Fluid Action in the Vortex Tube

A Report of Experiments in Which a Colored Liquid Is Introduced into a Vortex Tube To Enable Visual Study of the Strange Separation of Hot and Cold Air

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The perplexing phenomenon of the vortex tube, also called Ranque's tube or Hilsch's tube, which produces hot and cold air when air under pressure enters the tube tangentially, continues to intrigue various investigators. In this article the author describes the visual effects that were seen in uniflow and counterflow vortex tubes when a trace of colored water was injected into the incoming air stream. For a thorough discussion of the operation of the vortex tube, the reader is referred to the article "Ranque's Tube" which appeared in the May 1950 issue of REFRIGERATING ENGINEERING.

IN 1931 Georges Joseph Ranque developed a method of separating a stream of compressed gas into two streams of gas, at a lower pressure, having a definite temperature differential. The work of Ranque lay undeveloped until Rudolph Hilsch became interested in the vortex tube in relation to his low temperature experiments. The investigations of Hilsch were brought to the United States by Robert Milton of Johns Hopkins University. Since then much independent investigation has taken place in colleges and industry.

The vortex tube is a device that separates an incoming stream of compressed gas into separate streams of hot and cold gas, both at a lower pressure. This result is obtained by causing a vortex in a tube of circular cross section. The vortex is created when the gas enters into the tube on a tangent to the cross section at a high velocity. A study of the cross section of the vortex shows the center portion of the vortex to be at a lower temperature and pressure than the outer portion. The separation of the center and outer portions is necessary if the hot and cold streams are to be obtained. This is done by two methods, the uniflow and the counterflow.

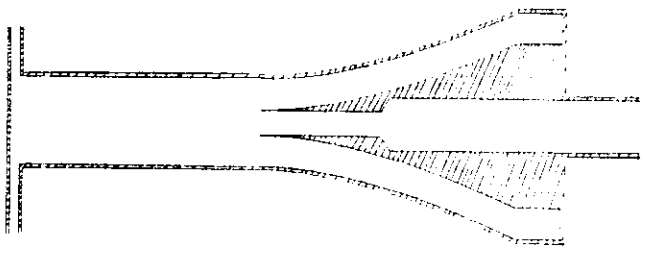

Fig. 1. The uniflow type of vortex tube.

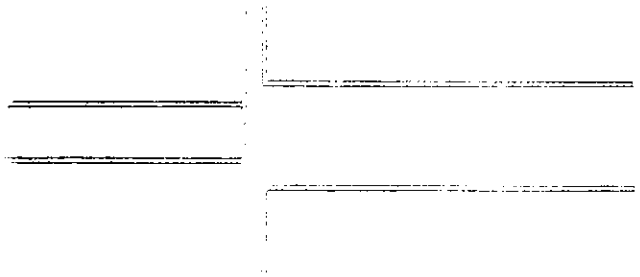

Fig. 2. The counterflow type of vortex tube.

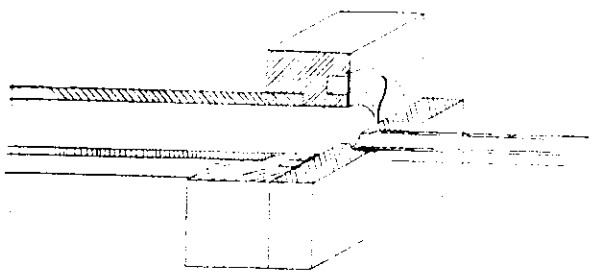

Fig. 3. A working model of the counterflow vortex tube.

The uniflow method of separation is shown in Figure 1. The center of the vortex is separated by using a sampling tube in the middle to remove the cold gas, and a concentric outer tube to take off hot gas.

The counterflow method of separation is shown in Figure 2. The center of the vortex is forced out the small tube on the left while the outer portion is allowed to flow out the larger tube on the right.

The hot stream tube must be kept at a higher pressure than the cold stream tube, since the center portion of the vortex is at lower pressure. If the cold tube exhausts to atmosphere, it is necessary to throttle the gas flow in the hot tube.

By holding the physical dimensions of the tube and inlet gas pressure and temperature constant, the amount of flow through the cold tube may be varied by adjustment of the hot tube throttling. Since the vortex tube obeys the laws of thermodynamics, this throttling also varies the gas temperatures with the gas flows. Two interesting cold gas points may be found, the lowest temperature and the greatest refrigeration.

The flow pattern of the gas in the vortex tube has come to be a point of discussion in the analysis of the tube. The actual facts are unknown to date; however, research is gradually reducing unknown factors.

It is easy enough to imagine what happens at the nozzles when the gas is inducted into the tube. However, this is not quite as easy as it looks when considerable thought is given to the action within the tube.

C. D. Fulton Jr. of the Massachusetts Institute of Technology first suggested the use of multiple nozzles rather than the single nozzle and spiral chamber used