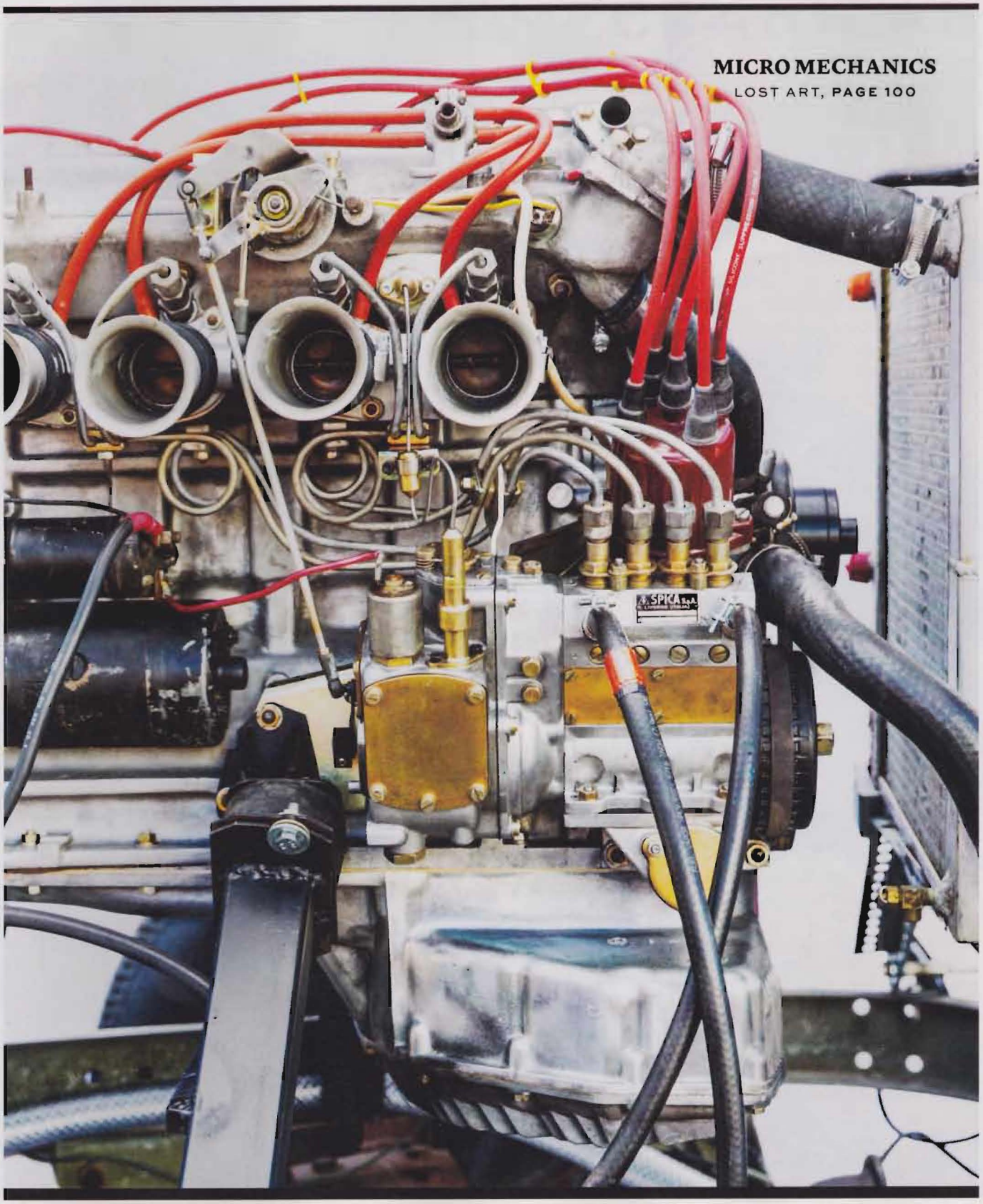
THE BOOT

GREASE | GEAR | DATA | KNOW-HOW



MICRO MECHANICS

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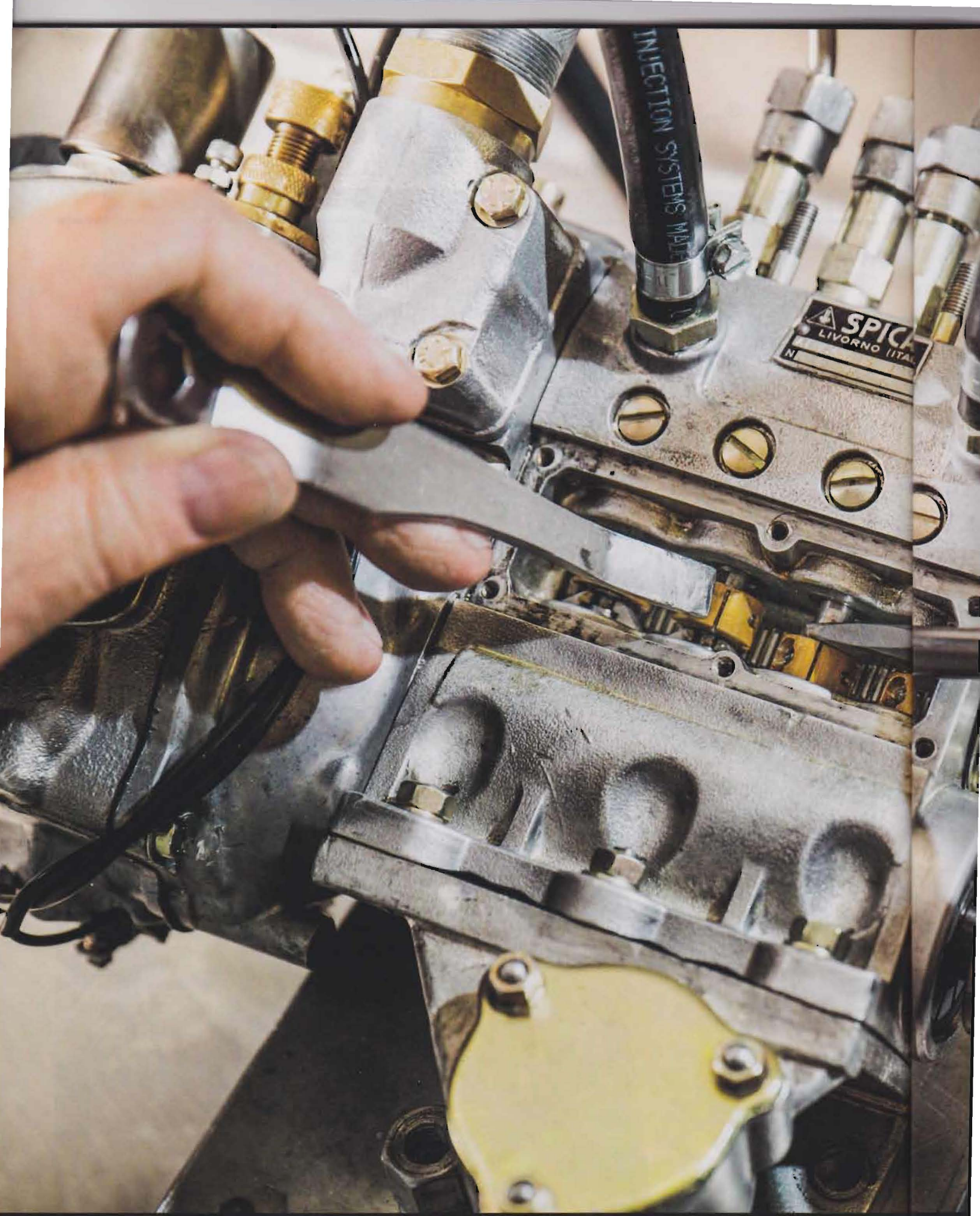


PHOTOGRAPHY BY **ROD McLEAN**

LOST ART BY SAM SMITH

MECHANICAL FUEL INJECTION

LIKE CLOCKWORK—JUST WEIRDER AND FULL OF FLAMMABLE LIQUID.

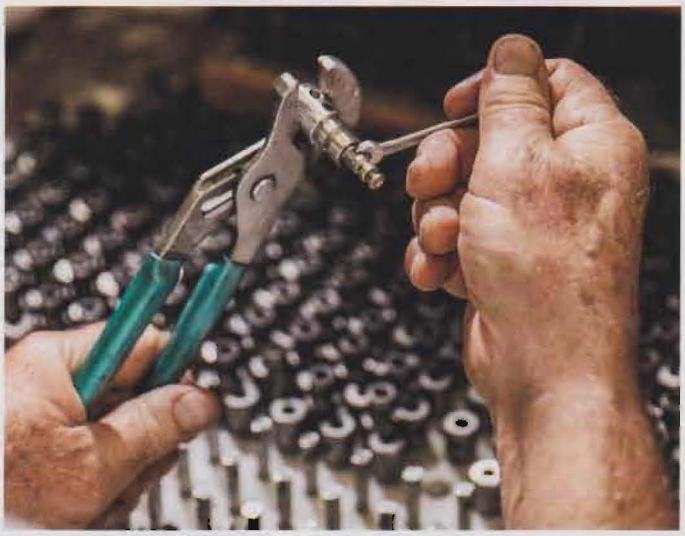
Picture an old windup desk clock. Now cross it with a gasoline engine, adding a tiny crankshaft and pistons. Tack on a few Buck Rogers bits, so it looks like Rube Goldberg's toaster. Flow gasoline through it at hundreds of psi. Finally, tweak the whole mess—maybe an oil feed, some balanced parts—to keep it from grenading in use.

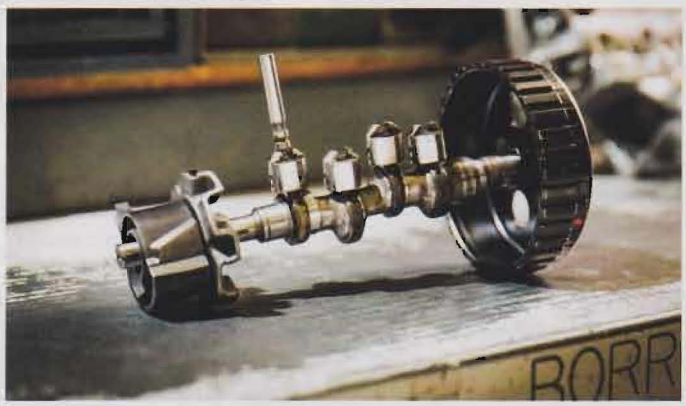
Congratulations! You've built a mechanical fuel-injection pump, from the days before digital engines. Think of it as a clockwork if-then statement: The "if" is engine condition, physically communicated to the pump by a handful of analog sensors and levers. The "then" is fuel delivery.

Generally speaking, this is how modern engine management functions, in everything from Fords to Ferraris. The difference is in the process. Modern cars use electronic sensors and computer-controlled injectors. Mechanical FI is brain and muscles in one box, a single organ handling both logic and distribution. And until the late 1960s, if you wanted a car without a carburetor, it was your only choice.

Wes Ingram and his business partner, Herb Sanborn, collaborate on rebuilding and modifying mechanical injection pumps for vintage Alfa Romeos. Ingram has been doing it since the Eighties, when, he says, "the cars were still driven every day." Sanborn, a retired oceanographer, joined him in 2000. We visited them in their Washington shop, Ingram Enterprises, because it's one of the only centers for such work. Also because SPICA injection—found on every U.S.-market Alfa from 1969 to 1981—is widely maligned. And thus a good way to illustrate the tech's darkness and light.

Like a lot of carmakers, Alfa Romeo arrived at fuel injection reluctantly, as a way to maintain performance while minimizing emissions. According to legend, carbureted Alfas failed the EPA's sniff test for 1968, so the marque went away for a year. When it came back, it brought a line of cars with a version of its racing injection, found on prototypes like the T33. Power outputs didn't change, and most Alfas in the rest of the world retained carbs. Some marque experts claim the pump's engineering cost was the same order of magnitude as the engine in the firm's legendary GTV coupe. ▸





Clockwise, from upper left: Hand-matching barrels. Sanborn's flow bench. The pump's crankshaft, cam, rods, and one plunger.

Diesel fuel behaves differently from gasoline, but like most Euro injection pumps, SPICA resembles a diesel unit. The pump is belt-driven from the crankshaft at half engine speed. It supplies timed, high-pressure fuel to one injector at each intake port. Each of those is essentially a spring-loaded valve that opens only when hit with fluid at a certain psi.

Early racing injection systems were almost binary, aimed at maximum power with little consideration for drivability. As such, SPICA's intelligence lies not in the fact that it pumps fuel, but how. The pump itself is a hydraulic device: one plunger per cylinder, pressurizing gasoline and actuated by a tiny connecting rod. Which makes its output linear with rpm. But because a gas engine's fuel appetite isn't linear—and here you can blame everything from the laws of physics to tuning choices—the pump has to compensate.

Properly explaining the way in which that happens would take a book. But broadly, a complex 3-D cam lives in the pump's rear section. It moves fore and aft with rpm, driven by centrifugal force, and is rotated axially by a linkage connected to the gas pedal. A follower on that cam moves a toothed rack that rotates the pump's plungers, varying the volume they deliver. A handful of mechanical compensating devices alter the follower's geometry even further, based on factors like coolant temperature and barometric pressure.

The whole thing looks like Leonardo da Vinci tried to design an artificial heart, failed, and switched to gyroscopes instead. While loaded on grappa. With the access panels off, it's virtually impossible to look away.

Fascinating details abound. Take the plungers. They run in steel barrels with micron-level clearance. No seals separate them from the oil in the pump's sump. Their fit alone holds back the 400 psi of fuel they can produce. All this for a marque where production inconsistencies mean body panels don't always fit when swapped between cars.

Boggle on that for a moment.

Ingram and Sanborn rebuild more than 120 pumps a year. Save a few standardized parts, everything has to be scavenged or made. ("There weren't even parts available in the Eighties," Ingram says. "The factory didn't want anyone messing with it.") Worn plungers are painstakingly hand-matched to their barrels from stockpiled spares. Since their clearances are essentially unmeasurable, the job has to be done by feel, with a roughly 50 percent reject rate. A flow bench ensures even output. Motorsport rebuilds see mixture altered by hand-tweaking the shape of the pump cam or its linkage—the results based either in experience, or live trial and error on a dynamometer.

"People used to replace these things with carbs because they didn't understand them," Ingram says. "Half the cars didn't run right when new, but the factory was afraid of the EPA, and they didn't want mechanics to know too much.

"I just hated seeing good parts go in the trash. But people are coming around. They're amazing little pieces. And you know what? It's crazy—we're backed up. More work than ever." ■