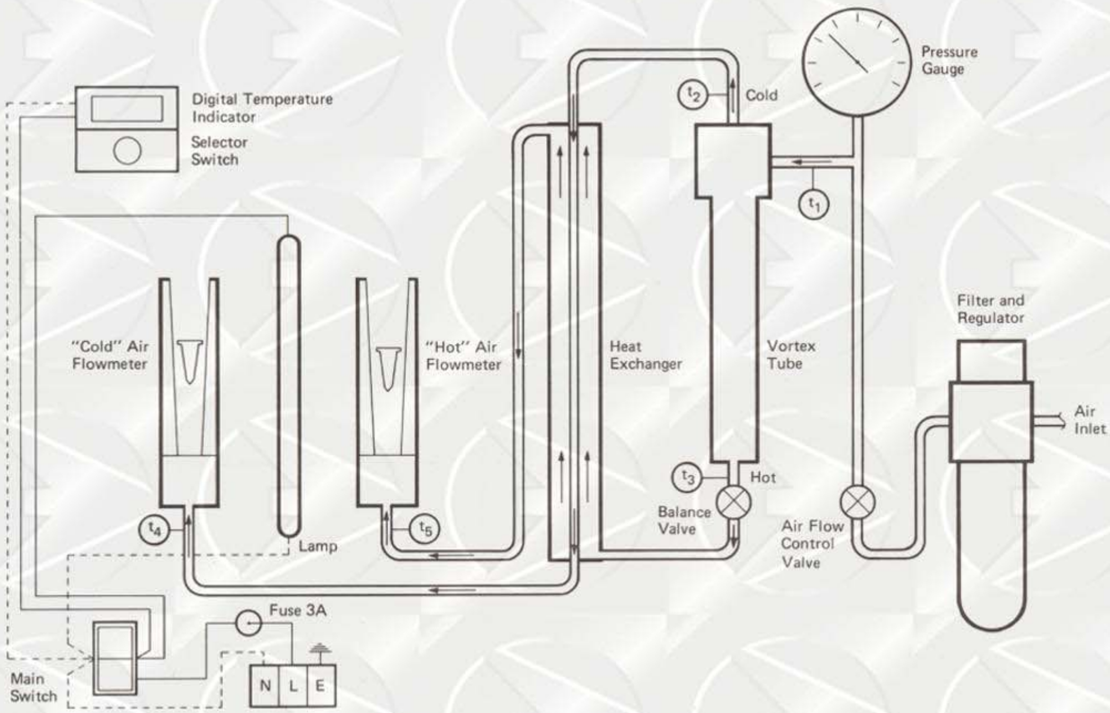
Vortex Tube Refrigerator R433

Machine Code R433 has been superseded by **R434**.
The air flowmeters, though physically smaller, are of similar range to those on the original unit.
A more efficient internal heat exchanger has removed the need for thermocouple stations t_4 and t_5.

Engineering Laboratory
Teaching Equipment

P. A. Hilton Ltd.

Vortex Tube Refrigerator R433



Introduction

The Vortex Tube is an interesting device in which a compressed gas (usually air) is divided into two streams at a lower pressure. One of these streams is about 50K colder, and the other is about 50K hotter than the compressed gas supplied.

Although a hot gas stream is more conveniently produced by other methods, the Vortex Tube has few competitors where a limited amount of cooling air is required in circumstances in which its small size, reliability and freedom from electrical supplies are of prime importance.

In this unit, a modified industrial Vortex Tube has been incorporated into a test unit with all the controls and instruments necessary to provide students with an appreciation of its characteristics and performance.

This unit will be of interest to those concerned with

Refrigeration

Thermodynamics and Fluid Mechanics

Plant and Process Engineering

Experimental capabilities

- Demonstration of the ability to produce hot and cold air from a device with no moving parts.
- Production of performance curves for a vortex tube with
  - (a) Variation of inlet pressure
  - (b) Variation of hot and cold gas ratios
  - (c) Variation of gas (if available)
- Determination of refrigerating effect and comparison of this with the estimated power needed to drive the compressor.

Description

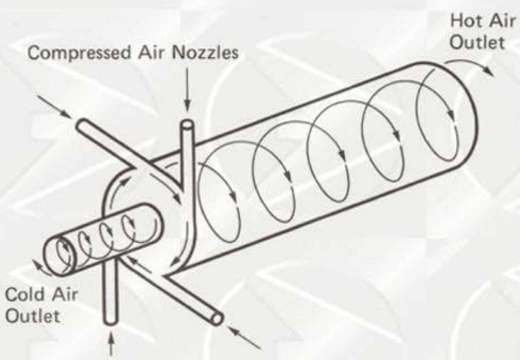


Diagram of Vortex Chamber

The Vortex Tube was invented by Georges Ranques, a Frenchman, in 1928 but initially it aroused little interest. In 1946, Rudolph Hilsch published an article which was widely read and which started the current interest in this unusual method of producing cooling air.

The Vortex Tube consists of two joined and concentric cylindrical chambers of different diameters, open at their ends. Spaced around the circumference of the larger chamber and close to the junction with the smaller chamber, are nozzles arranged to discharge tangentially into the cylinder.

When compressed gas is supplied to these nozzles, the jets discharge into the chamber at a near sonic velocity, and a forced vortex, rotating at approximately 500,000 rev/min, is created. The core of this vortex is cold and is extracted from the smaller end of the chamber, while the periphery which is hot, is extracted from the larger end.

The ratio of cold and hot gas flow rates can be varied by a valve which controls the hot gas discharge.

A number of theories have been put forward to explain the processes within the Vortex Tube and it is valuable for a student to be confronted with a device which works, but about which there is argument about how it works.

One theory due to C. D. Fulton is as follows.

Due to viscous forces, the vortex in the chamber rotates at constant angular velocity (i.e. is a forced vortex) and its linear velocity is proportional to the radius.

Since the momentum of the air leaving the nozzles is a constant, the angular momentum of the core must have decreased by the same amount as the angular momentum of the periphery has increased.

Thus, the core, having done work, falls in temperature, while the periphery having had work done on it, increases in temperature.

In this unit, air (or any other safe gas if available) flows through a pressure regulator and filter, and is supplied to the vortex tube at up to 700 kN m^{-2} gauge. After passing through the vortex, the cold air leaves from the upper end and the hot air from the lower end, both streams being at approximately atmospheric pressure.

To avoid problems with frosting and flow meter errors, the hot and cold air streams are passed in opposite directions through a concentric tube heat exchanger. The air streams, now close to ambient temperature, pass through variable area flow meters to the atmosphere.

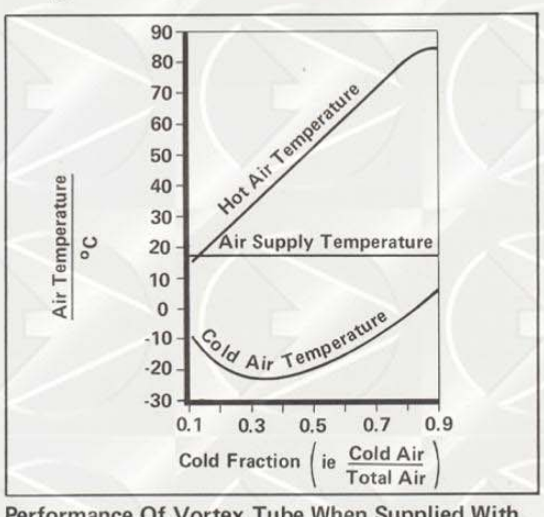
A "balance valve" fitted in the outlet from the hot end of the vortex tube controls the proportions of the total air flow which passes from the "hot" and "cold" ends.

Thermocouple sensors, with a selector switch and digital display allow the measurement of all important temperatures.

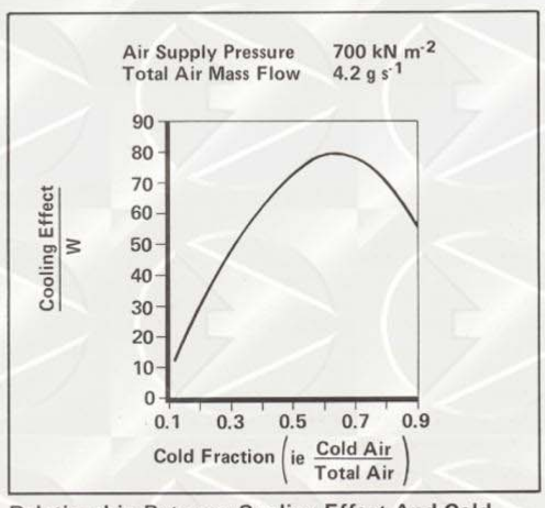
Although no direct measurement of the refrigerating effect is made, the mass flow rate and the temperature of the cold air stream are directly measured. It is assumed that any cooling which can be done by this cold air as it returns to ambient temperature, is its refrigerating effect.

Typical performance curves obtained from this unit are shown below.

Experimental Results



Performance Of Vortex Tube When Supplied With Air At 700 kN m^{-2}g



Relationship Between Cooling Effect And Cold Fraction

Specification

General

A fully instrumented bench top vortex tube test unit for use with compressed air or other suitable gas.

Detailed

Panel: High quality glass reinforced plastic on which all components are mounted.

Vortex Tube: Rated at 300 litre free air per minute at 700 kN m^{-2} gauge.

Pressure Regulator and Filter: To supply clean and pressure stable air.

Heat Exchanger: Concentric tube, contra flow.

Valves: Two, for isolation and balance.

Flow: Two, variable area type flowmeters, calibrated for air up to 4 gm s^{-1}.

Temperature: Digital Temperature Indicator (Resolution 1°C) with selector switch and five thermocouple sensors.

Pressure: 100 mm dia. gauge – range 0 to 800 kN m^{-2}.

Dimensions

Height:	710 mm	Depth:	240 mm
Width:	710 mm	Weight:	29 kg

Accessories and Spares

Unit supplied with:

One copy of Experimental, Operating and Maintenance Manual.

One copy T/S diagram for air.

Accessories and Spares for 2 years normal operation

Also available:

Recommended list of spares for 5 years operation (details on request).

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

Services required

Electrical:

Either: **A.** 220/240 Volts, Single Phase, 50 Hz. (With earth/ground)

or: **B.** 110/120 Volts, Single Phase, 60 Hz. (With earth/ground)

Compressed Air:

300 litre free air per minute supplied at 700 kN m^{-2} gauge.

Ordering information

Order as:

R433 Vortex Tube Refrigerator

Please specify:

Electrical supply –

Either: **A.** 220/240 Volts, Single Phase, 50 Hz. (With earth/ground)

or: **B.** 110/120 Volts, Single Phase, 60 Hz. (With earth/ground)

Language – either: English, German, French, Spanish

Shipping specifications

Nett Weight:	29 kg
Gross Weight:	84 kg
Packing Case Size:	0.889 x 0.889 x 0.483 m
Packing Case Volume:	0.382 m^3

Please note

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

P.A.Hilton Ltd.
Horsebridge Mill, King's Somborne,
Stockbridge, Hampshire, SO20 6PX, England.
Telephone: National Romsey (01794) 388382
International +44 1794 388382
Fax: (01794) 388129

Leaflet No. R433L/E/1/7758