Musical Metal

Science catches up with the shimmering sound of steel drums

By CORINNA WU

A steelpan held upside-down over a fire turns blue from oxidization. Heat ages the steel, modifying the drum's sound.

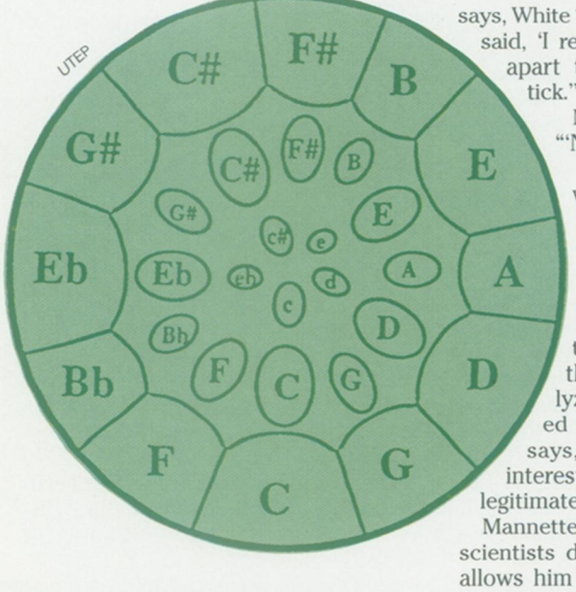
More than half a century ago in Trinidad, a teenage Elliot "Ellie" Mannette hammered 14 bumps into the steel bottom of an upside-down, 55-gallon oil barrel. Each raised section, when struck, resounded with a clear note.

Mannette entered a contest and brought along the new creation. "All the others played small drums," he says, "and I showed up with my big drum. Everyone was surprised."

That humble, street-band instrument would evolve into the modern Caribbean steel drum, or steelpan, loved around the world for its bright, shimmering tones.

Mannette, who turns 71 next month, today lives in Morgantown, W.Va., where he has served as an artist-in-residence at West Virginia University for about 5 years. An acknowledged master craftsman, Mannette is also training a group of a dozen apprentices in the art of making and tuning steel drums.

Mannette has always worked intuitively. Now, with Mannette's help, some scientists who are themselves fans of the steelpan have begun to study this intriguing instrument in hopes of divining the technical secrets of its celestial sound. At the University of Texas at El Paso (UTEP), materials scientists and musicians have teamed up to analyze the metallurgy of the drum, connecting what they see under their microscopes with what they hear with their ears.



A conventional pattern for a tenor drum contains 29 notes arranged in circles of fifths—each note is a musical fifth above or below its neighbors. The notes in the innermost ring are one octave higher than those in the middle ring, which are themselves one octave higher than the notes in the outermost ring.

Lawrence E. Murr, director of UTEP's Materials Research Institute, first encountered steel drums as many people have—on a cruise to the Caribbean. "I'm a metallurgist of sorts, so I got interested in how they work," he says. "I just fell in love with the music. It's a very special sound. I vowed I would get hold of a drum and cut the notes out and look at them."

A step toward doing just that came in 1996 at a cocktail party, where Murr learned that a UTEP music professor, Larry White, had just received a grant to purchase a set of steel drums.

"When we finally got together," Murr says, White "thought I was crazy because I said, 'I really want to take the drums apart to know what makes them tick.'"

Murr recalls White's reaction: "'Not my drums!'"

Luckily, White agreed to work with Murr—as long as he didn't cut up his new set of steelpans. Searching around for steel drum experts, Murr quickly found Mannette, who provided the team with some old drums they could cut apart and analyze. Mannette "was real excited [about the project]," Murr says, "because he was always interested in having somebody do legitimate science on the steel drum."

Mannette would like to see materials scientists determine what kind of steel allows him to make the most beautiful-sounding drum. Oil barrels made by different manufacturers have different steel compositions and, therefore, different properties. Right now, says Mannette, "I have no control over the composition. The ideal steel might be very different. We just don't know what it might be."

Soon, White and Murr assembled a group of music and engineering students interested in learning more about the instrument. White took Murr's engineering students into his classes to teach them how to read music and play the drums. Meanwhile, the engineers began the task of examining the metal up close.

They studied the microscopic structure of the hammered steel in samples taken from actual drums and tested idealized single-note disks cut from sheets of stainless steel. What they have found has amazed them, Murr says. "The more research we do, the more we realize that [Mannette's] intuition was fortuitous."

The design and processing methods that Mannette pioneered, and that steelpan makers have used ever since the 1940s, turn out to be perfectly suited for producing the drum's complex, rich sound. The researchers will publish their latest results in an upcoming issue of the JOURNAL OF MATERIALS SCIENCE.

When Mannette was a youth, discarded barrels were abundant in oil-rich Trinidad, so he and his compatriots shaped them to make music. Drums are still made mostly by hand using many of Mannette's original techniques.

To form a steelpan, the drum maker first "sinks the head" by hitting the bottom of the barrel with a sledgehammer, making it concave like a bowl. "If you don't do it correctly, it breaks," says Murr. Then, the note-making surfaces are hammered up from underneath, forming raised sections on the bowl's surface. Often, the side of the barrel is cut to make it shorter.

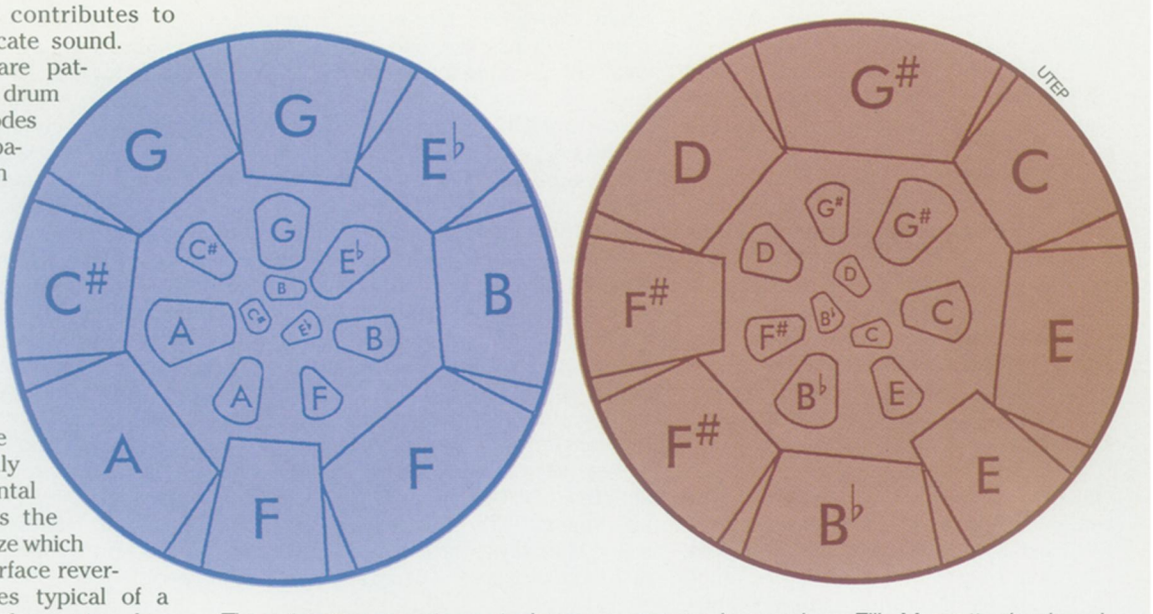
A tenor, or lead, drum can have as many as 32 striking surfaces arranged in a circular pattern. A bass drum might have only three. Other drums in a typical band include what are called guitars and cellos (each with 8 or 9 striking surfaces), which cover the midrange. The drummer strikes the notes with mallets, usually aluminum tubes covered with a piece of rubber.

Grooves or a line of holes bordering the raised surfaces help to isolate them from each other. Nevertheless, hitting one note causes some excitation of neighboring

notes, an effect that contributes to the instrument's intricate sound. "Because the notes are patterned onto the same drum head, the vibrational modes of one note will sympathetically vibrate with another," Murr explains.

Thomas D. Rossing, a physicist at Northern Illinois University in DeKalb, has examined the acoustic properties of steel drums with a technique called holographic interferometry. He excites one note electromagnetically at one of its fundamental frequencies, then uses the interferometer to visualize which areas of the playing surface reverberate. "At amplitudes typical of a performance, almost the entire drum vibrates and radiates sound," he reported in the March 1996 PHYSICS TODAY. Such extensive influence of one note on others is unusual in a musical instrument.

Through their metallurgical studies, the UTEP researchers tried to draw connections between the structure of the steel and the musical quality of the drums. They learned that drum makers ingeniously take advantage of the properties of the cylindrical steel oil barrels to create their multiharmonic instruments. Sinking the head allows them to make a range of notes on a single playing surface. In a tenor drum, for example, the lower notes are placed around the edge of the playing surface and the higher ones, in the center.



The note arrangements on steelpans vary among drum makers. Ellie Mannette developed this pattern for a set of double tenor drums.

Sinking the drum head stretches the steel, Murr says. At the center, the steel is pulled to half its original 1.2-millimeter thickness. Thinner metal produces higher notes. The deeper the drum head is sunk, the thinner the metal at the center, and the higher the range of the steelpan.

Steel, which consists primarily of iron and carbon, also proves to be an ideal material for the instrument. Hammering deforms the steel, introducing small defects and dislocations of atoms into the structure of the metal. These changes alter its hardness, which in turn affects the sound.

After the initial hammering, the drum maker heats the steelpan by turning it over a fire to restore some flexibility to the metal in preparation for more hammering. During heating, the carbon atoms in the steel collect around the dislocations, a process called strain aging, Murr says.

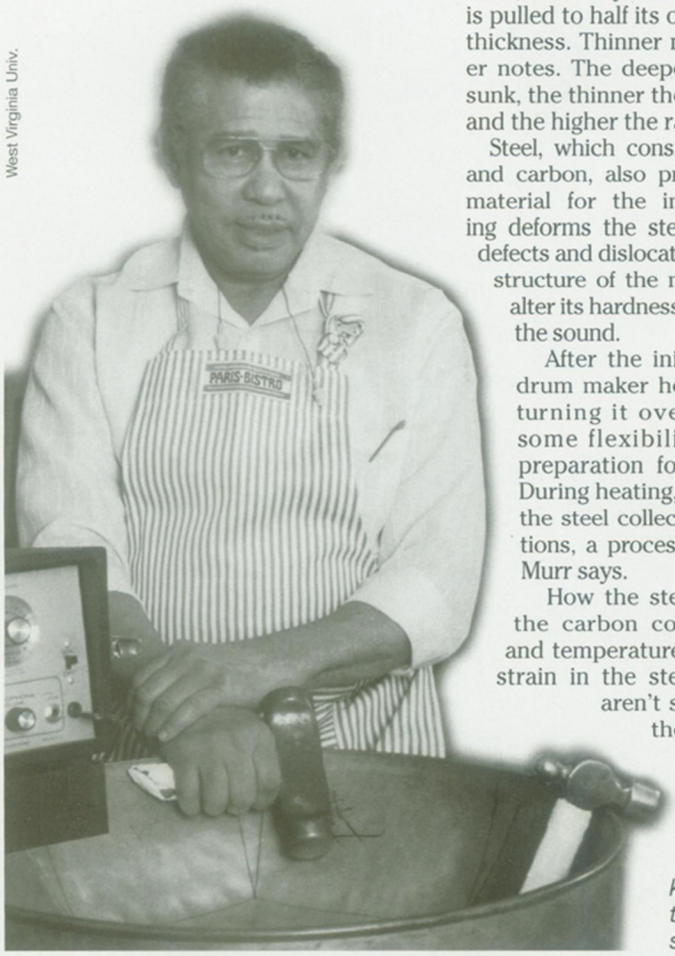
How the steel ages depends on the carbon content, heating time and temperature, and the amount of strain in the steel. The researchers aren't sure yet how each of these variables affects the acoustics. "We're still working on this because it's a multivariable problem," Murr says.

Nevertheless, the composition of the steel, typically 0.03 to 0.04 percent carbon, does seem to be important. Murr says that if there's too little carbon, the steel "will never age" and become malleable enough to be properly hammered and tuned. If there's too much, the carbon precipitates out of the material when it's heated. Also, too much carbon can make the steel brittle and cause it to shatter during the initial sinking procedure.

In Rossing's lab, Jerome Defrance measured the change in the note frequencies of a double-second (alto range) steelpan after heating it for 6.5 minutes. He found that heating raises the frequency of the drum's notes 10 to 30 percent. Drum makers rough out an instrument's notes before heating it, then fine-tune them afterward.

Inverting the drum over a fire also produces a fortunate temperature variation that suits the microstructure of the steel. The center of the bowl-shaped playing surface, which contains the most strain, is farthest away from the flame and thus is heated to a lower temperature, about 150°C compared with 315°C near the edges. This helps prevent overaging of the center, where more dislocations occur.

The techniques Mannette and his contemporaries developed were "serendipitously correct, but now we know they're correct," Murr comments.



West Virginia Univ.

Ellie Mannette is known to many as the "father of the steel drum."

The excitation of neighboring notes contributes to the steelpan's haunting sound, but there's more to the story, the UTEP group discovered. They fabricated some single-note disks out of stainless steel—rolling, machining, and heating them to model sections of an actual drum. Unlike parts of a real steel

drum, however, these disks are perfectly round and have a uniform thickness.

The isolated, idealized stainless steel disks serve as a simple way "to get a handle on the situation, so we know what to look for," Murr says.

When he and his colleagues struck these idealized notes and recorded their acoustic spectra, they observed something unusual. As expected, they found vibrations at each note's fundamental frequency, corresponding to its musical pitch, as well as at multiples of that frequency, called harmonics. At high harmonic frequencies, above 1,000 hertz, however, the spectra showed pairs of peaks, instead of the expected single peak.

The signal shows one peak above the expected harmonic and one below. For example, a section that is 60 percent of the original thickness produces dual-peak harmonic frequencies, split by as much as 160 Hz. On the other hand, a section hammered to 80 percent of its original thickness produces two harmonic peaks 60 Hz apart.

"It's very cool—not what you'd expect," Murr says. "The splitting is tied to deformation in the [disk] itself."

The researchers have also seen splitting occur in tones from an intact drum surface, he adds.

The UTEP scientists discovered that the harmonics resonated more strongly than the fundamental frequencies, which might contribute to the pan's unusual sound. "We hear the fundamental, but it's weak compared to the harmonic. We don't know yet what the ear does when it hears that," Murr says.

The side, or skirt, of the drum, acting as a resonator, also affects the notes. In tenor drums, the skirt is cut off to a length of about 13 centimeters. Bass drums retain the full length of the original barrel, which is 86 cm. Heating the skirt doesn't appear to change the tone, probably because it's not hammered and so doesn't undergo strain aging. The UTEP group is now doing experiments to see whether hammering the skirt can create interesting differences in the steelpan's sound.

Even seemingly cosmetic changes can alter the tone. Drum makers often coat the instruments with chrome to make them shiny, Murr says. Chromium, a harder metal than steel, gives the drum a crisper beat.

The drum maker's job doesn't end when the instrument leaves the workshop. Constant, enthusiastic pounding makes steel drums go out of tune very quickly. "Within a year, they're almost unplayable," says White.

Learning to tune steelpans well takes years of practice. It's much harder than for other drums, White says. Tuning timpani, for example, is a matter of adjusting the tension of a membrane until it produces the right pitch. The steel drum, however, requires tapping different areas of each note's surface to produce the right harmonics. The tuner must repeatedly tap around the circumference of each note, readjusting the sound along the way.

Mannette is one of only a few master steelpan tuners in the world, which places a high demand on his services. The UTEP music department flies Mannette to El Paso to minister to its collection of steelpans. Mannette brings his own tools: an array of ball-peen hammers. At West Virginia, he heads the University Tuning Project, a program designed to train a new generation of steelpan tuners who can carry on the tradition.

Murr hopes that the UTEP project gives the researchers clues on how to improve the drum manufacturing process or perhaps how to automate it. However, many people will insist on having handmade drums anyway, he concedes. "You probably couldn't make a machine that could make a Stradivarius violin"—or a Mannette steel drum.

"As more scientists see the potential of the instrument, the interest will grow," says Kaethe George, manager of the University Tuning Project. The science of the steel drum "hasn't been looked at this closely before."

As any lover of Caribbean music can tell, though, steelpan makers haven't done so badly on their own. □