Breaking through the acoustic shock barrier

A sonic boom produced by a jet aircraft can shatter windows and flatten structures. Such a shock wave, whether generated in the open air or inside a closed, gas-filled tube, represents a significant concentration of acoustic energy.

Nonetheless, the formation of a shock front also marks a limit on the amount of energy that can be pumped into a sound wave. Energy added to a shock wave would dissipate without increasing the wave's peak pressure.

It is possible, however, to evade that limit by generating sound waves inside specially shaped cavities that prevent the formation of shock fronts, says Timothy S. Lucas of MacroSonix Corp. in Richmond, Va.

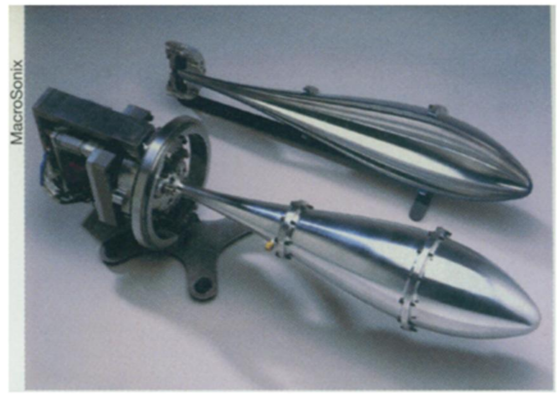
Lucas and his coworkers have developed cavity resonators within which standing sound waves of extremely high energy can be produced. The gas pressure inside such a resonator can reach hundreds of pounds per square inch, making the technology useful for compressing gases and other industrial processes.

For a long time, it was widely considered impossible to achieve such high-energy densities and acoustic pressures, Lucas says. "Our technology unlocks the power of sound."

The researchers described their work this week at an Acoustical Society of America meeting held in San Diego.

"The key is the shape of the resonator," says Gregory W. Swift of the Los Alamos (N.M.) National Laboratory. At high energies, shock waves form within cylindrical tubes but not inside tapered, streamlined cavities of just the right geometry.

Simply driving the new resonator back and forth at a frequency that depends on the size of the cavity and the type of gas it contains will produce a high-energy sound wave. As the oscillating pressure inside the cavity increases, gas molecules speed up, eventually traveling at about one-half the speed of sound.



To generate a large-amplitude standing sound wave inside a specially shaped, gas-filled cavity, a motor (front, left) drives the elongated, tapered metal container, about 0.5 meter long, back and forth at a frequency of approximately 600 cycles per second. The cavity itself (shown in cutaway at back) contains no mechanical parts.

The extreme pressure fluctuations in the resonator are analogous to surface waves on an imaginary lake, 1 kilometer deep, that shoot to a height of several kilometers and dip down to within a few hundred meters of the lake bottom, Swift says. Conversational sound, in contrast, corresponds to water waves about 1 millimeter high, and sound painful to the human ear is analogous to a wave height of 10 centimeters to 1 meter.

The new technology, known as resonant macrosonic synthesis, would offer a number of advantages if used in acoustic compressors for household refrigerators, in small turbines for generating electricity, and in chambers for separating, agglomerating, levitating, mixing, or pulverizing materials, Lucas says.

An acoustic compressor, for instance, eliminates the need for moving parts, such as pistons, connecting rods, crankshafts, and bearings, and thus for lubricating oil, he notes. An appliance manufacturer is already working with the technology to develop reliable, durable, energy-efficient refrigerators and air conditioners.

"You can use any refrigerant you want," Lucas says. "Because we have a simple, empty cavity, you don't have to worry about chemical incompatibility between the lubricating oil and the refrigerant."

Several scientific questions warrant further investigation. Lucas and his coworkers want to understand more fully the turbulence that accompanies the waves inside a resonator. "A large part of the dissipated energy goes into turbulence," Lucas says. "As we learn how to reduce turbulence, the energy efficiency of the machine would increase, perhaps double."

The researchers would also like to develop more accurate models of the acoustic effects that occur inside a resonator.

"This has turned out to be very interesting scientifically," Swift comments. "It's great stuff." —*I. Peterson*

Brain chemical may aid mouse mothering

The maternal instinct is one of the strongest directives animals possess, making scientists all the more puzzled by a strain of mutant mice in which mothers apparently neglect their offspring.

A research team led by Richard D. Palmiter of the Howard Hughes Medical Institute at the University of Washington in Seattle created the mouse strain several years ago by disabling the gene that encodes an enzyme called dopamine beta-hydroxylase.

This enzyme makes norepinephrine, a chemical that nerve cells release in order to communicate with other cells. Yet plans to study how the absence of this neurotransmitter alters rodent behavior were put on hold when the scientists discovered that the mutant mice die in the womb, apparently from heart failure.

The investigators then found that when they added a synthetic precursor of norepinephrine to a pregnant mouse's drinking water, the mutant fetuses would survive to birth. This precursor, known as DOPS, is converted to norepinephrine by a second enzyme. Once born, the mice reach adulthood without further administration of DOPS.

While studying the reproductive behavior of these mutant mice as adults, Palmiter and his colleague Steven A. Thomas recently noticed that the majority of pups born to mothers lacking the norepinephrine-making enzyme die within days of birth. The dead pups had no milk in their stomachs, even though the mothers were lactating, the scientists report in the Nov. 28 CELL.

They also found that the mutant mice, both male and female, do not promptly retrieve newborns placed away from the home nest.

Curiously, mothers lacking dopamine beta-hydroxylase will nurse and care for foster pups that have been briefly nurtured, and perhaps trained to feed, by normal mothers. Moreover, if injected with DOPS just before giving birth, the mutant females often seemed to take appropriate care of their litter.

"Without norepinephrine, maternal behavior is clearly impaired. Under certain conditions, however, it can be restored," concludes Thomas.

In the 1970s and early 1980s, several research groups offered some hints that norepinephrine plays a role in maternal behavior, notes Michael Numan of Boston College in Chestnut Hill, Mass. More recently, however, investigators have focused on other neurotransmitters, such as dopamine.

"This study will bring people back to looking at norepinephrine," predicts Numan.

Additional behavioral tests of the mutant mice are needed to confirm the flawed maternal behavior, he adds. If norepinephrine's absence is indeed responsible for the poor mothering, researchers will try to determine what brain circuits are involved.

Further studies may compare this mouse strain to one lacking a protein called FosB; the latter strain also shows impaired maternal behavior.

"It will be interesting to explore the relationship between norepinephrine and FosB," says Thomas. —*J. Travis*