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SCIENCE OBSERVER

A Sound Use for Heat

Waste heat can be turned into electricity via acoustic waves

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Of all the waste products of modern technological devices, heat might seem like the most benign. But overheating is a major concern for computers, electronics, power plants, automobiles, even humans who are tromping around hot climates. Heat seems like a particular waste since it is a byproduct of energy that could go to more useful purposes. However, since heat itself is a form of energy, if it could be captured and transformed into something useful like electricity, the process would increase efficiency while also getting rid of the problem of excess heat. That was the thinking of Orest Symko and his physicist colleagues at the University of Utah. Their approach is somewhat unconventional: They turn the heat first into sound, which is then directly converted to electricity.

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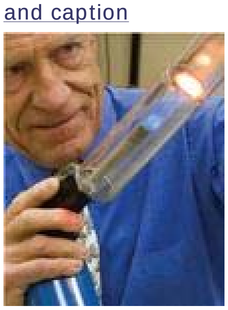

In the 18th century, glass blowers discovered by chance that heated glass tubes would spontaneously produce sound. Thermoacoustic refrigerators, which use sound to pump heat, have been investigated for some time (see *American Scientist,* November-December 2000). As Symko and his students reported at the Acoustical Society of America conference in Salt Lake City in June, they have been working to make the devices smaller and more efficient, so that they can function with lesser amounts of heat and be incorporated with microelectronics.

Right now most of their devices are metal tubes 9 millimeters to 3 centimeters long that contain a "stack" of material in the middle. The stack is made of insulating plates or fibers to provide a greater surface area to interact with the air in the tube. When heat is applied to one end of the stack, the temperature gradient builds up and changes the air pressure, which causes an acoustic wave to travel through the length of the tube.

At some point, depending on the length of the tube, the temperature gradient hits a threshold that causes the waves to bounce back and forth in the tube at a single frequency, a phenomenon called resonance. Longer tubes produce low frequencies, shorter tubes produce higher ones. Symko likens this to playing a flute: "When you blow into the hole, you produce little disturbances, and they excite the resonance of the tube itself. Here instead we have heat hitting the air and producing little pulses of sound."

"First you have heat which is very random and disorderly, and then you have sound that's coming out at one frequency. There's a similarity to lasers, you pump in energy and you get a coherent output," Symko explains.

The next step in the process involves a material called a piezoelectric ceramic crystal. These crystals link mechanical squeezing to electric voltage. The effect was first discovered by Pierre and Jacques Curie in 1880. The crystals were used in sonar to detect submarines in the 1920s, since the crystals can both emit sound pulses when given an electric signal, and return an electric signal when they receive the sound wave bouncing back from an object. They have since been used in everything from phonographs to gas-grill lighters. They are also used to set off automotive airbags, where the shock of impact causes the crystal to emit an electric signal.

Essentially, a piezoelectric crystal has domains of positive and negative charge which are symmetrically distributed, so the overall material is electrically neutral. When the crystal is deformed, the domains become misaligned, generating a voltage across the material.

The impact from the resonating sound wave in the tube actually causes the crystal to change shape, which leads it to emit electricity. Symko says that their devices typically have 10 to 25 percent efficiency in turning heat into power. His colleagues at Washington State University are developing new piezoelectrics that are single crystals, which should have a higher conversion rate from sound to electricity. A group at the University of Mississippi are creating computer models of the devices.

The thermoacoustic converters can work with a temperature difference as low as 25 degrees Celsius. Higher temperature gradients increase the efficiency of the energy conversion, but this heat difference is not always possible to obtain when the energy source is coming from small electronics.

Symko and his team are working on several improvements to increase the power conversion of the devices. They are developing ring-shaped tubes, which would allow the sound waves to continue to travel around the device instead of bouncing back and forth, which aids in their synchronization and increases efficiency. A similar mechanism is already used in some lasers to create a powerful coherent light beam. They are also pressurizing the air inside the tubes, as the greater density of the gas allows for higher energy transfer. They are looking into using carbon nanotubes to increase the surface area of the stack.

The team is figuring out how to further decrease the size of the devices so they can be mass-produced with some of the same techniques that are used to fabricate microelectronics. However, this raises another problem, as it's harder to maintain a temperature gradient in tiny tubes. Another goal is to synchronize many of the devices into an array to increase the output.

"A big advantage of these devices is that they have no moving parts so they are relatively easy to fabricate and require low maintenance," says Symko. There is not even a worry of sound pollution from these devices, as the smaller ones produce frequencies in the ultrasonic range. Adding insulation can solve any noise problems.

Within a year Symko plans to test small arrays of the 3-centimeter version of his team's devices on the hot-water power plant at his university. He notes that current piezoelectric crystals work well with the frequencies produced by tubes of this size. The military has interest in the devices for cooling radar and also for portable power sources for soldiers—Symko notes that the devices easily charge standard batteries and capacitors for energy storage. He also has high hopes for the devices as a complementary approach to increase the energy conversion of solar panels, as the heat that builds up in these panels is currently unused. As Symko points out, "There's always some heat around somewhere, whether it's car exhaust or fire."

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