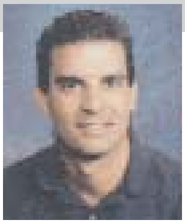
BY MIKE PRINCIPATO



Sprocket science

I received a blizzard of e-mails in response to my recent column about what I perceive to be a significant but unquantifiable side effect of our country's shrinking manufacturing base: The loss of the problem-solving skills acquired by osmosis by youngsters reared in an economy that emphasizes engineering and manufacturing. Most came from frustrated dads who lament that their kids find the virtual world of video games much more engaging than, say, building a tree house or repairing a broken skateboard. Many pleaded for help.

For those readers, I've got two words: science fair.

The term almost invariably provokes cold sweats and stuttering heartbeats from even the most devoted dad. For many of us, it conjures painful memories of poster board-borne experiments gone horribly awry for all to see amidst an elementary school auditorium swimming in elegant working models of crystal radios, photosynthesis demonstrations that God Himself would envy and expertly home-built, copper-wound machines that generated hair-raising electricity and more "oohs" and "aahs" than an episode of Oprah. Oh, the humanity!

Don't despair, Pop. The school science fair, local engineering fair, vocational-technical fair or any other good-natured scholastic competition that requires your kid to conceive, plan, create, measure and, ultimately, be responsible for the outcome of a product is actually a valuable "teachable moment," as the academics like to call it. In fact, prepping for a science fair is nothing if not a simulation of just the kind of manufacturing exposure youths need. So grab it when the opportunity arises and ride it for all it's worth. You might be amazed at the impact it has on your child.

Case in point: My seventh grade son—the one I discuss from time to time in this space, and is, in effect, my own personal science experiment—is steeling himself right now for his first experience with his school's annual science fair. Here is a rough recap of the first conversation we had on the subject:

Son: Dad, I need to decide what I'm going to do for the school science fair.

Me: What do you have in mind?

Son: Well, kids are testing batteries, the effects of saltwater on different metals, that kinda stuff.

Me: Totally lame. What are you gonna prove about an AA battery that a bazillion kids don't already know? And what happens to metals when they're exposed to saltwater?

Son: They rust. Or they don't.

Me: Wow, now that's a revelation, huh?

I gradually steered him toward combining his career interest—engineering—and his typical 12-year-old's fascination with anything that explodes, burns or, in general, scares the hell out of responsible adults. The result? He's building two scale models of medieval-era siege weapons, test-firing them at a Styrofoam block wall, gauging the "destruction" each firing causes by measuring the aggregate distances between the blocks, and recording and reporting the results.

In other words, he's simulating a product development cycle. Granted, there isn't much of a market for catapults and trebuchets these days, but this is for a science fair. When his school holds a marketing fair, we'll deal with that subject. Meanwhile, he's pumped about the chance to build something, and I'm pretty darned proud that I was able to inspire that excitement merely by guiding the process.

Public education has all but abandoned any concerted effort to provide youngsters with the hands-on experiences they need to truly learn how fulfilling creating something out of nothing can be. But parents have always been a child's first and foremost educators.

Can he pull it off? Absolutely. Would he have considered this science project without direct influence from me? Absolutely not.

And that, parents, is the point of this little story. Public education has all but abandoned any concerted effort to provide youngsters with the hands-on experiences they need to truly learn how fulfilling creating something out of nothing can be. But parents have always been a child's first and foremost educators. So when presented with an opportunity to spark that interest in your budding manufacturing professional, make the most of it.

Lest you think I'm one of those parents that lives vicariously through his child in the classroom and on the soccer field, I'm not. But I also recognize that I can't rely on our school systems to cultivate those problem-solving skills that I lament. That's up to me—and you.

Will my son's exhibit get a ribbon? Maybe. But in the long run, he wins either way. After all, does the world really need to see another Van der Graaf generator?

About the Author

Mike Principato owns a machine shop in Pennsylvania. He can be e-mailed at ctemag1@netzero.net.

Fundamentals of face driving

BY JEREMY MICHAEL, RITEN INDUSTRIES INC.

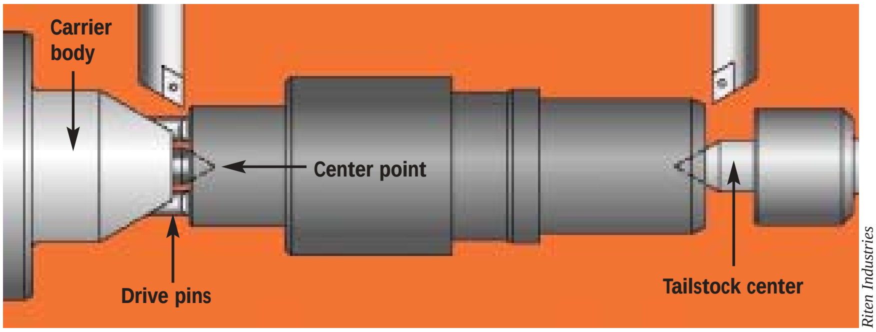


Diagram of a face driver setup.

In a world where success is determined by the bottom line, manufacturers are always researching and developing new ways to cut costs and increase productivity. Whether it's at the grinding wheel or the CNC lathe, plant managers are always looking to get the most out of their tooling. The need for progress and innovation has led to many workholding developments, including the engineering of high-precision face drivers.

Though not a new concept, face driving has been gaining ground as a cost-effective way to hold any type of metal workpiece that needs to be turned.

In a typical lathe application, a machinist chucks one end of the workpiece and begins cutting. As he nears the area that is chucked, he is forced to stop the machine and turn the workpiece around to cut the portion that was in the chuck jaws.

This process causes two problems. The first and most obvious is increased cycle time. When running production quantities in the hundreds or thousands, the time it takes to chuck each part twice adds up quickly and begins to cut into profits.

The second problem lies with the concentricity of the finished part itself. If a manufacturer is producing axles or a similar type of shaft, it is important that the dimensions of the part be precise from end to end. However, the dimensions may vary slightly if the workpiece is not perfectly aligned when it is chucked for the second time. Both of these problems can be avoided with the use of a face driver.

A face driver eliminates the need to flip the workpiece during cutting and allows the entire part to be machined in one fixturing. The workpiece is centered in the machine via a live center that locates its point in the center hole on one end of the workpiece. A face driver then uses the machine's tailstock pressure to engage the workpiece with the face driver's center point, which locates the workpiece and provides a consistent axis of rotation.

As the tailstock pressure continues to drive the workpiece against the center point, the axial pressure forces the spring-loaded center point back into the carrier body of the face driver until the drive pins engage the end face of the workpiece, eliminating the need to chuck the OD. The pins compensate for any irregularities in the end face until all of them are fully engaged.

This technique removes the chuck jaws from the path of the cutting tool and enables the part to be machined from end to end, simultaneously cutting production time and increasing concentricity.

A face driver is made up of four main parts and is available in two designs and three mounting options.

■ Flange/shank: The lower portion of the face driver that is mounted in the machine.

■ Carrier body: The upper portion of the face driver that serves as the guide and housing for the drive pins, center point and compensating medium. The medium allows the pins to compensate for any irregularities in the end face while they engage the workpiece. The pins must have the medium. In a mechanical face driver, the medium is a split-washer assembly. In a hydraulic face driver, the medium is hydraulic fluid.

■ Center point: A replaceable spring-loaded point that locates in the center hole of the workpiece and provides an axis of rotation while enabling the drive pins to engage the end face of the workpiece.

■ Drive pins: These act as the teeth of the face driver and bite into the end face of the workpiece. Drive pins are replaceable and, depending on the size of the driver and the workpiece, are used in sets of three to 10.

■ Mechanical face drivers: The drive pins move independently to allow a 5° pitch on the end face of the workpiece. The mechanical compensation and lock-down center point allow a constant length to be held from the center of the workpiece to the taper.

■ Hydraulic face drivers: The pressure equalization of the drive pins is provided by hydraulic fluid. This permits a 7° pitch on the end face of the workpiece. Behind every drive pin is a sealed piston that prevents oil leakage. The oil cavities behind the pistons are interconnected and the whole system is enclosed. This design is generally used in medium roughing operations and can handle loads of up to 3,000 lbs.

■ Shank mount: Used when the machine spindle requires a Morse-taper mount.

■ Chuck mount: The shank is gripped using chuck jaws.

■ Flange mount: With a spindle adapter, this type mounts directly to the machine. A flange mount is the most rigid mounting procedure.

About the Author

Jeremy Michael oversees international sales for Riten Industries Inc., Washington Court House, Ohio. For more information about the company's face drivers and other workholding products, call (800) 338-0027, visit www.riten.com.

A small challenge

BY BILL KENNEDY, CONTRIBUTING EDITOR

For medical parts, smaller is usually better. One example is a hearing aid with miniature components connected by a tiny balljoint that enables the instrument to flex and conform to different-shaped ear canals. Small parts specialist MiniMachine Inc. made a number of parts for the device, including a 0.440"-long, 0.200"-dia. brass housing, which has the ball component of a balljoint connected to it.

MiniMachine performed the first machining operation on a Hardinge GT27 Super Precision gang-tool lathe with an indexable C-axis and live tools. A hydrodynamically stabilized, single-tube Seneca bar feeder fed the workpiece, a 12'-long, ⅜"-dia. bar of ASTM 36000 free-machining brass, into the lathe.

Mike Rosenboom, MiniMachine cofounder and vice president, used a TPCB 2200 triangular carbide insert from Circle Machine to turn the OD to a diameter of 0.175" for a length of 0.235", then step up to a 0.200" diameter for a length of 0.205". The spindle speed throughout the job was about 4,500 rpm—"as fast as the machine would go," Rosenboom said. The feed was about 0.0003 ipr. For DOC, Rosenboom said his rule of thumb is to keep about 30 to 50 percent of the tool's nose radius engaged when finishing. "Say you are going with a 0.002" corner radius, you're going to get your best finish right around 0.0006" into the part," he said.

The light feed and DOC made multiple passes necessary, but Rosenboom said: "I didn't want to put a lot of stress into the part. If it gets really hot while I'm cranking the material off, then when I go to a thin wall it won't be round anymore. As a manufacturer of tiny components, we have to understand material engineering, to a degree."

Small part diameters can make achieving optimal surface speed a problem. "I could use a 20,000-rpm lathe on something like this," Rosenboom said, "but it's kind of a mixed bag." With a 12' bar in a stabilized feeder, running at even 40,000 rpm is possible. But when only 3' of the bar remains and is supported only in the headstock, vibration can occur. "So just having a consistent speed throughout the whole course of the bar was really the way to go," he said. "We weren't going after the minimum cycle time; it was more important to have a part with a really awesome finish."

The part's most challenging feature was two sets of machined teeth, or barbs, on the housing's 0.175" OD. The barbs grip a foam cylinder that slips over the housing to cushion it in the ear canal.

To create the barbs, Rosenboom began by turning four angled grooves—0.015" deep and 0.04" apart—around the housing's full diameter. He applied a Thinbit grooving insert he had custom-ground to a 3° angle.

Key to the operation was a custom broaching tool Rosenboom designed to remove the grooves from most of the OD while leaving behind two 0.100"-wide × 0.145"-long grooved sections on opposite sides of the housing.

Rosenboom contracted an electrical discharge machining shop to make the broach from a ½"-dia., 2.5"-long carbide blank. EDM Labs Ltd., Fremont, Calif., first burned an axial 0.160"-dia. hole through the blank, then, via wire EDM, cut two 0.100"-wide × 0.015"-deep D-shaped full-length axial pockets along opposing walls of the hole. The 4-axis EDM created back taper in the cavity so the tool could be resharpened by simply grinding its face flat at 90° to its axis.

In operation, the spindle was stopped and the broach, clamped in a holder like a drill, was forced axially over the workpiece at 6 ipm. The axial pockets left the barbs untouched, while the broach's 0.160" diameter scraped smooth the rest of the OD. Rosenboom deburred the barbs by rerunning the grooving program.

Next, with another custom-ground Thinbit insert, Rosenboom machined two 0.015"-wide flanges, 0.032" apart, in the housing's 0.200" OD. In the flange closest to the chuck, a 0.020"-dia. carbide endmill cut two 0.020"-wide × 0.020"-deep slots. The endmill was driven at 35,000 rpm by an NSK Airmotor RA100 pneumatically driven spindle, which was clamped in the lathe's gang-tool plate and plumbed into the machine's CNC and air system. At a feed rate of 5 ipm and a 0.005" DOC, each slot required four passes.

B. Kennedy

It took a total of about 11 minutes to machine this nickel-plated, brass component for a hearing aid.

Rosenboom then drilled a 0.275"-deep axial hole in the housing with a ⅛"-dia. carbide circuit-board drill. "I tend to run small circuit-board drills at a conservative feed—maybe 0.0005 ipr—and as fast as I can spin them, which would be 4,000 rpm, and I peck."

He used the Hardinge machine's variable-depth drilling cycle, during which pecks become shallower as the hole gets deeper. "The trick to any drill is making sure the metal you remove doesn't exceed the volumetric area of the flute," he said. When the hole depth exceeds 5 diameters, pecking strokes are shortened to about 30 percent of the drill diameter.

Next, Rosenboom put a flat bottom in the hole with a ⅛", 2-flute carbide endmill, run at the same parameters as the drill. He finished the hole to 16 R_a and a diameter of 0.140" with a Micro 100 BB120600 solid-carbide boring bar.

For the first operation when machining the ball feature, an NTK TB3205R insert rough-turned the 0.200" OD behind the flanges down to 0.125". Then, using the Hardinge lathe's live tooling capability, a ⅛", 2-flute carbide endmill run at 4,000 rpm and 0.0005 ipr machined flats on opposite sides of the

0.125" OD. Finally, a 0.020"-dia. carbide drill, driven by another NSK Airmotor spindle, made a cross-hole through the flats.

To complete the first operation—which consumed about 8 minutes—a custom-ground Thinbit blade, run at maximum spindle speed and a 0.0003-ipr feed, cut the housing off the bar.

Rosenboom used a Hardinge DSM 59 lathe fitted with an Omniturn slide to handle the remaining machining. He held the housing by its 0.140" ID with a Rovi expanding minicollet. A Circle Machine TPCB2200 insert and another custom-ground Thinbit tool back-turned and finished the ball and also formed a 0.033"-long, 0.060"-dia. shaft between it and the housing. Tolerances for the ball were ±0.0003". The final machining step was drilling a 0.020"-dia. axial hole through the ball into the housing with a carbide circuit-board drill. The second operation's cycle time was about 3 minutes. The part, of which MiniMachine made about 10,000 over the life of the contract, was nickel-plated after machining.

Since Rosenboom produced the hearing aid part, he has added state-of-the-art multispindle machines. There is no doubt, he said, that he would make the part differently with his new machines.

For more information about MiniMachine Inc., Bend, Ore., call (541) 330-8641 or visit www.minimachine.com.

Regaining the edge

INTERVIEWED BY KEVIN COLE, ASSOCIATE EDITOR

Rep. Donald A. Manzullo (R-Ill.) represents the 16th Congressional District of Illinois. He was appointed chairman of the House Committee on Small Business in 2001. The congressman also founded the House Manufacturing Caucus, which he chairs, and serves on the House Financial Services Committee. Manzullo discussed the importance of a strong U.S. manufacturing base and fair global trade practices.

CUTTING TOOL ENGINEERING: What does it mean for the U.S. economy if the manufacturing base continues to erode?

Donald A. Manzullo: Manufacturing is necessary for the most basic of tasks in America, including our ability to defend ourselves. You can't fight a war if you can't make bullets. And as we learned recently, we can't always depend on our allies to help. The good news is that our nation's political and business leaders are now much more concerned about the future of manufacturing in America and are taking steps to strengthen this critical sector of our economy. I believe our nation's leaders now realize how crucial manufacturing is not only to our economy, but also to our national security.

CTE: What is being done to help U.S. manufacturers overcome the hurdles to fair trade?

Manzullo: Working with [the administration and Congress], I have developed a plan to ignite the economy and help put employers on a more level playing field with their international competitors. The American Jobs Agenda is aimed at passing legislation to make companies more efficient at home so they can compete better internationally. The result will be more orders for U.S. goods and services and more jobs for Americans. The main elements of this agenda involve tax relief, health care reform, regulatory relief, trade fairness, lifelong learning, spurring innovation, energy self-sufficiency and ending lawsuit abuse. The House has passed several pieces of legislation this year that would dramatically reduce the cost of doing business in the United States. Bills to reform our out-of-control medical liability system and to allow national associations to offer health insurance at group rates to members have passed the House and are awaiting Senate action. The House also passed an energy bill as well as legislation to extend "bonus" depreciation and higher Section 179 expensing limits for capital purchases, which have prompted many companies to expand and hire new workers. Our plan will reduce costs and help make U.S. businesses more competitive. But, competition with foreign companies can only thrive on a level playing field. And right now, many of our foreign competitors—especially China—have an unfair edge.

Rep. Donald A. Manzullo

CTE: You have said currency manipulation is a practice hurting U.S. manufacturers. What is this issue all about, how is it affecting U.S. companies and what is being done about it?

Manzullo: In the late 1990s, the U.S. dollar was riding high against most foreign currencies. It was great for Americans who could buy less-expensive products from overseas. But it was horrible for U.S. manufacturers who had to compete internationally because U.S. goods were artificially more expensive than products made overseas. Over the past few years, the U.S. dollar has dropped to more appropriate levels. However, we are still having problems, specifically with China, Japan, Korea and Taiwan. They are manipulating their currencies to keep them artificially low against our dollar. This became a huge problem as China has emerged as a low-cost global manufacturing force. Economists estimate these manipulations give Asian products a 15 to 40 percent competitive advantage over U.S. manufacturers. Last year, Treasury Secretary Snow, Commerce Secretary Evans and President Bush all addressed the issue during separate meetings with Chinese officials. While progress is being made, China is not moving fast enough. The U.S. government should ratchet up the pressure to convince China to freely float its currency. In addition, the federal government should strengthen its trade enforcement laws to provide more relief for America's small businesses. H.R. 3716 [is] a bill that would allow the U.S. to pursue countervailing duty cases against "nonmarket" economies, including China and Vietnam. The legislation would allow the U.S. government to impose tariffs on imports equal to the subsidies a nonmarket government provides to its exporters.

CTE: Some concern has been expressed by our readers that skilled manufacturing trades are not being promoted as good careers for America's young people. What are your thoughts on young people and manufacturing?

Manzullo: I believe one of the main reasons manufacturing has lost its prominence as a preferred career field dates back several decades, when our leaders began promoting college as the only avenue for success in young people's lives. Not every young person was meant to go to college, and they were set up for failure if they did not receive a degree. I believe we are making progress in changing this attitude. The House recently passed legislation to provide tax credits to companies that send their employees to school to get the latest advanced technology training. Manufacturing is becoming more and more technical, and U.S. companies' ability to continue to compete will depend on a well-educated workforce. We must encourage high schools to continue to offer vocational opportunities to their students. In addition, manufacturing executives can help promote manufacturing careers by sponsoring these manufacturing camps, offering internships to students and providing assistance to high school vocational programs.

Managing lubrication

BY DAVID GEHMAN AND GREGORY FARNUM

Lubricants can be seen as the chief enabling technology in any shop, because they keep sliding, rolling or turning bearings and surfaces from tearing themselves up. By maintaining machine dimensions and a smooth operation, lubricants also help keep part dimensions and tolerances under control.

If you could make sure your lubricants are not breaking down—the chief lube killers are oxygen and water, including water vapor in the air—and if you could get fresh dollops of grease and oil in the right places at the right times, your machines would last years longer.

But, without some sort of focused lubrication initiative, shops are often stuck in one of two modes: grind, cut and bend until the noise and heat indicate something is wrong, or change out lubricants solely at set intervals, risking waste of good lubricant.

However, there are lubrication management software packages that can help.

"We're biased of course, but we think lubrication is a great place to put time and effort," says Eric Rasmusson, president of Generation Systems Inc., Issaquah, Wash., home of Lube-It, a PC-based industrial lubrication management software. "When you give it the focus it deserves, you soon see that lubrication is a lot of small tasks, in and of themselves not difficult or complex, but critical."

Computerizing this multitude of tasks is a logical next step since computers are adept at retrieving information, comparing results with preset conditions and applying stored procedures.

Consider the following menu found in lube management software: best practices for machine lubrication; scheduling; lubricant specs for each machine; consolidation to the fewest number of products; lubrication equipment tracking; procedures for lubricant disposal or reclamation; analysis timing, instruments and monitors; and types of analysis, such as which lab to use and what actions to take depending on the results.

For these tasks, lubrication management software is a kind of ultimate notebook. It also pays attention to location.

"Lube management software can show you where your maintenance should be focusing every day, and it can route the tasks through the shop for minimum backtracking," said Rasmusson. "It tells you what fluids to take with you on today's rounds. You'd be surprised at how much time is lost going back and forth without that information."

Computers can be good repositories of knowledge as well. The specific use of lubricants has grown more complex as scientists combine molecules in new ways. Synthetics have begun to supersede traditional oils. Lube management software has ways to capture details about specific lubricants, such as optimum pH or operating temperatures.

Similarly, lubrication points on machines and lube recommendations vary from one machine builder to the next. Mapping these in software ensures the information does not go out the door with retirements or cutbacks, and it saves thumbing through manuals when human memory fades.

A number of lubricant suppliers include lubrication management, both software and services such as in-plant audits of current practices and conditions, as part of their offerings.

"Everyone is trying to do more with less," points out Dave Como, U.S. Lubricants Expertise Group, Dow Corning Molykote, Midland, Mich. Dow Corning employs Lube-It as one software platform in its total lubrication programs. "When you're trying to get to the leanest possible operation, maintenance is on the bubble, because it naturally seems less productive than machine operators. Software helps stretched maintenance personnel keep up with the jobs that most need to be done."

Dow Corning's implementation of Lube-It comes preloaded with information about Molykote products, including their applicability, approved or recommended lubricants for a range of specific machines, and good and bad values for analyzed parameters.

There's a final layer to the equation: drawing on the expertise of regional suppliers. Scott Niggemann, technical services manager for Rock Valley Oil & Chemical Co., Rockford, Ill., said, "We use a couple of tools including Lube-It to survey plants and help keep them operational." Rock Valley provides lubricants and fluid recycling services from Iowa to Ohio.

Shops can contract with Rock Valley not only for supplies and lubrication management software integration, but also for regular analysis, close control over lubricant content in recycling or disposal (important, say, for EPA or medical manufacturing needs), lubricant consolidation and more.

Ultimately, it makes sense to rationalize your lubrication needs—computerized or not. You gain longer machine life, and you should see more consistent production.

The following companies contributed to this report:

Dow Corning Molykote
(405) 773-0361
www.dowcorning.com/content/molykote/

Generation Systems Inc.
(425) 391-9046

Rock Valley Oil & Chemical Co.
(815) 654-2400
www.rockvalleyoil.com

About the Authors

David Gehman has been writing about manufacturing and software for more than 20 years as both a journalist and a marketing communications specialist. Gregory Farnum is a Detroit-based journalist specializing in industrial and scientific issues.

BY MICHAEL DEREN

The mushroom theory

Well, it has been a good year for many companies, and some of those companies are begging for good help. Other companies haven't fared as well though—they have shut down or are on the verge of shutting down. Many employees of these companies have been caught off-guard. They've had their wages frozen for the last 2 or 3 years, had their hours cut or, even worse, suffered layoffs. Didn't the employees see this coming?

The employers probably told them everything was going to be all right. "It's just a minor setback in our growth," workers may have been told.

Other employers just don't say anything. I've developed a theory about this type of employer response. I call it "the mushroom theory." This is where the employees are kept in the dark and fed a lot of … manure. Let's look at how to avoid getting caught off-guard with a company that's headed downhill.

Look at the quality of new-hires at your shop. As senior personnel retire, who is management replacing them with? Are talented machinists being hired and then leaving after a week or two? Ask yourself why. Better yet, ask them.

Or are the replacements less skilled? Do they really know their stuff? If they don't seem particularly qualified, why aren't they let go?

If a company can't keep skilled machinists and would rather hire and retain unqualified replacements, there's trouble brewing. The company is just trying to get bodies at the machines.

Remember, a company needs a certain number of machinists to cover the overhead, which includes all the utilities, rent or mortgage payment, equipment payments, staff salaries and other miscellaneous monthly costs. This is because the number of machinists correlates directly to the amount of billable hours a shop can have. For example, if a shop needs 500 hours of billable shop time at, say, $50 an hour to break even, the shop needs 12.5 machinists (assuming each works 40 hours a week) to generate the required dollars. If the shop has less than that number of machinists, it can't meet its costs.

In addition, look at your company's customer base. Is it dwindling? Does the company have only one or two major customers and a few customers that place only one or two orders every 6 months or a year? When was the last time you saw an order from a new customer? If it's been 6 months or more, look out. This could mean that your company is not competitive anymore. Pricing may be too high or delivery times are too long.

Perhaps the salesmen have left and haven't been replaced. Management then needs to drum up sales. If this is the case, are managers out in the field trying to make sales or are they just staying at the plant? When was the last time a potential customer toured your plant? Many customers want to visit the facility that they will be doing business with. They want to see the equipment and capabilities that will be used to produce their parts.

Ask yourself, too, what is your company's owner like? Does he walk around the shop to see how things are going? Does he talk with the guys at all? Can you ask him a question or just plain talk to him? Is he genuinely interested in the well-being of employees? Does the owner or general manager have meetings periodically to have a "state-of-the-shop" address with the employees? If the answer to these questions is yes, you're probably doing OK. If the owner used to do these activities but doesn't anymore, there may be a problem.

What can you do? First, don't listen to the rumor mill. Keep track of the company yourself. After all, you have a vested interest in it. It's your livelihood. If business drops off somewhat, don't panic. Ask yourself why. Perhaps it is just the economy in general. Short-term lulls are common in our industry. But if the economy is in good shape, then it might be time to look for some of the warning signs I mentioned. By keeping your eyes and ears open, you can be prepared and avoid being caught off-guard.

About the Author

Michael Deren is a CNC applications engineer and a regular CTE contributor. He can be e-mailed at mderen@prexar.com.