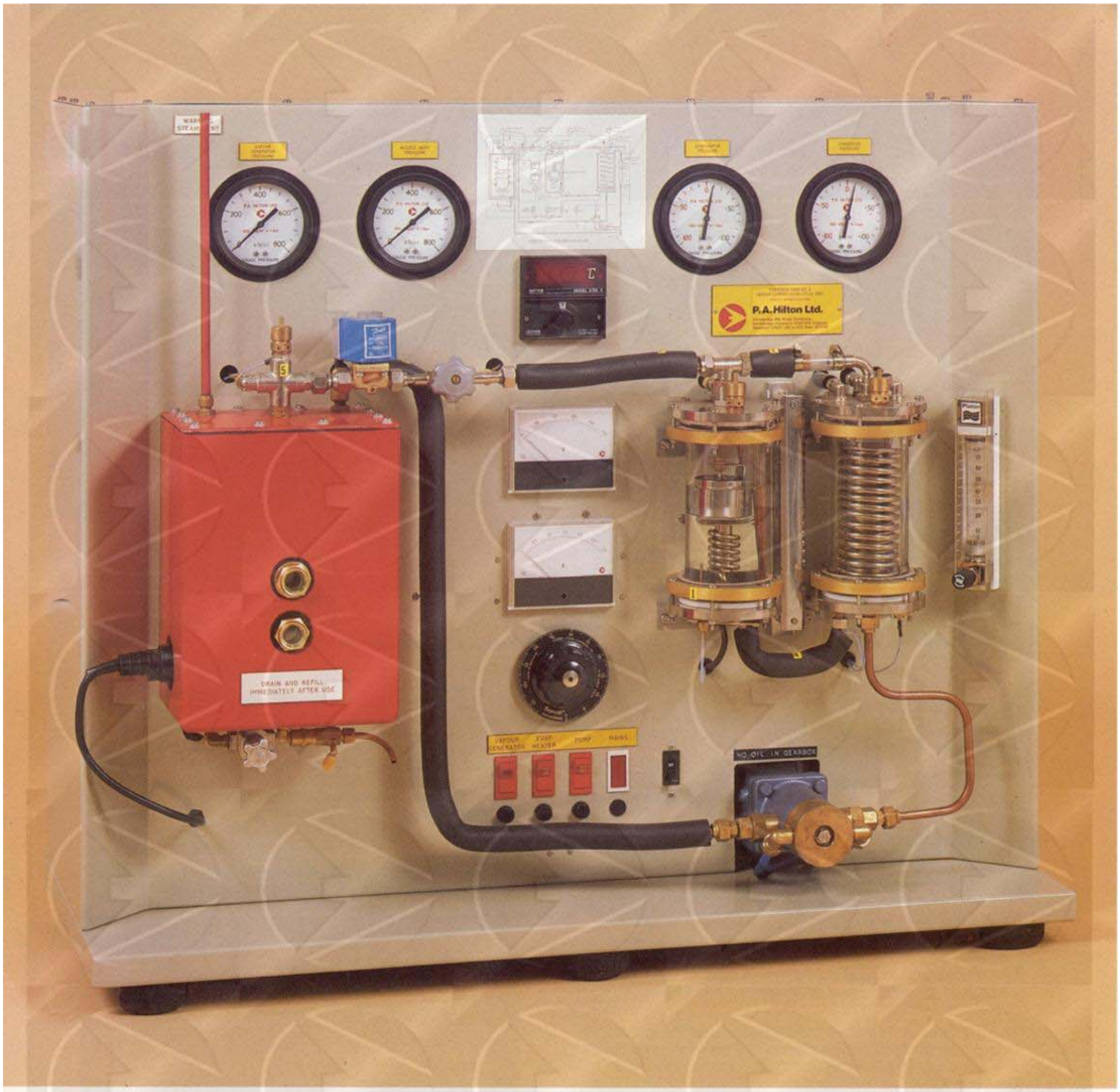


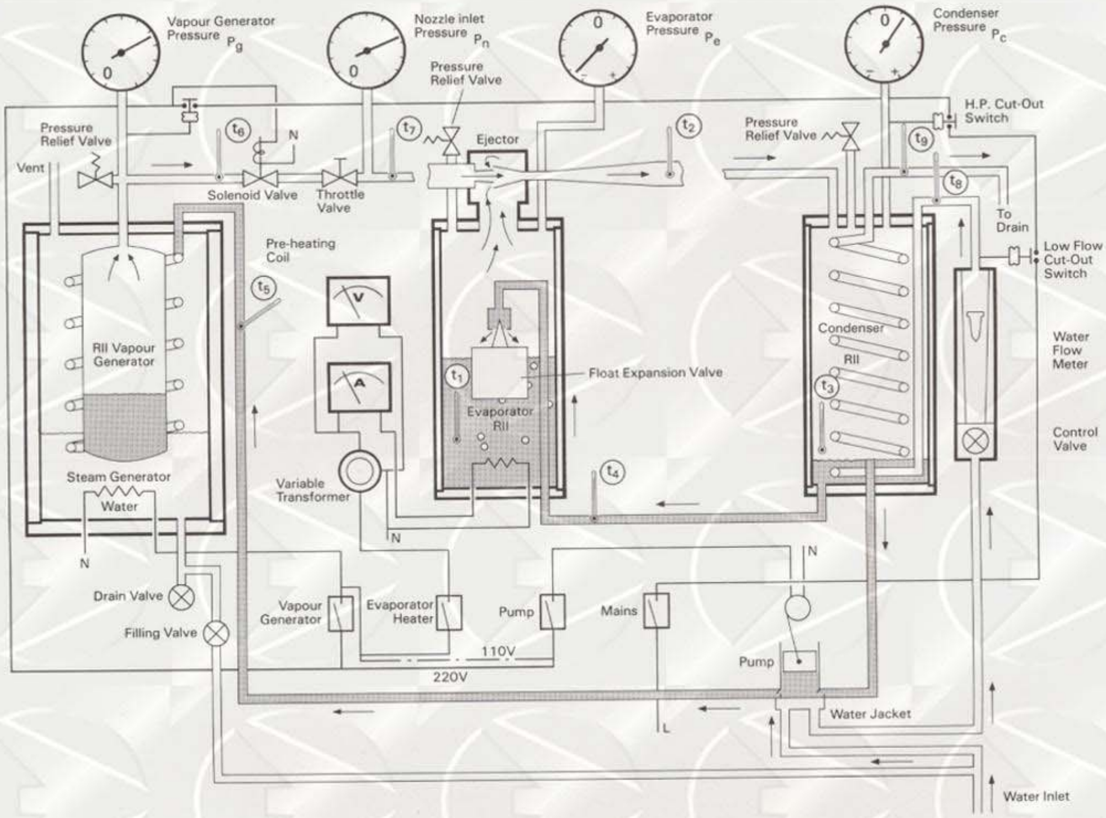

# Vapour Jet Refrigerator/Heat Pump R850

Model No R852 has replaced Model No R850. Model R852 has a revised panel layout and improved design of vapour generator, pump, evaporator heater and ejector. The vapour generator heater rating has been increased to 2kW and the evaporator heater rating has been slightly reduced. The working fluid is R141b, instead of R11, the use of which is being phased out under the terms of the Montreal Protocol.

Engineering Laboratory
Teaching Equipment

**P. A. Hilton Ltd.**

# Vapour Jet Refrigerator/Heat Pump R850




The Hilton Vapour Jet Refrigerator/Heat Pump has been specifically designed for student use. It provides for a visual and quantitative assessment of the characteristics of a refrigerator or heat pump which uses a HEAT INPUT instead of the more usual work input from an electric motor.

The unit works on a combined Rankine and Vapour Compression Cycle, and employs the same energy chain (from the primary fuel) as does the common refrigerator or heat pump, i.e.

HEAT INPUT at generating station

↓

WORK PRODUCTION

↓

WORK TRANSFER to drive refrigerator or heat pump

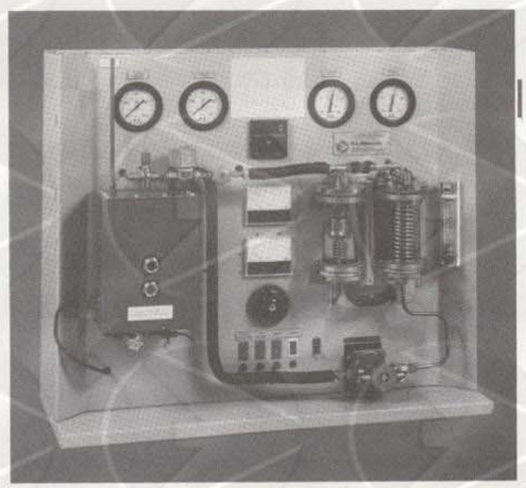
↓

COOLING or HEATING effect at refrigerator or heat pump

All of these processes take place in a bench top unit, working at moderate temperatures and pressure and, where possible, constructed in glass.

The interesting and stimulating range of investigations possible make this unit of interest to those involved with courses in:

**Thermodynamics**
**Refrigeration**
**Air Conditioning**
**Plant and Process Engineering**
**Energy Management and Conservation**



## Special features

- Believed to be the only teaching unit commercially available to demonstrate and investigate the combined Rankine and Vapour Compression Cycle.
- Is an example of a refrigerator or heat pump driven by a HEAT INPUT as opposed to the more usual work input.
- Uses hot water as the 'high grade' heat source, thus limiting the maximum temperature to 100°C.
- As a heat pump, the unit shows approximately the same primary energy ratio as a work-driven heat pump.
- Evaporation and condensation may clearly be seen through glass cylinders.
- Has no moving parts other than a low speed reciprocating feed pump.
- All important components are mounted on the front panel.
- Quickly responds to a change in operating conditions.
- Easily controlled and safe for students to operate.

## Experimental capabilities

- Analysis of the combined Rankine and Vapour Compression Cycle.
- Demonstration of the characteristics of an ejector or thermo compressor.
- Production of performance curves as a refrigerator and comparison with ideal Rankine/Vapour Compression Cycle.
- Production of performance curves as a heat pump and comparison with ideal Rankine/Vapour Compression Cycle.
- Investigation of entrainment mass ratio at various pressures.
- Demonstration of 'adiabatic' mixing of hot and cold vapour.
- Demonstration of 'adiabatic' throttling.

# Introduction

Refrigerators and Heat Pumps are machines which extract heat from a low temperature region and reject heat to a region at a higher temperature. If the prime function of the machine is to extract heat from a low temperature region, the machine is a REFRIGERATOR. Conversely, if the prime function is to deliver heat at a useful temperature, the machine is a HEAT PUMP.

The Laws of Thermodynamics indicate that the transfer of heat from a cold to a hot body is impossible without the aid of external assistance, i.e. a high grade energy input. This input can be in the form of a WORK TRANSFER or of a HEAT TRANSFER AT A HIGH TEMPERATURE.

Since work is the most valuable form of energy, the quantity of work required for a given heat transfer from a cold to a hot body, will be less than if a high grade heat input is employed. However, work is usually derived from a very high grade heat input in a Thermal Power Station or other Prime-Mover. As the thermal efficiency of these is usually between 25 and 35% there can be an overall advantage in using a heat input to drive a heat pump or refrigerator.

### The Combined Rankine and Vapour Compression Cycle.

The pressing need to conserve fossil fuels has aroused interest in two distinct possibilities associated with refrigeration:

(a) **Refrigerators which will operate from a non fuel consuming input (e.g. solar radiation, waste heat, geothermal heat).**

(b) **Combined prime movers and heat pumps which burn fuels, but which make more heat available for intermediate grade heating purposes than was available from the fuel consumed.**

The Combined Rankine and Vapour Compression Cycle makes both of these possible. In a Combined Rankine and Vapour Compression Cycle, Fig. 1, a high grade heat input generates high pressure vapour in a boiler. This vapour expands in a turbine producing work, and then passes into a condenser where it is liquified by rejecting heat. The liquid is then pumped back into the boiler for re-evaporation.

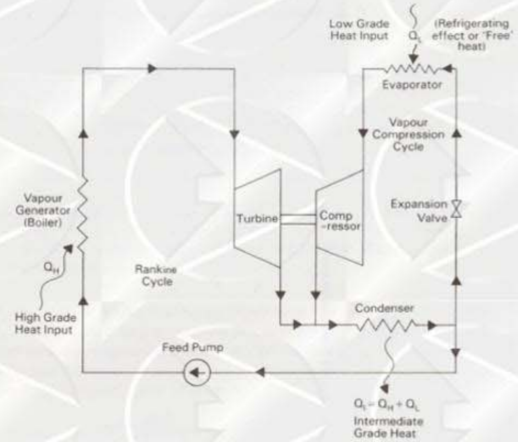



Fig. 1 COMBINED RANKINE & VAPOUR COMPRESSION CYCLE (USING A TURBINE & COMPRESSOR)

The work produced by the turbine drives a conventional vapour compression cycle refrigerator or heat pump.

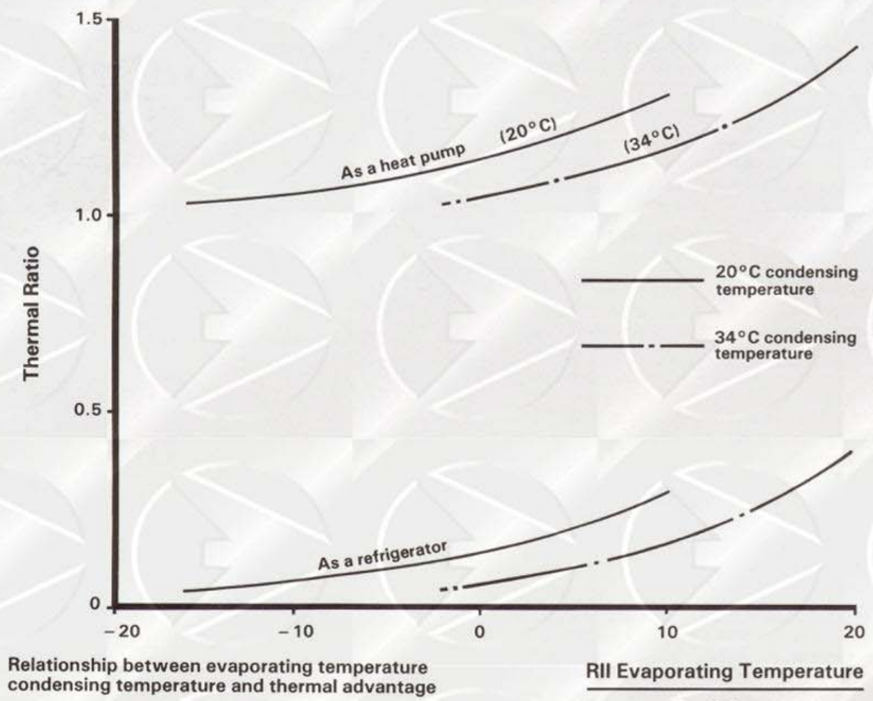
Assuming that the same fluid is used throughout, the turbine and compressor can discharge into a common condenser. Neglecting heat losses, it will be seen that the ratio

$$\frac{\text{Intermediate Grade Heat Delivered}}{\text{High Grade Heat Input}} = \frac{Q_H + Q_L}{Q_H} \text{ is greater than unity}$$

The effectiveness of the combined Rankine and Vapour Compression Cycle depends upon the temperatures at which,

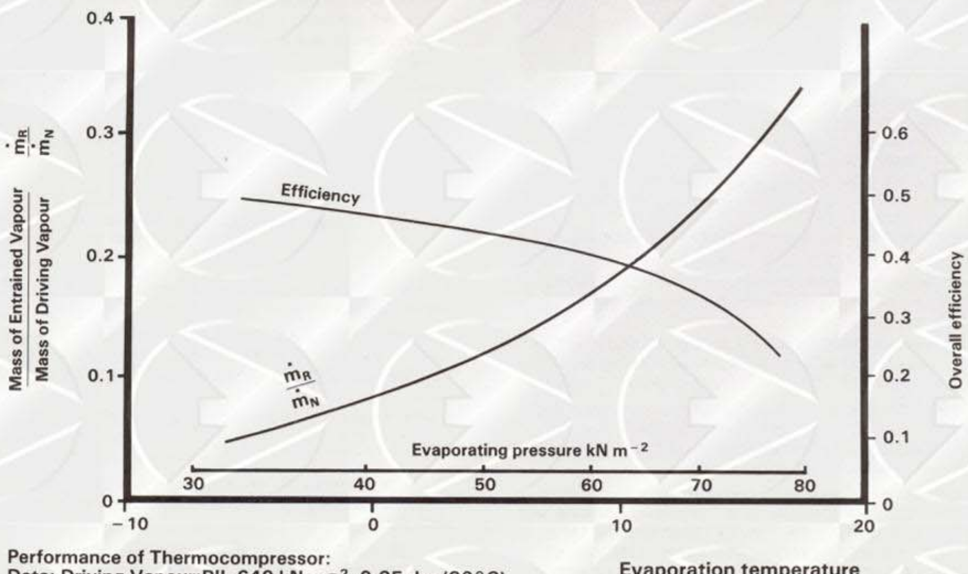
(i) heat is supplied at the boiler,
(ii) heat is available to the evaporator,
(iii) heat is rejected at the condenser,
and (iv) the efficiency of the expansion and compression processes.

# Experimental Results




Relationship between evaporating temperature condensing temperature and thermal advantage

$$\text{Thermal Ratio} = \frac{\text{Desired Energy Transfer}}{\text{High Grade Heat Input}}$$




Performance of Thermocompressor:
Data: Driving Vapour: RII, 640 kN m$^{-2}$, 0.95 dry (90°C)
Condensing temperature 32°C (137 kN m$^{-2}$)

# The Hilton Vapour Jet Refrigerator/Heat Pump

(Please refer to Fig. 2)

Because small turbines and compressors are not practical for bench top units suitable for student use, P. A. Hilton Ltd. have devised the Vapour Jet Refrigerator/Heat Pump which demonstrates the characteristics of a Combined Rankine and Vapour Compression Cycle, but in which the expansion and compression take place in an ejector or thermo compressor. In this, the work output of the turbine is represented by the kinetic energy of the vapour leaving the nozzle, and the compression takes place in the diffuser instead of the compressor.

The ejector or thermo compressor has the advantages of simplicity, low cost and reliability. Although there are losses associated with the diffuser which has to compress both the driving vapour and the vapour from the evaporator, P. A. Hilton Ltd. believe that the performance is at least equal to that which could be obtained with a turbine and compressor of similar capacity.

**Operating as a heat pump the unit can deliver appreciably more 'intermediate grade' heat than the 'high grade' heat input required to drive it. (It is worth noting that few heat pumps driven by an electric motor are able to equal this because of the generating conversion and transmission losses involved.)**

**As a refrigerator the unit demonstrates that a source of heat at quite a moderate temperature, e.g. waste heat from an engine cooling or exhaust system, solar radiation, etc., can be used to bring about a cooling or refrigeration effect.**

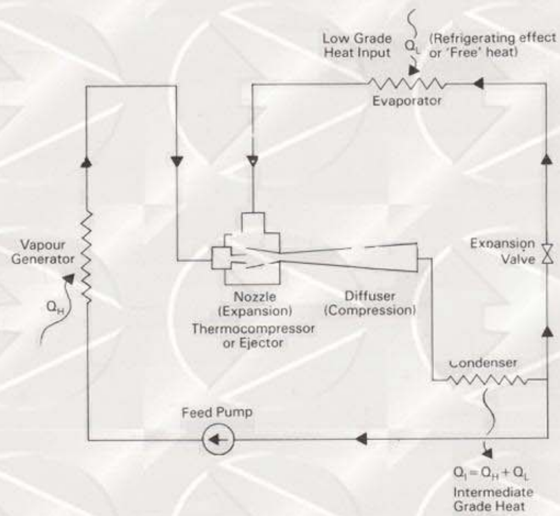



Fig. 2

# Description

(Please refer to Fig. 2 and the Schematic Diagram on Page 2)

The system is charged with Refrigerant II (RII)

In the steam generator, heat transferred from an electric immersion heater converts water to steam at atmospheric pressure. The steam at 100°C condenses on the RII vapour generator and its pre-heating coil producing RII vapour at about 85°C and 500 kN $m^{-2}$ gauge. This vapour then expands through a convergent-divergent nozzle to a supersonic velocity.

RII vapour formed at a low temperature and pressure in the evaporator is entrained by this high velocity jet and the resulting mixture passes into the diffuser. The diffuser is designed to reduce the velocity of the mixture and increase its pressure to the higher pressure in the condenser. The RII vapour condenses on the water cooled coils in the condenser and is then returned to the evaporator via a float controlled expansion valve, and to the vapour generator via a reciprocating feed pump.

NOTE: An important safety feature is the method of heat transfer at the vapour generator. The heating medium is steam at atmospheric pressure—thus, the RII vapour generator temperature can never exceed 100°C and the generator may be run dry without harm. This feature also prevents decomposition of the RII which might take place at higher temperatures.

# Controls and operation

The unit has three simple controls:

1. Condenser cooling water flow rate—this, in conjunction with the inlet temperature of the cooling water, determines the temperature and pressure in the condenser, and thus the temperature at which heat is rejected.
2. A variable transformer—this varies the heat input to the electric heater in the evaporator, which in turn controls the evaporation temperature. A voltmeter and ammeter indicate the energy input to the heater.
3. A manually adjustable throttle valve—this is placed between the vapour generator and the nozzle and enables the unit to be operated below the maximum pressure.

NOTE: Since the RII mass flow rate is reduced when the throttle valve is partly closed, the heat input at the steam generator is greater than can be transferred to the RII vapour generator and the surplus causes excess steam to be discharged from the vent.

Instrumentation is provided for temperature and pressure measurement, the heat input to the evaporator and the water flow rate. The mass flow rates of the RII at the evaporator can be readily obtained from the measured energy transfer rates and the enthalpy changes.

The heat transfer at the RII vapour generator is obtained by the difference between the heat transfer at the condenser and that at the evaporator and the heat transfer rate to or from the surroundings at both the evaporator and condenser is allowed for at the rate of 1.8W per degree K temperature difference.

Typical performance curves obtained from this unit are shown on Page 4.

It should be noted that the performance of all vapour power plants, refrigerators and heat pumps falls as the condenser temperature rises. This is true of the Vapour Jet Refrigerator/Heat Pump and it is recommended that, if a useful range of test conditions is to be investigated, the condenser cooling water temperature should not exceed 22°C.

# Specification: Vapour Jet Refrigerator/Heat Pump R850

| | |
|---|---|
| **Panel:** | High quality glass reinforced plastic on which the following are mounted: |
| **Steam Generator:** | Rectangular glass reinforced plastic insulated vessel fitted with 1.5kW immersion heater and containing the RII vapour generator. |
| **RII Vapour Generator:** | Cylindrical stainless steel shell, 75mm dia × 200mm long, with dished ends—fitted with sight glass and pre-heating coil. |
| **Ejector or Thermo Compressor:** | Nozzle: Convergent-divergent, throat diameter 1.7mm.<br>Diffuser: With combining cone, parallel and divergent portions. |
| **Evaporator:** | Thick walled glass cylinder fitted with metal end plates and P.T.F.E. seals. Evaporator incorporating a 500W heater controlled by a variable transformer and a float type expansion valve. |
| **Condenser:** | Thick walled glass cylinder fitted with water cooling coil. Surface area of coil: $0.1 m^2$. |
| **Feed Pump:** | Reciprocating plunger type pump fitted with P.T.F.E. seals and water jacket, driven by electric motor through worm reduction gearbox to give approximately 60 double strokes/minute. |
| **Throttle Valve:** | Manually adjustable to vary nozzle inlet pressure. |
| **Instrumentation** | |
| **Thermometer:** | Digital Ni/Al electronic thermometer with 0.1°C resolution and 12 way selector connected to 9 thermocouples to measure all important temperatures. |
| **Pressure Gauges:** | Two 0 to 800 $kN\ m^{-2}$ to indicate RII vapour generator and nozzle inlet pressure.<br>Two $-100$ to $+100$ $kN\ m^{-2}$ to indicate evaporator and condenser pressure. |
| **Flow Meter:** | Variable area glass tube type fitted with control valve to measure water flow rate through condenser. Range 0 to $75 g\ s^{-1}$. |
| **Voltmeter and Ammeter:** | To measure power input to evaporator. Ranges 0 to 250V and 0 to 3A respectively. |
| **Safety features** | |
| **Pressure Relief Valves:** | Fitted to vapour generator, evaporator and condenser. |
| **High Pressure Cut Out Switches:** | Fitted to vapour generator and condenser. |
| **Low Water Flow Switch:** | To switch off power supply if insufficient water flows through the condenser. |
| **Solenoid Valve:** | To isolate vapour generator from ejector, evaporator and condenser. |
| **High Temperature Cut Out:** | Fitted to all heater elements.<br>All circuits are protected by a fuse. |
| **Dimensions** | Height: 0.925 m Depth: 0.43 m<br>Width: 1.060 m Weight: 102 kg |
| **Software** | ONE—Copy of Experimental, Operating and Maintenance Manual.<br>Large plastic coated Pressure-Enthalpy diagram for Refrigerant II. |

# Services required

| | |
|---|---|
| **Electrical** | Either A. 2.5kW 220/240 Volts, Single Phase, 50Hz. (With earth/ground)<br>or B. 2.5kW 110/125 Volts, Single Phase, 60Hz. (With earth/ground) |
| **Cold Water** | 250 litres/hour at 15m head. Water temperature should not exceed 22°C if a useful range of test conditions are to be investigated. (If required, P. A. Hilton Ltd. can supply a water chilling unit.) |

# Spares

Each machine is supplied complete with accessories and spares for 2 years of normal operation—details on request. A list showing recommended spares for 5 years of normal operation is also available.

# Ordering information

| | |
|---|---|
| **Order as** | R850 Vapour Jet Refrigerator/Heat Pump |
| **Please specify** | Either A. 220/240 Volts, Single Phase, 50Hz. (With earth/ground)<br>or B. 110/125 Volts, Single Phase, 60Hz. (With earth/ground) |
| | Language—either English<br>French<br>Spanish |

# Shipping specifications

| | |
|---|---|
| **Nett Weight:** | 102 kg |
| **Gross Weight:** | 190 kg |
| **Packing Case Size** | 1.25 × 0.622 × 1.194 m |
| **Packing Case Volume:** | 0.928 $m^3$ |

# Please note

Units fitted with instruments calibrated in other units or for use on non-standard voltages are available on special order.

(The policy of P. A. Hilton Limited is one of continual improvement and they reserve the right to revise this specification without notice.)

## Guarantee

**Hilton products are guaranteed for a period of two years from the date of despatch.**

- Manufactured to the highest standards using components and materials resistant to corrosive attack.
- Assembled by highly skilled technicians and subjected to a comprehensive testing programme before despatch.
- Packed in specially designed cases suitable for air or sea freight to any part of the world.
- Supplied as complete units with all the necessary accessories to conduct the experiments described in the literature.
- Supported by comprehensive software which is available in four languages—English, French, German or Spanish. The supporting literature fully describes the installation, maintenance and operating procedures for the equipment and where applicable includes physical properties charts.

## Product Range

**We manufacture a range of engineering laboratory teaching equipment which is used for studying:**

**Refrigeration**

**Air Conditioning**

**Heat Transfer**

**Fluid Flow**

**Combustion**

**Propulsion**

**Further details are available on request**

## After Sales Service

**P. A. Hilton Limited aim to retain the confidence and goodwill of their customers by offering an effective after sales service.**

- Are kept in close contact with their customers by over sixty representatives throughout the world.
- Maintain large and comprehensive stocks of component parts and can rapidly supply spare parts and consumable items to any part of the world.
- Will make every effort to answer customers' correspondence quickly and to provide advice on subjects related to their products.
- Consider it is essential to respond quickly to any problems encountered by a customer. In the extreme case, where there is a problem which is seriously disrupting a teaching programme, P. A. Hilton Limited will accept a reverse charge telephone call from a customer anywhere in the world.

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LEAFLET No. R850L/E/1