MANUFACTURING ENGINEERING®

April 1993

SEEING THE UNSEEN

NEW AGE COMPUTER GAGING

A DOSE OF TPM

HOW SMOOTH IS SMOOTH ENOUGH?

SME® Society of Manufacturing Engineers

A Dose of TPM

Downtime needn't be a bitter pill

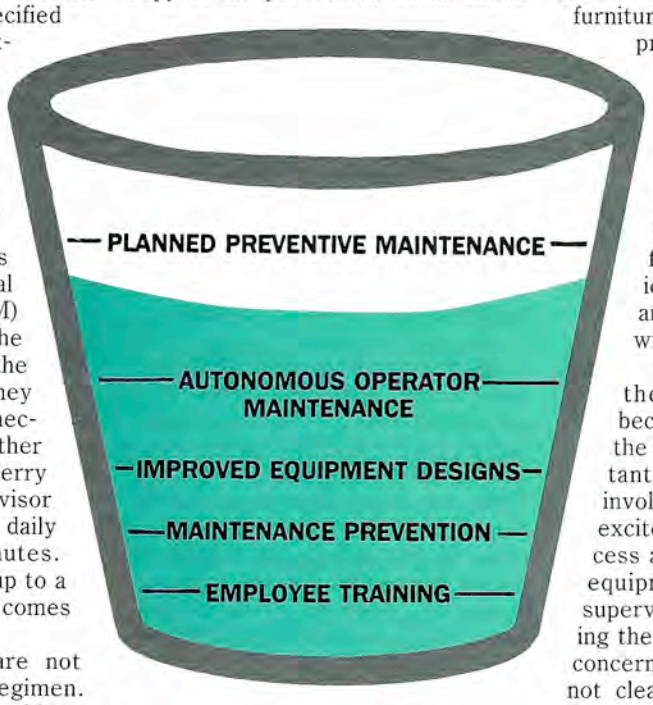
Teamwork and planning makes downtime easier to swallow at Steelcase Inc.'s Western Div. (Tustin, CA). Instead of spewing out office-furniture parts to the last second, pressbrake operators there end each shift by wiping their equipment clean with a cloth. And before resuming production on the next shift, operators perform tasks specified on daily and weekly checklists, which include inspecting the machines for oil leaks and other problems and doing simple maintenance like lubrication and tightening loose bolts.

This planned downtime is part of a company-wide total productive maintenance (TPM) program. "Wiping focuses the operators' attention on all the machines' blemishes so they notice loose bolts and connections, oil leaks, and any other abnormalities," explains Terry Berrier, maintenance supervisor and TPM coordinator. "The daily tasks take about 15 minutes. Weekly tasks take longer, up to a half hour, especially when it comes to detailed cleaning."

Pressbrake operators are not alone in executing this regimen. Workers on resistance welders, paint lines, and assembly benches have housekeeping and maintenance jobs too. Besides cleaning their equipment, assembly bench workers, for example, oil staple guns, look for air-hose leaks, and check their areas of the conveyor. Welders might replace cables or damaged gages.

For problems requiring a skilled technician, operators still turn in repair orders. Operator involvement, though, has freed maintenance to do more prevention work. "Maintenance is no longer a fire-fighting department," notes Berrier. "It's now schedule driven, focusing on preventive maintenance tasks done at prescribed times." His department schedules maintenance up to a year in advance and automatically generates work orders based on 30 and 90-day cycles.

The goal is to make preventive maintenance part of production wherever it makes sense. As production develops its schedule, they will use a copy of the preventive maintenance schedule to plan machine downtime for maintenance. "That way we won't have to fight one another for the equipment," says Berrier.



Maintenance also tracks equipment and downtime history and records whether the problems were due to mechanical, electrical, or setup failures. "Operators keep score of failures on downtime control charts on six-week cycles," says Berrier. "Every 90 days, we review this information to see what we can do to prevent the failures." He also feeds that information back to engineering so they can improve the efficiency and reliability of existing and new processes.

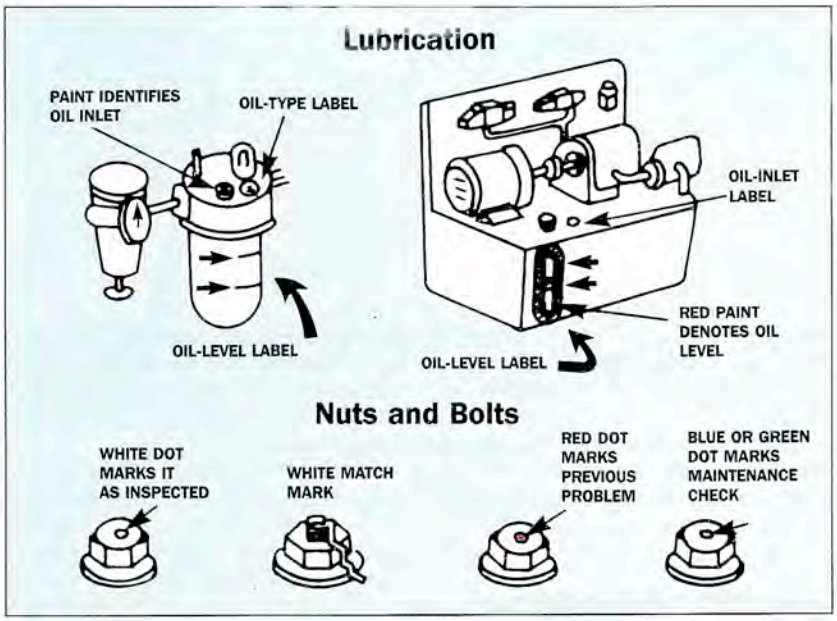
Steelcase is using TPM in all seven focus factories (each devoted to one product line) that constitute the 1 million-ft^2 plant. The office-furniture maker began with a pilot program for the most critical machine in each factory. Since then, the program has expanded to include the second-most critical pieces of equipment. The file factory, for example, focused on frame welders first, because they are critical for tolerance and quality, and then included the stretch wrappers.

Barrier admits that starting the process was difficult because many people didn't feel the cleaning process was important. "As the operators got involved, though, they became excited about improving the process and took ownership of their equipment," he recalls. "Line supervisors took longer in accepting the idea because their primary concerns were meeting schedules, not cleaning machines." That has turned around now that they see the benefits as more uptime. TPM has also reduced unscheduled maintenance 80% and overall maintenance costs 30% in the first year.

Another Quality Concept

An outgrowth of Dr. Deming's work in Japan, TPM is a quality-control practice involving everyone from top management to the shop floor in maximizing equipment effectiveness. With visible support from top management, machine operators, maintenance technicians, and manufacturing engineers work closely toward the goals of zero breakdowns, zero defects, and minimum equipment life-cycle cost (total cost equip-

James R. Koelsch
Managing Editor



Visual aids help machine operators with their daily inspection tasks. For example, match marks show whether a bolt is loose, and color coding speeds inspection.

ment incurs during its life).

"The term 'total productive maintenance' often misleads American manufacturing engineers, who tend to think of maintenance first as reactive repairs rather than proactive preventive work," notes Constance Dyer, director of research and TPM product development, Productivity Inc. (Cambridge, MA). "They think of separate departments competing for custody of the equipment. A more descriptive phrase would be total productive *manufacturing*.

"TPM strategies were developed in Japan in response to the demands of just-in-time [JIT] production and an increasingly cost-competitive environment," she continues. "JIT cannot be successful unless equipment is always available when needed, changes over easily and quickly, and produces quality products reliably. So gaining control over when and how long equipment will be down is critical."

TPM places special emphasis on curtailing costly chronic losses such as stoppages in automated equipment, excessive tool wear and setup time, sluggish production, and long Monday morning startups. These problems often have complex causes that foil repeated attempts to solve them. So production and maintenance simply ignore them. TPM, however, solves them through rigorous failure-mode analyses and careful attention to minor defects in equipment conditions, operating procedures, and routine care.

"Although preventive and predictive maintenance strategies increase uptime and reduce reactive-maintenance costs, maintenance technicians in roughly half of US plants still spend more than half their time putting out fires rather than preventing them," observes Dyer. She recommends changing that practice because companies that adopt TPM are seeing 50% reductions in breakdown labor rates, 70% reductions in lost production, 50–90% reductions in setup, 25–40% increases in capacity, 50% increases in labor productivity, and 60% reductions in cost per maintenance unit.

To get such results, manufacturing must drive the effort, and management must form cross-functional teams with members from maintenance, production, and engineering from the outset. "Too often, we see TPM programs begin and end within the maintenance department," says Dyer. "Production offers inadequate support because they underestimate the potential savings."

Before operators begin their housekeeping and maintenance routines, though, the teams must measure the machinery's performance in terms of losses in availability, efficiency, and quality. To be successful, a TPM program must also include training before implementation. "People performance is not simply more operation and maintenance skills, but applied diagnostic skills, teamwork, ability to use new technologies, and effective information gathering, communication, planning, and management," says Dyer. "The more workers apply these skills to improving equipment performance, the greater the efficiencies achieved."

We're a Union Shop

Be sensitive to historical lines of demarcation between skilled trades and unskilled workers. While TPM might appear as simply better resource allocation, workers usually perceive it as just another productivity-enhancement program that increases their burdens to reduce direct labor. "Include union leaders in the initial discussions so they hear that management doesn't understand all its ramifications either and doesn't have a hidden agenda," urges Steve Hougham, president, Management Technologies Inc. (Troy, MI).

He recalls how the plant manager in one US company and the union local's president worked together and made a joint statement about making TPM work. "Once the plant manager and the union local president hashed out the details, they were already in the shop in overhauls cleaning the equipment when the workers arrived the next morning."

Even though TPM sometimes does consolidate jobs, that is not its purpose. "TPM is a gold mine of ways to improve efficiency just through better asset utilization," says Gifford Brown, plant manager, Cleveland Engine Plants, Ford Motor Co. (Cleveland). "It would be a shame to waste it by focusing on the short-term goal of cutting jobs. If skilled trades and unskilled employees work together to improve uptime and quality output, the natural outcome is lower cost, higher productivity, and better customer satisfaction. You don't have to look for other ways to cut costs.

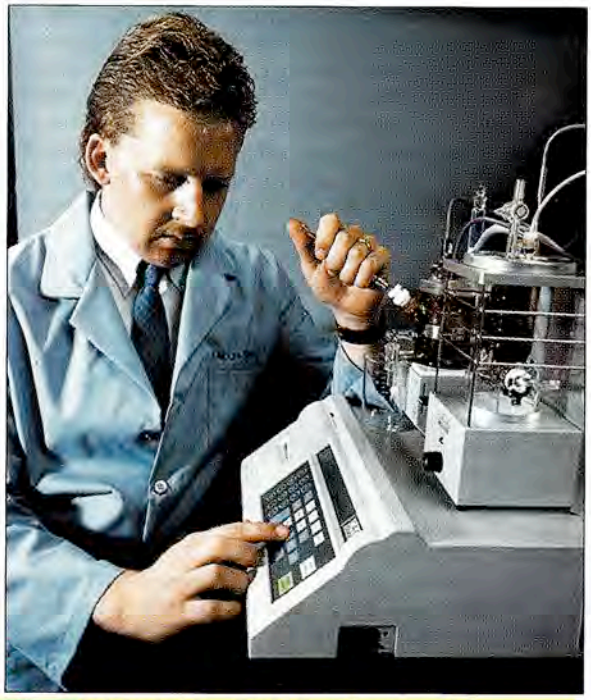
"Everyone likes to dwell on the emotional side of TPM," he continues, "which is whose job are you doing? The problem is everyone is doing the wrong jobs." Rather than repairing equipment, manufacturing engineers should be using reliability growth curves to design equipment and processes that meet productivity numbers yet minimize operating costs. With the proper training, workers should be able to determine what mechanical or electrical work is

necessary to get machines back up and running.

Training also helps workers understand such things as lubrication and how it affects quality. For example, if a transfer-machine station has a plugged lube block in a slide, the operator would not see oil as the head moves back and forth. So part of an operator's check could be to look for oil. "Without training, operators wouldn't be aware of what the presence of oil means and, probably, wouldn't even look at it," says Brown. "They also wouldn't know why we have different lubricants and what happens when we mixed them."

Ford's two Cleveland engine plants are in various stages of implementation. In the older plant, TPM is expanding from the original pilot program. Everyone in the new plant is receiving TPM training. Brown advocates giving workers the necessary tools to implement the program, getting out of their way, and supporting them. "If you just tell the people the goal is to improve uptime by X% or that these are the requirements necessary to satisfy customers, you'll be surprised at how ingenuous they'll be at finding ways to maintain the equipment. They know it best."

That philosophy will pay off in the new plant as better quality at lower cost. Processes will be more predictable, investment efficiency will be 28%, and uptime will be about 98%. "TPM will cut our launch costs by half," predicts Brown, "with a 30–50% improvement in quality."



Oilpure lab technician Scott Severt uses moisture titration to quantify the amount of water in an oil sample. Water is the most damaging, yet least checked for, oil contaminant.

What's the Diagnosis?

While Brown attributes the program's success to training and worker ingenuity, he says predictive maintenance systems—like infrared thermography, ultrasonic tests, and vibration and oil analyses—are important too. "But all they tell you is the condition or wellness of the equipment at the time you look at it," he cautions. So he advocates checking often, even if it's simply listening to the machine run. "You'd be surprised at the list of opportunities for improvement you can record just by sitting beside a machine for a half hour and listening to it run."

Using condition-monitoring devices helps you spot developing problems and gives you time to plan corrective maintenance before failure occurs. On machine tools, for example, condition monitoring can show a bearing running out and, therefore, predict parts will soon be out of tolerance. Exploiting such intelligence cuts forced downtime, helps prevent catastrophic failures, and reduces spare parts inventory. "Once in while, a good program will also get better insurance rates," adds Scott Hoover, president, Predictive Maintenance Inspection Inc. (Madison, AL).

Cost of monitoring devices need not frustrate this part of TPM. Many services, such as Predictive Maintenance, make plant calls. "We are a complete condition-monitoring company in a van," says Hoover. "All of our capabilities are in the vehicle when we show up on site."

One of those capabilities is motor-current signature analysis (MCSA), which the firm licenses from Oak Ridge National Laboratory (Oak Ridge, TN). Using the motor as a transducer, technicians can monitor the load on electric motors and analyze signal fluctuations to find signs of deterioration.

"MCSA is primarily for simple systems, such as those with few gears," notes Hoover. "Feedback comes as one spectrum, which can get complex quickly." MCSA spectra resemble that of vibration analysis, except they also contain electrical attributes, like slip frequency. Vibration spectra contain mechanical attributes only.

A good monitoring program collects data periodically for comparing against set limits and establishing trends. Computerized monitoring devices can take measurements every few minutes, but "safety, cost, and significance determine whether to monitor continuously or periodically," says Hoover. "Routine vibration analysis, for example, is usually monthly. Oil analysis is typically every six months."

"While oil maintenance in many plants is distinctly secondary to equipment maintenance, the two are tied tightly together," adds Vichai Srimongkolkul, general development manager, Oilpure Systems (Rockford, IL). "Heat and pressure combine with dirt, moisture, and other contaminants to build sludge and, in turn, change viscosity." Chemical changes can degrade hydraulic oil performance too. Reagents—water, air, and copper or iron oxide—can oxidize oil rapidly and boost acidity and interfacial tension.

A proactive hydraulic oil maintenance program that filters oil continuously and checks contaminant levels frequently can extend equipment life from 2 to 100 times. "While the kinds of tests depend on the specific equipment, job at hand, and ambient conditions, they generally include particle size, viscosity, acidity, specific-gravity, and water-content analyses," says Srimongkolkul.

Many equipment suppliers recommend 10-micron filters for their machines, but Srimongkolkul points out that, in hydraulic components with small clearances, extrafine 0.5–10-micron particles can accumulate enough to cause wear and plug gaps. For example, gear to side-plate clearance in gear pumps and valve-plate to cylinder clearance in piston pumps are 0.5–5 microns. Spool-sleeve clearance is 1–4 microns in

servovalves and 1–23 microns in control valves. In machine tools, contaminants can jam the servovalve spool, causing it to lag the torque motor and the machine to hunt for commanded positions.

Changing or adding new oil only does little to lower contamination levels because contaminants line reservoirs as oil drains or otherwise becomes depleted. "Also, new oil is seldom, if ever, really clean," notes Srimongkolkul. He recommends contamination-control technology that does the following:

- Extracts suspended particles before they enter tight clearances and cause abrasive wear, leakage, and unplanned downtime.
- Purges emulsified water, the most harmful yet most uncontrolled agent of oil deterioration.
- Removes oxidation byproducts to prevent gummy or waxy residue from building on parts and affecting machine performance.
- Uses additives that preserve the oil's important lubricity, antiwear, and other properties.
- Saves money through reducing new-oil purchases, minimizing waste-oil disposal, and increasing machine uptime.

Root Out Problems

Another critical TPM element is analyzing maintenance and failure data to identify root causes of problems and devise ways to eliminate them permanently. Many software vendors offer tools called computerized maintenance management systems (CMMSs), most of which manage periodic preventive maintenance based on calendar time and production cycles and rarely on machine condition. Real-time links to controllers and monitoring systems, however, are changing the situation.

To help identify problems, though, CMMSs must do more than simply issue work orders regularly and control spare-parts inventories. For example, Mainsaver, from JB Systems Inc. (Woodland Hills, CA), is a management information system that lets users examine information in the database through *ad hoc* queries. It can help you decide whether a machine needs more frequent preventive maintenance, a vendor is providing good parts, workers are performing to standard, or you can tighten inventory.

"Such an analysis can help find out why certain machines are breaking down," explains Donald Pullease, vice president. "By searching through maintenance records, you might trace the problem to inferior bearings from a particular vendor. Or maybe you discover Employee 1001's work in the last six weeks didn't stick, suggesting that person needs more training and supervision."

A common shortfall of a CMMS is its data entry facilities are cumbersome for maintenance and operators use. "Computer illiterate people must be able to report information quickly and with little training or supervision on a 24-hour-a-day basis," says Ted Williams, president, Comac Systems Corp. (Framingham, MA). Otherwise they will not bother with reporting small problems.

"Product jams and short-duration downtime caused by such things as misaligned limit switches or excessive vibration can be costly if they happen frequently," Williams continues. "Without tracking even minor failures and slow downs, equipment reliability engineering efforts cannot focus on the correct problems. Crude data only breeds crude management." While measuring to the second is unnecessary, records too often vary from actual elapsed time by as much as 10 min, and some companies do not even record failure downtime unless it exceeds 30 min.

Most CMMSs are far too difficult and time consuming to use to make this level of reporting from the shop floor practical. Some software vendors, however, are introducing packages that allow users to design data entry screens and create custom reports matching existing paper forms without any programming skills.

While giving people the right tools is important, the primary focus must be on process changes to bring improvement. "Unfortunately, people do not balance tools with process changes correctly," says Robert Hilligoss, senior manufacturing consultant, Maintenance Systems Integration Group, EDS (St. Louis). "The how to of TPM is straight forward. It's really a question of how to initiate a successful TPM program.

"The foremost error usually is failing to get the necessary top-management commitment, not buying the wrong tools," he continues. "Even with top management's endorsement, success does not automatically come from a top-down directive. It needs a bottom-up, grass-roots process involving workers and making them aware of the need for TPM to get their ownership and commitment."

Because of the necessary changes in attitudes and procedures, he also points out that TPM requires a significant preparation stage, which can last from two to five years. So implementation must come as small incremental improvements and build on them slowly over time. "Too many people don't understand the inertia of an organization's culture and the magnitude of the effort necessary to change it while continuing to manufacture product," notes Hilligoss. "Changing an organization is like opening Pandora's box. If you try to bring change too fast, you can't manage it."

Introduce the concept on one pilot project, and expand it throughout the plant. Pick a pilot with the greatest opportunity for success because success is a spoon full of sugar that helps even the most bitter medicine go down. ■

Want More Information?

An excellent source to introduce both management and workers to the intricacies of TPM is "TPM: Total Productive Maintenance," a 40-min installment in SME's *Manufacturing Insights* video series. SME also offers these three books: *Quality Maintenance: Zero Defects Through Equipment Maintenance* by S. Tsuchiya; *Total Productive Maintenance: An American Approach* by T. Wireman; and *Introduction to TPM: Total Productive Maintenance* by S. Nakajima. Call Customer Service at 1-800-733-4SME from 8 am to 8 pm Eastern time, Monday through Friday.

For more about TPM tools and maintenance services, circle the following numbers on the reader service card:

Company	Circle
Comac	390
EDS	391
JB Systems	392
Oilpure	393
Predictive Maintenance	394