Vortex tubes
blow hot and cold

Can you find new uses for this strange pipe that mystifies scientists?

By GREG STONE

CINCINNATI, OHIO

For nearly half a century the vortex tube has been an orphan of modern technology, an engineering curiosity that couldn't break the umbilical cord that held it to the laboratory.

That doesn't mean it hasn't been loved. Quite the contrary: It has had its own small, devoted group of followers. Heck, what calculator-toting science buff wouldn't be fascinated by a device that weighs just six ounces, looks like an ordinary pipe with a nozzle on one side, has no moving parts, no electrical connections, no heating or cooling coils, and yet can take an ordinary stream of compressed air and simultaneously deliver very cold air out one end and hot air out the other?

Perhaps you've met the vortex tube before under one of its aliases. It's been kicking around engineering laboratories since 1928, variously known as the Maxwell Demon Tube, Ranque Vortex Tube, Hilsch Tube, and Ranque-Hilsch Vortex Tube.

When the vortex tube is applied to large heating and cooling problems it turns out to be (for shame!) an energy guzzler. It needs compressed air to function, and compressed air requires energy.

Yet it can provide an efficient and practical means of solving the right problems. That's why Vortec Corp., a small firm here, is selling nearly 1000 tubes a month. It has built a business on finding problems the

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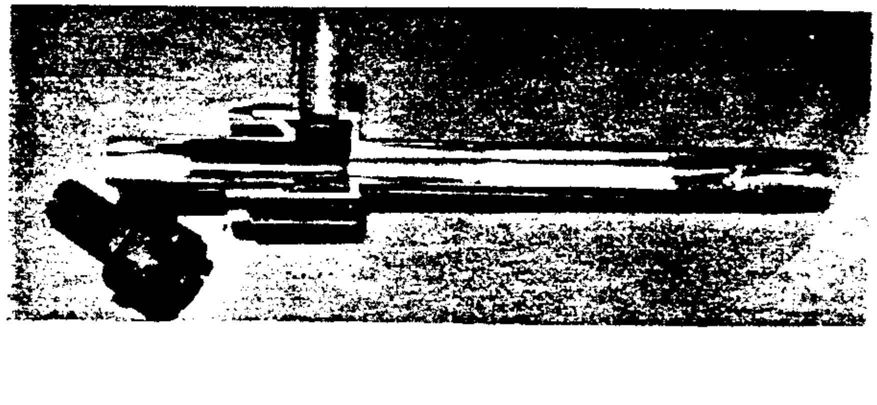
Reflective suit has vortex tube on belt, connected to compressed-air hose. Incoming air cooled by tube keeps occupant comfortable in 200°F environment.

Cone-shaped interior of cold outlet shown in cutaway of Vortec Corp. tube forces air up the longer, warm-air outlet. Turn page to see air flow in a tube.



vortex tube can solve efficiently. "When it comes to cooling something small to a very cold temperature, the vortex tube really shines," says Leslie R. Inglis, chief engineer and president of Vortec.

Vortec's is not an overnight success story. The company began under another name when Charles Darby Fulton, Jr., engineer and dedicated advocate of the vortex tube, founded Fulton Cryogenics, Inc. In 1961 Fulton set out to make and sell vortex tubes with nothing more than a basement workshop, a lot of determination, and a tiny ad in the back pages of POPULAR SCIENCE. The ad boasted of the "simply amazing" new Ranqu Hilsch Vortex tube that "blov blue cold (below -30°F) from on end and hot from the other. . . ."

That stream of cold air, which can be as cold as −100°F, is something that has to be felt to be believed. I became a believer when Inglis hooked one of the little pipes

A mysteriou energy exchange between hot and cold vortexes of air

to an ordinary supply of compressed air (about 100 p.s.i., the pressure normally used in an industrial shop). There was an ear-piercing scream like that of a jet priming for takeoff. Gingerly I moved my hand toward the air stream rushing from one end. Warm. I switched to the other end. Cold. Darned cold. In fact, a thermometer showed it was approaching -30°F, and this was just a few seconds after the air was turned on.

How does it do it? Well, the whimsical explanation I favor (because it's the one I'm sure I understand) was advanced by the great 19th century physicist, James C. Maxwell. He postulated that since heat involves the movement of molecules, we might someday be able to get hot and cold air from the same device, through the help of a "friendly little demon" who would sort out the cold molecules and toss them in one direction while letting the hot ones go in another.

Of course when Maxwell conceived his busy little demon he didn't have the vortex tube in mind. No one did at that time. In fact, the history of the tube is a tale of misplaced credit that Dr. Fulton has with some success set straight. The following account draws upon Dr. Fulton's research and correspondence with the tube's inventor, the late George J. Ranque. It was Ranque, Dr. Fulton maintains, who deserves credit for what is commonly called the "Hilsch Tube" after its supposed discoverer, Rudolf Hilsch.

Confusing? Then begin in 1922 when Ranque, a French physics student, was experimenting with various vortex phenomena. By 1928 Ranque had invented several uses for the vortex effect, including a vacuum pump. This last device looked much like the modern vortex tube, only it didn't have a valve at the hot end. Ranque wanted to use it to exhaust dust in a steel plant and had a valve placed in one end.

The result? Warm air appeared where all the laws of physics said the air should be cooler, if anything. After all, compressed air was being put into the tube, and as any gas expands it cools slightly. Respecting the law of the conservation of energy, Ranque reasoned: If warm air was created at one point, cold air should appear at another.

Early failure

Though it took some time for Ranque to discover that the cold air emerged from the other end when it was uncovered, he immediately saw the tube's commercial potential. However, notes Inglis: "In those days the compressed-air systems weren't very reliable." The initial vortex tube was a commercial failure, and Ranque's vortex firm died after a few years. Other scientists challenged Ranque's thesis and said, in effect, that a vortex tube was impossible.

Ranque continued with other work and the vortex tube drifted into obscurity until Rudolf Hilsch, a German physicist who knew of Ranque's work, did some investiga-

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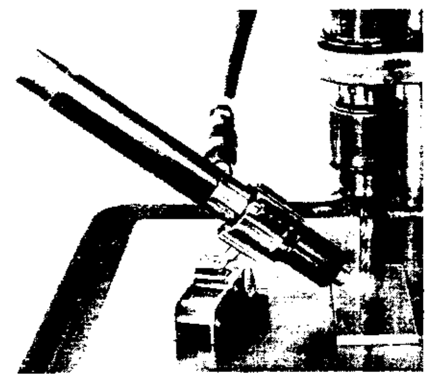
Thermometer needle plummets to -30°F seconds after vortex tube is started. Muffler can soften noisy screech caused by compressed air.



Sub-zero blast from tube is effective coolant when machining poor conductors, or where liquid coolants cause more problems than they solve.

Compressed air at about 70°F enters a vortex tube tangentially; that is, it's shot along the inner circumference of the tube and begins spiraling in a familiar vortex formation. (Vortec Corp. tubes, illustrated here, have a small wheel at the air input with several tangential-entry nozzles.) Centrifugal force keeps the air near inside circumference. Since the tube's inner diameter is larger toward the section that becomes heated, the air spirals that way first. As the vortex moves up the tube, a partial vacuum is created near its center (fewer molecules near the vortex center mean lower pressure).

The air is typically heated to 162°F as it moves up the tube. (One suspected reason for the heating will be explained shortly.) A needle valve at one end of the tube allows some of the warmed air in the outer circumference of the vortex to escape. But about half of the air heads back down the tube as a second vortex inside the low-pressure area of the larger vortex. While one airstream moves up the tube and the other down it, both rotate in the same direction at the same angular velocity. That is, a particle on the inner stream completes one rotation in the same amount of time as a particle in the outer stream.

However, because of the principle of conservation of angular momentum, the rotational speed of the smaller vortex might be expected to increase. (The conservation principle is demonstrated by spinning skaters who can slow or speed up their spin by extending or drawing in their arms.) But in the tube, the speed of the smaller vortex remains the same. Thus, angular momentum has been lost from the inner vortex. Where has this energy gone? One theory presented by Vortec Corp. is that the energy shows up as heat in the outer vortex. Thus the outer vortex becomes warm, the inner vortex is cooled. Vortec Corp. readily acknowledges there's still disagreement on how tubes work.

A somewhat different explanation of the cooling effect was offered by William Taylor of the National Bureau of Standards in a May, 1947 PS article on experimental vortex tubes. Taylor's explanation was that compressed air passing through the entry nozzle speeds up and loses heat, the velocity gain being made at the expense of the lost heat energy. This fast, cold air is then slowed up as it spirals in the tube. Some molecules drop toward the center. Instead of heating up as they lose speed, however, they pass along some of their energy to their next outer neighbor, and remain cool.

An additional cooling effect comes from the centrifugal force of the whirlpool itself. This force throws air molecules out to the edge of the spiral so that there are fewer molecules—and thus lower pressure—in the inner layers than in the outer ones. When air moves from the high-pressure outer layers to the low-pressure inner layers, it naturally expands and cools.

The shorter, smaller-bore tube section draws off the center cold air; the longer, larger-bore arm draws off the hot molecules at the vortex's periphery.

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tions of his own. In 1945 he published a scientific paper on the vortex tube that gained recognition for both Hilsch and the tube. Hilsch briefly cited Ranque in his article, but a misprinted footnote made it difficult for other researchers to find Ranque's work. Thus the vortex tube became known as the Hilsch tube.

Inglis now favors the name "vortex tube," which has the same meaning as "tube tourbillion," Ranque's French name for it.

Compressed-air appliance

At first glance the vortex tube looks like the solution to a variety of cooling problems. (Even today there are very few heating applications.) Why couldn't it be used to air-condition home, car, boat, or plane? Inglis chuckled. "That's what everyone thinks when they first hear about it. I always tell them that they wouldn't buy a toaster for the kitchen if they had to buy the generator to produce the electricity. You've got to think of this as a compressed-air appliance."

As a compressed-air appliance, however, the vortex tube excels in various applications. Take the guy in a protective suit working in a 200°F environment. How to keep him cool? He's not about to carry a conventional air conditioner with him. Try to pump cold air to him through a long hose, and the air will warm up en route. But hook him to a half-inch compressed-air hose, attach a vortex tube smaller than a flashlight to his belt and he'll stay cool all day.

What else? How about cooling:

- Drinking water in a paint spray department, which has plenty of compressed air, but where electrical devices would create a hazard?
- A remote television camera in an industrial location so hot it would normally damage electronic components?
- Drills used on tough substances, such as titanium, where conventional liquid coolants just create more problems?

Can you make your own? Yes. Plans for a simple one accompany this article. You won't necessarily achieve the efficiency of Vortec Corp. models with your home-built tube. Vortec's includes a "braking device" that shortens the tube considerably and a little wheel that contains several tangential nozzles

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to get the air spinning at near sonic speeds. If you are interested in experimenting with applications, you can get an experimental package for $107. Included: a tube that gives 400 Btu of refrigeration per hour and temperatures to –40°F; a filter for the compressed-air supply; noise muffler; a handful of changeable internal parts that vary the performance, plus instructions. (Vortec Corp., 4511 Reading Rd., Cincinnati, Ohio 45229.)

How to build a vortex tube

You can build this simplified vortex tube, originally designed for *Popular Science* readers by RCA researchers and described in the November, 1947, issue. Most dimensions aren't critical, and the tube can be operated from a service-station air hose or any 75- to 100-lb.-pressure compressed-air source.

Drive the brass tubing through the 9/32" hole in the ½" brass stock until the two arms are about equal length. Don't cut off the square vortex-generation section from the length of stock until drilling is completed. It's crucial to drill the hole tangent to the tube's inner wall, 5/64" from the center of the 9/32" hole. Drill a 1/16" hole straight down through the stock just through the tube wall. Counter-bore the inlet hole ⅛" to about half its depth.

Saw off the inlet block from the stock. Solder the valve from an inner-tube stem to the block, using a 1/16" rod to align the valve and inlet hole. A plastic or wood washer is pushed down the cold arm of the tube to the 1/16" rod. If a fiber washer isn't available drill a ⅛" hole in a slice of ¼" wooden dowel. For the throttle, cut a ¾"-long piece of ¼" brass rod. Drill through lengthwise with a No. 28 drill, then use an 8-32 tap. Press this into the tube's hot end and drill a No. 20 hole through one wall of both tube and rod.

With the throttle wide open, both arms will be at the same temperature. At half-throttle, the cold arm reaches its lowest temperature. Close the throttle almost entirely, and the hot arm reaches its highest temperature.