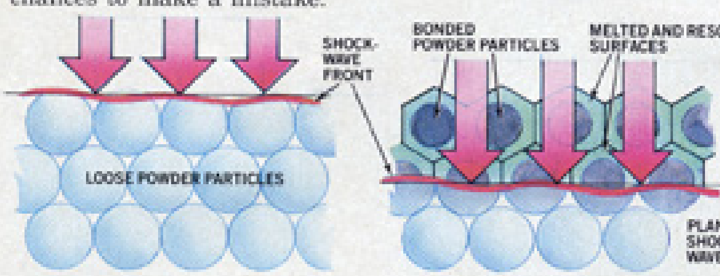
By STEVEN ASHLEY
Illustrations by Jana Brenning

With the casual air of a homeowner who is filling his lawn spreader with grass seed, Tom Gould hefts a brown paper sack to the top of an upright section of eight-inch plastic pipe and starts to pour. BB-size pellets flow into the white cylinder until they cover a short metal pipe that's standing at the bottom of the enclosure. After placing the bag on the ground, Gould reaches down to spread the white granules around the interior. From his placid expression, you'd never know that he's sticking his hand into a 20-pound pile of high explosives.

"That stuff looks like fertilizer," I remark as the explosives technician checks over the apparatus. "It is," Gould replies, absently stroking his beard. "It's pelletized ammonium nitrate, a fertilizer, mixed with fuel oil—ANFO, for short," he notes in the soft measured tones that seem to characterize the speech of many staff members at the New Mexico Institute for Mining and Technology's Center for Explosives Technology Research (CETR). When I make this observation, Gould smiles slowly and then says, "That may well be so. In a business like this, you *have* to think things out beforehand; you just don't get many chances to make a mistake."



At CETR the business is bombs, blasts, bangs, and booms. The Socorro, N.M., campus, which extends over a barren range of high desert mountains suited for testing explosives, is just up the Rio Grande from the Trinity site—where the first atomic weapon was detonated. In 1983 the State of New Mexico, provided money for CETR's establishment. The Department of Defense, the National Science Foundation, Sandia and Los Alamos National Laboratories, and other governmental and industrial organizations now fund explosives research projects there.

Explosive metallurgy

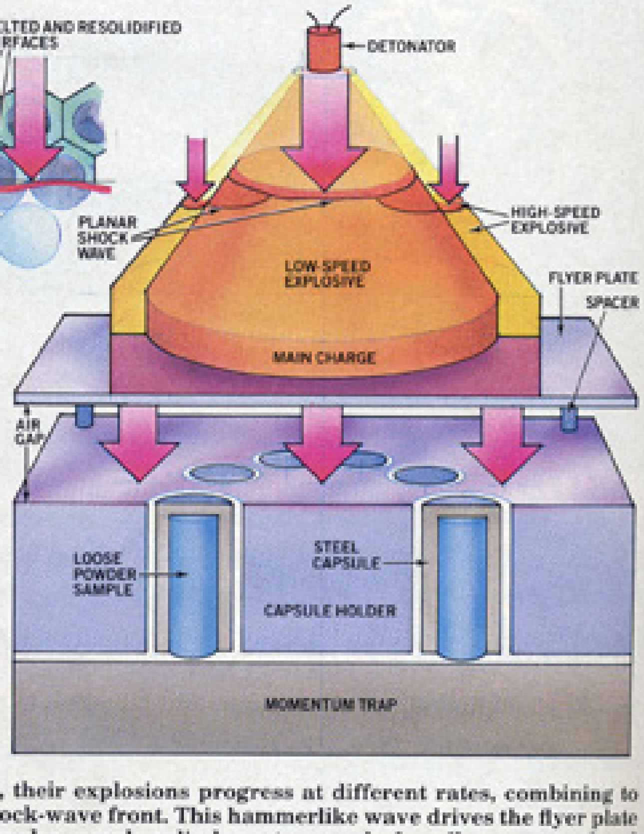
For years explosives have been used in metal manufacturing. In one application they bond hard-to-weld metals to one another. For instance, when silver was removed from U.S. coins several years ago, much of the so-called "sandwich metal" that replaced it was formed by using explosive sheets to slam metal slabs together and bond them.

Interestingly, several artists working at New Mexico Tech have adapted similar techniques to create art. This "detonography" technique involves a single sheet of metal, which is projected at supersonic speeds against a sculptured plaster mandrel by the firing of an explosive sheet. The design cast into the mandrel transfers to the metal sheet, yielding a handsome bas relief.

Lately, CETR researchers have been using explosives a little differently—to *make*, rather than bond or deform,

Most explosives are used to destroy things. But they can also create them. Researchers at New Mexico Tech are tailoring explosives to produce shock-wave "hammers" that can instantly forge super-hard metal and ceramic powders into ultra-high-performance solids.

DYNAMITE METALS



Using technology developed for the first atomic bomb and adapted for use at New Mexico Tech, the shock-compression device shown to the right subjects samples to transient pressures of up to one million times that of the atmosphere. At the top is a "lens" consisting of two concentric cones of explosives with differing detonation speeds. When detonated at the apex, their explosions progress at different rates, combining to produce a planar shock-wave front. This hammerlike wave drives the flyer plate down against the powder-sample cylinders at a speed of a mile per second and compacts the contents. The diagram at top left depicts the flat shock wave as it compresses the powder particles with force sufficient to melt their outer surfaces.

metals and ceramics themselves. By hitting powders with explosive shock waves that work like giant instantaneous mechanical presses, the particles can be fused into solids that are difficult to make otherwise.

"It turns out that certain high-performance materials such as hard ceramics and what are called rapidly solidified metals cannot be consolidated from powders by other means," explains Naresh Thadhani, an assistant research professor at New Mexico Tech. "Ceramics are good at resisting compression and heat," he says. "And rapidly solidified alloys, produced by instantly 'freezing' small drops of the molten metal into tiny hard particles, will separate into their elemental constituents if they're heated too long. But both types of materials can be consolidated into bulk forms by explosive compaction. When the particles are forced together under tremendous pressure, the surfaces melt, then solidify quickly, bonding them together."

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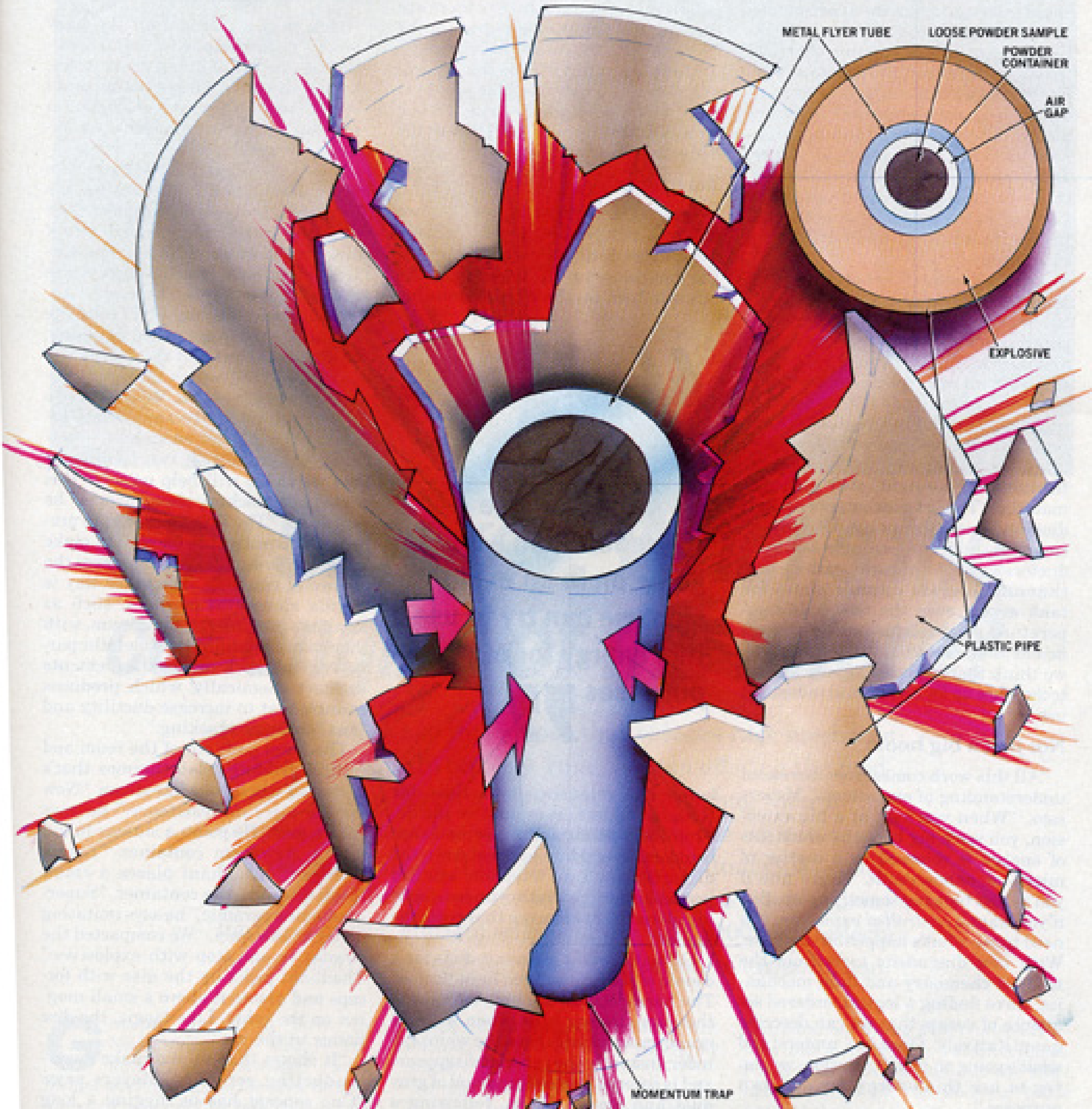

The cylindrical shock-compression apparatus shown above surrounds the powder sample with explosive pellets. Upon detonation, the explosives cause the sample material to implode, compacting the powder granules into a solid.

Thadhani and I are now standing inside a concrete bunker that's buried beneath the clearing where Gould is finishing assembling the experimental charge. CETR staffers call this test site Big Eagle. The low-lighted blast shelter is filled with conduits, detonation triggers, timing devices, data recorders, and computers. In addition, it has a periscope and two ultra-high-speed cameras to film the experiments.

"Under shock compression," Thadhani continues, "interesting chemical reactions can occur. For instance, normally incompatible metals such as titanium and aluminum react under explosive shock to form titanium aluminide, an extremely lightweight, strong, and heat-resistant intermetallic alloy that's being considered for use in the skins of future hypersonic airplanes. In fact, that's what we're making in today's shot."

Amidst Thadhani's short discourse, Marc Meyers, CETR's associate director, moves out of the bright desert sunshine, past the heavy steel-plate door, and into the shady bunker. "Of course, that's not all we're fabricating with explosives," Meyers adds as he lounges against a concrete-block wall. "Other materials include nickel-base superalloys for jet engines and aluminum-lithium alloys—light, stiff airframe materials. The list goes on: super-tough diamond and cubic boron nitride cutting tools, gallium arsenide semiconductors, ultra-hard boron carbide and titanium diboride ceramic plates for tank armor, even the new high-temperature superconductors. With sufficient understanding of the process, we think that it's possible to scale the techniques up for economical industrial use."

Not just a big boom

"All this work comes from increased understanding of explosions," Meyers says. "When you look at a big explosion, you see a big boom in which lots of energy is released in a matter of micro- or nanoseconds. That's fine if you're just blowing something up. But if you want a *controlled* explosion, you need to see what's happening in there. With new diagnostic tools from the fields of chemistry and fluid mechanics, we're finding a logical, ordered sequence of events that we can describe quantitatively. Once we understand what's going on in an explosion, we can try to use this energy for our own purposes."

By now Gould, two other technicians, and Jim Kough, the graduate student whose experiment we're going to witness, have entered the underground enclosure to set up the equipment for the shot. The three of us decide to survey the test site above. The test apparatus sits in a clearing at the base of a small valley. Piles of splintered wood, twisted rusty metal, and other debris dot the dusty plateau.

Thadhani kneels down to describe the apparatus: "Basically, we have the loose metal powder inside a metal cylinder that's surrounded by the explosive ANFO. All this is contained in the plastic pipe. On the side here there are sensors that report the progress of the shock wave to the computer." He points at wires leading to a cable that snakes across the ground to a hole where it dives into the bunker's roof. "When Tom gets back up here, he'll install the detonator and we'll be ready to go."

Zero hour

Ten minutes later the stone-strewn valley is still. Nothing moves, not even a stray dust devil. Barely visible among the dun-colored rock slides, cacti, and creosote bushes, the bunker crouches below the relentless sun. Save for Kough and me, everyone is inside. From our perch among some large boulders several hundred feet down the dirt access road, my telephoto lens can just make out the white cylinder standing alone in the clearing that roofs the bunker.

> **"Once we understand what's going on in an explosion, we can try to use this energy for our own purposes"**

Off to the right a siren sounds for a couple of seconds as a red light flashes. The horn's echoes are just fading into the surrounding hills when a flame erupts momentarily from the white cylinder. Instantly the cylinder disappears and is covered by a roiling cloud of gray dust and smoke. Then, following a short pause, the loud rumble of the blast arrives. The cloud continues to rise until it fills the valley.

As the dust settles, the massive door to the bomb shelter opens and several figures emerge. By the time we reach ground zero, the others are hunkered down near where the white cylinder once sat. Now there's a lunarlike crater dug out of the gray dust.

After picking through the dirt for a few moments with long tongs, Kough lifts up a five-inch-long blackened metal bar. It still smokes a bit from the blast.

Cracking conundrum

Back in a classroom on the New Mexico Tech campus, a small well-watered enclave of green grass, trees, and low school buildings sitting amid the dry desert, Meyers and Thadhani show me a series of explosively compacted samples.

"You can see that many of these bars have cracks in them," Meyers says. "It's our biggest problem. The cracks arise when the initial compressive shock waves reach outer surfaces. The surfaces reflect back tensile stress waves that crack the now-solid metal."

"That's why we use ANFO for the explosive," the researcher explains. "ANFO has about half the detonation velocity of TNT, which means it produces a gentler shock. We also try to trip the wave with the appropriate geometry. But it's not enough.

"We're working on two techniques that we think will help us solve this post-shock cracking phenomenon," he continues. "The first method is to preheat the powder just enough to make it a bit more ductile, which reduces the chance of cracking. The other way is to mix elemental powders, such as straight titanium and aluminum, with the rapidly solidified intermetallic particles. The shock causes the elements to react chemically, which produces enough heat to increase ductility and thus minimize cracking."

Thadhani pads out of the room and returns holding a lab thermos that's giving off what looks like steam. "Now for the *pièce de résistance*," he says with a grin. He pours a steamy liquid into a styrofoam container. "Liquid nitrogen." Thadhani places a small black disc into the container. "Superconducting ceramic," he says imitating a magician's spiel. "We compacted the powder in one step with explosives." Thadhani picks up the disc with forceps and places it above a small magnet on the table. Like magic, the disc hangs in the air.

"It shows that we did make superconducting ceramic," Meyers says. "One concept has us digging a long ditch, pouring the ceramic precursors into it, and then explosives. Afterward you detonate the explosives, and the shock forms superconducting cable *in situ* in the ground." It's a nice idea. ■