speed control to give a speed between 60 and 120 rev/min. The speed can be judged by observing the revolution counter. Place 4 off 50gram weights on the light weight carrier and adjust the support for the spring balance so that the band and weights are held with the pointer of the spring balance near the centre of the scale. If necessary add or remove weights from the light weight carrier to achieve this condition. After a few revolutions the coefficient of friction between the brake and the calorimeter drum will become practically constant and the temperature should rise approximately 10C every 100 revolution.

(iv) Record the temperature of the water, the number of revolutions shown on the revolution counter and the spring balance reading. Repeat these readings either once per minute or every 100 revolutions to suit your preference. Continue the experiment until the water temperature is 50C higher than the room temperature, again record the ambient temperature.

(v) Record the value of the large weights and small weights including the weights of the carriers.

RESULTS AND ANALYSIS

Table 4.1: Table of results.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S/N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Revolution Counter Reading |  |  |  |  |  |  |  |  |
| Water Temperature 0C |  |  |  |  |  |  |  |  |
| Spring Balance |  |  |  |  |  |  |  |  |
| Ambient Temperature 0C |  |  |  |  |  |  |  |  |
| Large Weights and Carrier Kg |  |  |  |  |  |  |  |  |
| Small Weights and Carrier g |  |  |  |  |  |  |  |  |
| Mass of water g |  |  |  |  |  |  |  |  |
| Specific heat of water J/g0C | 4.1855 |  |  |  |  |  |  |  |
| Mass of Calorimeter g |  |  |  |  |  |  |  |  |
| Specific heat of Calorimeter | 0.368 |  |  |  |  |  |  |  |

EXERCISES

Select from the table of results those readings, which cover a range of at least 500 revolutions during which time the water temperature rose from below the mean ambient temperature to above the mean ambient temperature.

Using a consistent set of units calculate

(a) the mechanical work done from

     Work Done = (WL – WS + S) N πD

(b) the heat generated from

     Heat Generated = MH2O CH2O McalCcal)∆T

(c) the mechanical equivalent of heat from

     J = Work Done/Heat Generated

NOTE: Ensure that the Calorimeter is empty and dry before storage. Remove the belt from the apparatus and wrap it in paper for storage. Never use any hard material to clean the surface of the Calorimeter.

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