GEAR TECHNOLOGY

The Journal of Gear Manufacturing

THINGS YOUR INDUCTION FURNACE SUPPLIER WANTS YOU TO KNOW
CHOOSING THE RIGHT HEAT TREATER
PROGRAMMABLE SEPARATION OF RUNOUT FROM PROFILE & LEAD INSPECTION DATA
1998 HEAT TREAT PROVIDERS BUYERS GUIDE

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HEAT TREATING

March/April 1998

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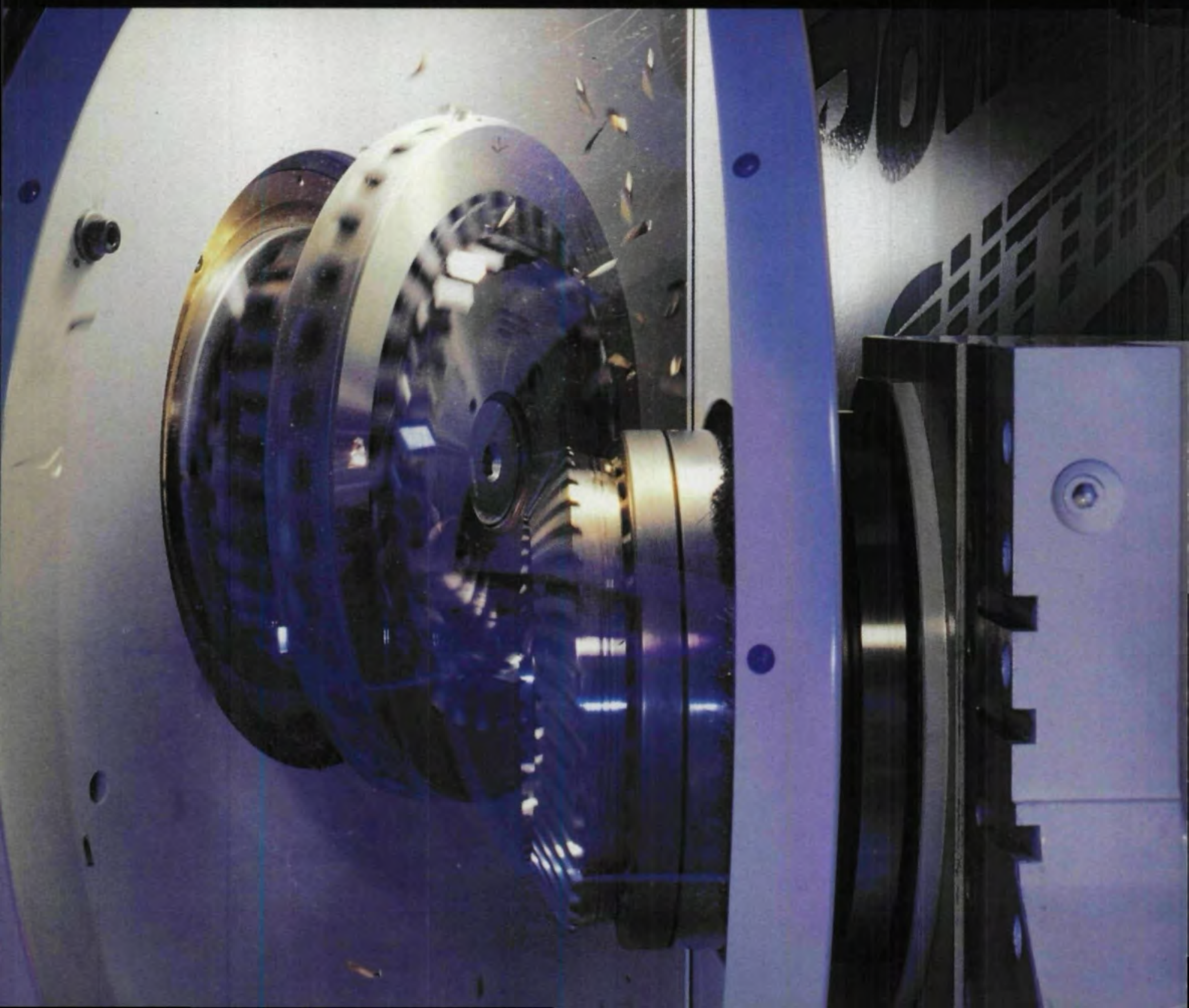

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RIDING OUT
The Good Times

Happy days are here again, says the old song, and given the current economic numbers, one can scarcely argue. Productivity is up; unemployment is down; inflation is practically nonexistent; the budget deficit is shrinking fast.

So we can all kick back, put our feet up and let the good times roll, right? Well, not exactly.

Good times have their own complications. First, there's the nagging question of just how long they're going to last. We're seven years into a recovery, and common sense says that it can't go on forever. Should we prepare for more boom or for a big bust? Then there's the matter of our neighbors in Europe and Asia. Recently both of them, especially Asia, have stumbled badly. In this global economy, one trading partner's misfortune can turn into bad times for everyone with alarming speed. Stagnation in Europe and the free fall of markets in Asia are bound to affect our numbers here. The only questions are how and when?

There is no lack of answers out there. Anybody with access to a microphone, printing press or Web site is willing to tell us what's going to happen next. Unfortunately, the old wag about laying all the economists in the world end to end and still not coming to a conclusion still holds. Pare away the rhetoric, and the answers seem to boil down to, "It all depends."

One thing we can be reasonably certain of is that competition, often ruthless and cut-throat, is going to be part of the picture for some time to come, and no matter what the economic numbers, we are going to be under great pressure to be more efficient and to keep our costs down in order to keep our profits up.

Our customers in Asia and Europe, under the pressure of troubled economic times, can't buy as many of our products as we'd like to sell them, and they can't afford to pay high prices for what they do buy. The only way to keep these markets open is to keep prices—and, therefore, costs—down.

At the same time, these economies are under pressure to unload their goods here because we have become the customer of last resort. We have the money to buy the goods. And because overseas companies need cash now, they will have little option but to cut prices. They're going to be wheeling and dealing with a vengeance because they have to.

Monetary policy factors also play a part here. With our competitors' currencies devalued, their goods are cheaper than ours here, and ours are more expensive there. The result is the same: pressure on us to keep our prices low, our costs down and our productivity up.

Even if you only do business in the U.S., you can't really avoid the problem. Your customers may be trading overseas or competing against imported products, and they're going to have to pressure you to keep your part of their costs down. Whether your markets are here or overseas, these pressures mean you have to wring every dime of efficiency out of your operations.

The buzz word then for us should be modernize, modernize, modernize. If you're still debating about the wisdom of taking the next step, stop. The answer is clear. Do it now.

I've been repeating this mantra for years, but every day that goes by confirms its importance. Our operations here (and, I would guess, most of yours) are already on the third, fourth or fifth generation of hardware and software. Every time we install an upgrade, once the initial break-in period is over, our productivity and efficiency—the keys to competitive success in this economy—go up. The same thing will continue to happen. The only difference now is that pressures to keep up are growing, and the time lag between important technological improvements is shrinking.

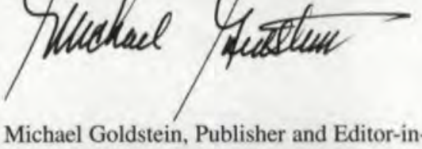
So the drill remains the same. If you already have CNC machinery, now is the time to look at the latest improvements. This is also true if mechanical machines still make sense in your operation. You should be looking at getting the latest models you can afford. Any piece of equipment that will increase your production and keep your costs down is worth the investment today.

Production machinery is not the only place to look for more efficiency. Examine your entire operation—all your processes and practices. Can they be streamlined? Made more cost-effective? Do your computers and software need upgrading? Your testing, sharpening, inspection or quality systems? What about your customer service operation? Your shipping? The pennies shaved from the cost of every operation performed and every part produced can add up to real savings.

And don't forget your people. Investment in training for efficiency and productivity is worth every nickel spent on it. Nor should you overlook that simple, low-cost, low-tech approach to shop floor productivity gains: Ask the people doing the work how to do it better and more efficiently. They usually know better than anyone else and will be glad to tell you without charging the five figures that are the going rate for some out-of-town consultants.

Sure this kind of thing can be expensive in the short term, and deciding on just the right investment moves for your company is a complicated issue. But boom times can't last forever, and if you can't afford improvements now, when will you be able to?

Keeping your footing in this complicated global economy is tricky. It will require a lot of hard work, close analysis and careful investment in the right equipment and people. You may find yourself working harder during these good times than you ever have before. On the other hand, it beats working just as hard or harder just to stay afloat during bad ones.



Michael Goldstein, Publisher and Editor-in-Chief

COMPETITION —OFTEN RUTHLESS AND CUT-THROAT— WILL BE PART OF THE PICTURE FOR THE FORESEEABLE FUTURE.

Choosing the Right Heat Treater

Getting the right provider for your job.

Kurt Hawker

Heat treating is a critical operation in gear manufacturing. It can make or break the quality of your final product. Yet it is one that frequently gear manufacturers outsource to someone else. Then the crucial question becomes, how do you know you're getting the right heat treater? How can you guarantee your end product when you have turned over this important process to someone else?

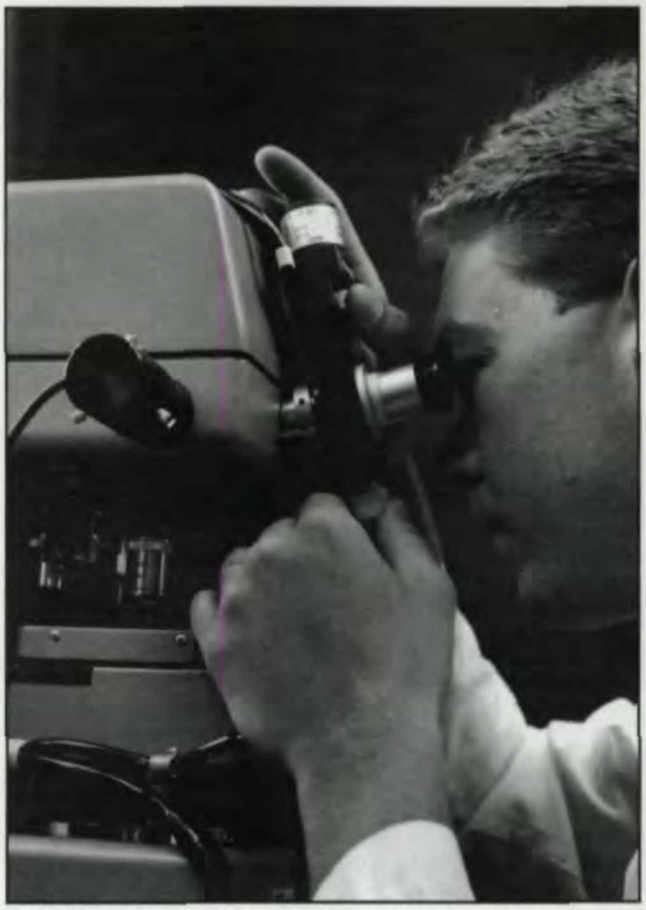
The answer is a straightforward one, but one which in my experience is overlooked far too frequently. The secret to buying good heat treating service is to do your homework. Ask lots of questions and demand clear and *documented* answers.

This documentation is crucial. In the present competitive environment, when more and more of your customers are seeking some kind of quality system registration, like ISO 9000, QS-9000 or NADCAP (National Aerospace Defense Contractors Accreditation Program), and demanding the same of you, a heat treater who is also registered or who can provide detailed documentation of his or her processes is becoming almost a necessity. Even if you or your customers don't absolutely require such documentation, its existence will certainly help you to sleep at night.

But documentation alone is not enough. You need answers to over a dozen important questions before deciding on the right heat treater. The easiest way to get them is to ask your heat treater (or potential heat treater) to fill out a supplier survey (see sidebar on page 00), which should contain the answers to most of them. If a heat treater can't or won't take the time to do that, maybe you should be taking your business elsewhere.

Here are some of the questions that might be included in your survey.

1. *Are the company's operations certified for quality?* If so, by whom? When was it last audited? The last is the most important. Programs like ISO 9000 and QS-9000 require regular audits, and your potential supplier should be current. At the same time, beware of the buzz words in company literature to the effect that "... we have processed work for Ford" or "GM processing capabilities." Maybe the heat treater did one job for Ford or GM 15 years ago. Find out specifically what this phrase means to the company.



Good heat treaters have good, documentable quality control systems.

2. *What kind of quality system is in place?* How closely is it followed? There should be four parts to this system: A quality control manual explaining the entire system; clearly outlined procedures that are followed consistently; job instruction sheets for each job and controls on portions of the job that involve outside suppliers.

Kurt Hawker
is the director of sales and marketing for Progressive Steel Treating, a commercial heat treater in Loves Park, IL. He has over 15 years' experience in heat treating and quality control.

SAMPLE QUESTIONS FOR A HEAT TREAT SUPPLIER SURVEY

I. GENERAL		
1. Do you have a written quality policy?	Yes	No
2. Who is responsible for quality assurance and planning ___________?		
3. Is management committed to quality and the use of statistical methods to control quality?	Yes	No
4. Is there a management statement in the manual?	Yes	No
5. Is the quality policy reviewed at least annually, and are actions taken to assure compliance with the policy?		
6. May we see your quality manual?	Yes	No
II. ORGANIZATION—ADMINISTRATIVE		
1. Does a current formal organizational chart exist that defines responsibility and authority?	Yes	No
2. Do departments other than quality participate in the quality planning?	Yes	No
3. Are statistical/analytical or other new techniques used in the planning process to improve process capability?	Yes	No
III. TRAINING		
1. Is there a documented quality training program for management, quality and production personnel?	Yes	No
2. Are written test and inspection instructions readily accessible to operators and inspection personnel?	Yes	No
3. Are these updated and reviewed?	Yes	No
IV. LOT CONTROL		
1. Are lot control procedures documented?	Yes	No
2. Is product identification maintained throughout the process?	Yes	No
3. Is traceability maintained throughout the operation?	Yes	No
V. INCOMING PRODUCT/MATERIAL, PROCESS CONTROLS		
1. Are adequate incoming/receiving inspection procedures and/or instructions available?	Yes	No
2. Is incoming material approved and properly identified prior to release to production operations?	Yes	No
3. Is nonconforming material properly identified prior to release to production operations?	Yes	No
4. Are materials awaiting inspection properly identified and segregated from previously inspected materials?	Yes	No
5. Are in-process routing sheets, process sheets or routing cards used to control material throughout the manufacturing process?	Yes	No
6. Are written operator and inspection instructions that include frequencies and sample sizes available at control points or the proper area?	Yes	No
7. Is statistical process control used for significant product characteristics and process parameters?	Yes	No
VI. PRODUCT VERIFICATION		
1. Do all finished materials receive a final audit/inspection?	Yes	No
2. Is there a written procedure outlining final inspection including sample size?	Yes	No
3. Is the final audit performed by the quality department?	Yes	No
4. Is supplier willing to certify conformance to requirements?	Yes	No
VII. HOUSEKEEPING		
1. Is there a system to assure plant cleanliness and to assign responsibility for housekeeping?	Yes	No
2. Are the company's facilities clean, well-lighted and properly marked?	Yes	No
3. Do plant, offices and personnel reflect a positive image?	Yes	No

This form should also contain information about the total number of employees, number of shifts worked, number of q.a. personnel, building size and contact names.

3. *What are the company's capabilities?* Can this heat treater do your job? Are his or her furnaces big enough? What about ancillary equipment? For example, if you have very large gears to be worked on, does he have sufficent equipment and facilities to handle your parts without damaging them? Does she have enough personnel to do your job in the time frame you require?

4. *Can you get a statement of liability?* This comes down to the question of whether this heat treater will stand behind his work. If something goes wrong, if there is a catastrophic failure of one of your gears that can be traced to the heat treating process, does this supplier have an umbrella insurance policy to cover losses and damages? In what amount? What happens if your job is damaged or lost in the heat treater's plant? Are you going to be left holding the bag?

5. *Is there a metallurgist on staff?* The answer to this question will tell you a lot about how seriously this heat treater takes quality control. Heat treating is a metal structural transformation process, and someone on staff who is well-versed in the science of metals can solve a lot of small problems before they become big ones and can avoid a great many of them altogether. A metallurgist also can be critical to assessing liability. Supposing a batch of gears fails because of defects in the metal. A heat treater may compensate you for the damages, but with a trained metallurgist on staff, you might discover that the material house was really responsible for the failure.

The compensation should have come from them. Furthermore, this leads to a question you might otherwise not have asked—do I need a different *material supplier*?

6. *Will this company provide you with an organizational chart, and does it show how many departments are really involved in quality control?* Who is responsible for quality at this company? What other responsibilities does this person have? Is he or she a full-time quality person, or does he also double as the receptionist and the delivery driver? Does more than one person have input into quality issues? What kind of reporting system exists? What kind of communication takes place between departments? Are there quality checks in every department as a matter of routine?

7. *How well-trained are the people at this company?* How long have they been employed? What kind of ongoing training does the company provide? How do you know the company doesn't routinely call up the local day labor provider and ask for "five loaders and five furnace operators today"?

8. *What kind of process and lot control goes on here?* Are instructions conveyed by word-of-mouth or are computer-generated job instruction sheeets assigned to each job that follow it through its time at the facility? A modern plant will have a system of identification and control that tracks a job from the moment it enters the plant until it leaves again. Job instructions may be locked into a computer, with changes to procedures, except by supervisors, prevented. Does this company have any way to track its rate of repeatability? How consistent is its work? Can anyone from the company document the answer?

9. *How thorough are the company's inspection procedures?* How many samples from each job are checked? Is this number adequate to the size of your job? If the company checks two pieces per load, and your job consists of 10,000 pieces, is that a sufficient sample? Will it meet the documentation requirements of *your* customer? How often does this heat treater check and calibrate his instruments and furnaces? How new are they?

10. *How far back are records kept?* My company keeps records for seven years or for the life of a program. Do you need that level of documentation? Can this heat treater provide the level you need?

11. *What about the company's housekeeping practices?* This involves more than just keeping a clean and tidy shop, although that is important. How safe is this plant? Is it well-lit? Well-ventilated? Well-organized? Is it in danger of being shut down by OSHA?

12. *Does this company have a locked and bonded holding area?* Short of that, does it have some verifiable method of preventing bad gears from slipping back into the system? Companies that produce aerospace parts will often have a gated area where rejects are kept under lock and key until the customer can be notified of inconsistencies.

13. *Does this plant do inspections of incoming product?* If there is a prob-

lem with your gears upon delivery to the heat treater, will you be notified, or will this supplier just go ahead and heat treat them anyway?

14. *Will this heat treater let you come to the plant to see product samples run?* Will they allow an on-site inspection?

After The Vendor Survey

An on-site inspection is really the next step in the procedure. Getting a vendor survey is only the beginning of choosing a good heat treater. You should visit the plant. I'm always surprised at how many manufacturers want to seal the heat treating deal over the phone without ever seeing where their product is going to be sent or how it's going to be handled once it gets there.

You should pay a visit, and your potential heat treat supplier should welcome it. Bring along the important people who will be involved with the production of your gears. These should include your quality control manager, the purchasing manager, the production manager, the expediter and anyone else who's going to be interfacing with the heat treater. They should be able to see a sample of your product run through the heat treater's system, see how the product's handled and then evaluate what they've seen.

Each of them should be evaluating the heat treater's system from his or her point of view. Is the quality control manager satisfied with the inspection process and equipment? What about the level of documentation? Does your production manager feel good about the way the product is handled on the shop floor? Is your expediter comfortable with what he's seen in the warehouse in terms of both incoming and outgoing product and storage and handling in between?

This is the time to watch for discrepancies. If a heat treater has said he can handle your 40" gears, but all you see on his floor are small furnaces, this should raise questions. Is he sending your product out to be done by someone else? This sometimes happens, but it's not an acceptable practice without your prior approval. If another supplier is involved, who is it? What kind of quality and documentation can you count on from him? What kind of security can you be assured of? Is your product going to end up running right next to

When evaluating a heat treater, ask how recently his inspection machinery was calibrated.

that of your competitors? What other parts of the process are being outsourced? To whom?

This is also the time to be getting answers to other important questions. When a heat treater says he offers 48-hour turnaround, what does that mean? Does it mean in Friday and back Monday, or in Friday and back Wednesday because the heat treater doesn't work weekends? Does this heat treater offer 24/7/365 service, or does he close on weekends and holidays? That's something you'll want to know if you don't want to find your product accidentally held hostage because the heat treater has closed for the two weeks over Christmas or for a summer vacation.

If you've had a problem with getting product back consistently in a timely manner, the reasons may lie here. If the product is being outsourced, the delay may be with the other vendor or with the fact that your heat treater has built-in delays in her schedule you didn't know about.

Is All This Effort Worth It?

This may seem like a lot of hassle, especially if you're not making aerospace quality gears. If your customers don't demand this level of documentation and quality, why should you care?

Because in this era of increasing global competition and more and more demanding customers, you can't afford not to. Remember that in the end, with your customer, it's *your* reputation that's on the line. He or she is going to buy the excuse that the problem lies with your heat treat supplier only once—if that.

In the long run, it always pays to get the best heat treater you can afford—one who, ideally, exceeds your expectations. You can get away with heat treating on the cheap for some time, but in the end, the practice will catch up with you. It takes the loss of only one big, expensive job to bad heat treating to cost far more than you would have paid to go with a quality product to begin with.

You can benefit from dealing with an aerospace-quality heat treater for your AGMA 8 or 10 gears in another way. You get his expertise and quality practices without have to pay the aerospace tariff. His or her practices will be the same on your gears as on aerospace gears because the quality is built into the plant systems, and the prices will be competitive because your gears don't require the liability coverage that aerospace gears do. Finally, there's the intangible of having the security of dealing with a company that has a proven quality track record. What is that worth to you and your customers?

The In-House Question

Many gear manufacturers today are addressing the question of getting documented quality heat treating on time and within budget by exploring the option of bringing the whole operation in-house. They think, and not without reason, that there is no better way to ensure the job is done the way they want it done.

But making the decision to bring heat treating in-house is a big one. The ultimate equation is a simple one—are the costs involved going to be more or less than what you spend on outside heat treating now?—but the variables complicate the issue.

Much more is involved than choosing a furnace. First, generally speaking, you need to be doing a significant amount of heat treating to make bringing the process in-house worthwhile. Also remember that the cost of the furnace is only the beginning. What's a turn-key operation is going to cost; i.e., what is the price of the furnace, the installation, the plumbing, the extra materials like appropriate gases, and the backup equipment to keep it running?

Then there's the question of the skilled labor necessary to do heat treating and to keep the equipment running. Do you have this kind of personnel available? Can you get it? Can you afford the kind of trained personnel it requires to run the machines and manage the department? And there's the issue of what to do if your one furnace breaks down or needs extended maintenance. If you have only one furnace, and it goes off-line for some reason, all of a sudden your entire delivery schedule for this job is in jeopardy. At that point, you have to go to an outside source for one or two jobs, and you'll go to the end of the line after all his or her regular customers have been serviced.

If you can answer all these questions in a way that makes sense to you economically, then maybe bringing heat treating in-house is the answer. But that may not be as likely as you think.

One way that some very large customers address the control problem is to negotiate with a heat treater for a dedicated furnace at the heat treater's site. This can be a mutually beneficial arrangement for both parties, but again, it requires someone with a lot of product to be heat treated to be worthwhile.

In the end, buying quality heat treating is just like buying any other goods or services. It's a matter of doing your homework, taking the time to get the answers to all your pertinent questions and making certain cost/value decisions. As with most other transactions, you get what you pay for.

Good quality gears are the end result of a lot of hard and expensive work. After you've gone to all the trouble and expense of designing and cutting the best gears you can, do you want to jeopardize the whole operation with sloppy heat treating? Scrap is expensive, not only in terms of lost revenue, but also in terms of increased frustration, lost time, missed deadlines and damaged customer relations.

When heat treating is such an important component of building a quality gear, can you afford to settle for anything less than the very best you can afford? ○

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New Guideless CNC Shaper for Helical Gears

Kenji Ueno

Product announcements so often trumpet minor, incremental advances with words like "revolutionary" and "unique" that even the best thesaurus can fail to offer a fresh alternative to alert the reader when something really innovative and important is introduced. In the case of Mitsubishi's new CNC gear shaper, the ST25CNC, both terms apply.

The ST25CNC (Fig. 1) eliminates the need for expensive helical guides that cost several thousand dollars for each gear size and lead change. Changeover on this machine requires only reprogramming the CNC to cut each new configuration, unlike older machines that require several hours to set up a new guide set. Windows®-based, user-friendly CNC controls with a touch screen feature make custom programming easier and eliminate lengthy programming time. This combination of lower cost, simplified changeover and streamlined programming means that gear designers can now experiment with new refinements in order to provide the most efficient power transfer components.

Engineers at MHI Machine Tool U.S.A., Inc., Itasca, IL—a subsidiary of Mitsubishi Heavy Industries America, Inc.—believe that this new flexibility will be the reason the innovative ST25CNC shaper will be adopted by initial users. S. Amano, President of MHI Machine Tool, reports that a major automotive company in Japan has already placed an order for the new shaper.

The Impetus for Innovation

One strong impetus behind Mitsubishi's investment in the ST25CNC has been vehicle downsizing, which has created the need for smaller transmission gears. Smaller gears have less contact area, which translates directly into lower strengths. To increase contact area and strength at a given gear diameter, designers have increased the helical angle. The 25° angle that was once common has given way to helical angles that are now often more than 35°.

When an internal gear is manufactured, gear shapers are generally used. As shown in Fig. 2, in this machining method, the cutter and workpiece are turned synchronously and the cutter reciprocates axially. In the case of helical gears, because helical motion is matched to the cutter lead, a helical guide is used. When the cutter lead is different, the helical guide must be changed.

The NC Guide Drive Principle

In helical gear machining using a gear shaper, the relationship between workpiece helical angle β and cutter lead H is given by the formula below.

$$H = \frac{\pi dc}{\tan\beta}$$

where β is the workpiece helical angle, H is the cutter lead length and dc is the cutter pitch circle diameter.

In Fig. 3, the design of a conventional shaper (a) is contrasted to that of the new ST25CNC (b). In the latter, the male and female helical guides are absent. In the Mitsubishi design, reciprocating and

Fig. 1 — Mitsubishi Flexible Gear Shaper ST25CNC

THE ST25CNC'S CONTROLLER OPERATES AT MUCH HIGHER SPEEDS THAN THOSE ON CONVENTIONAL MODELS.

Dr. Eng. Kenji Ueno
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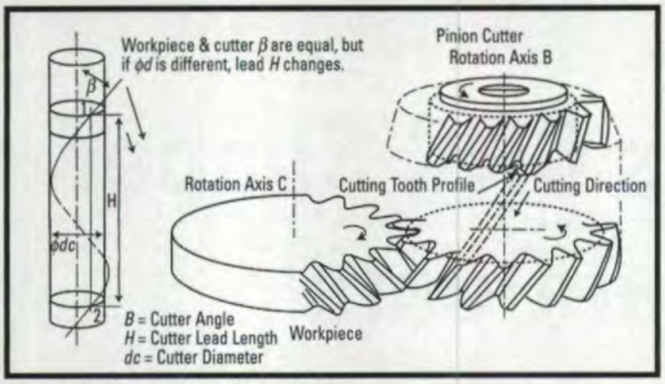


Fig. 2 — Outline of machining method.

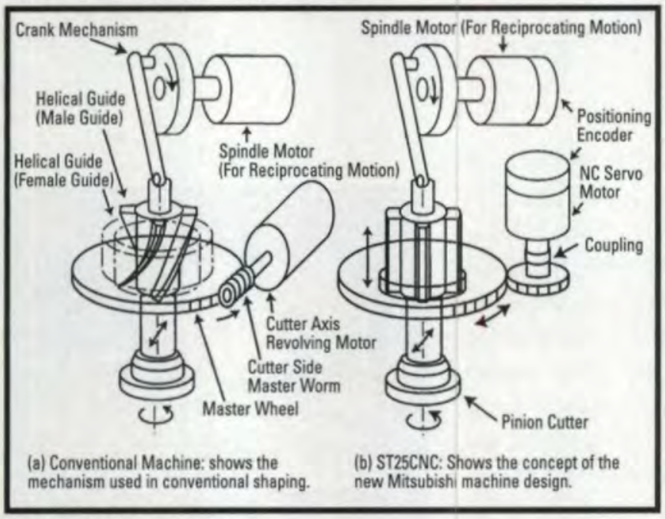


Fig. 3 — Guide mechanism.

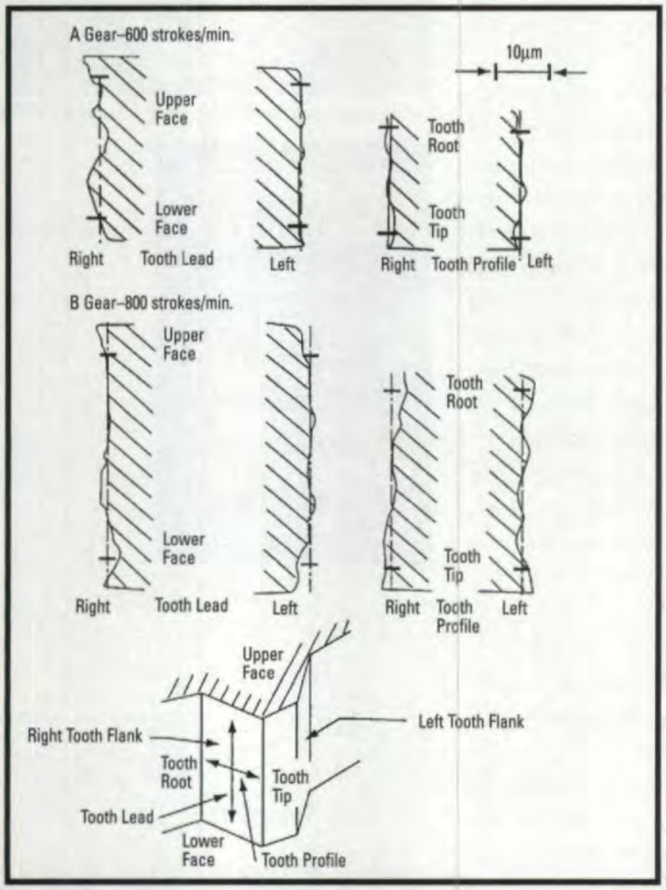


Fig. 4 — Accuracy achieved: AGMA 10 data points obtained from measuring gears cut on ST25CNC according to cutting conditions shown in Table 2.

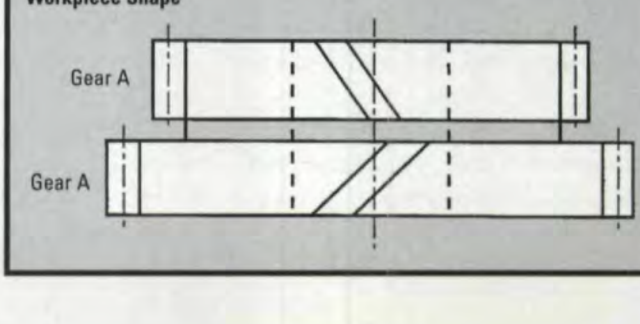
TABLE 1 — MAJOR SPECIFICATIONS

Maximum Helical Angle	±36°
Workpiece Maximum Diameter:	
External Gear	250 mm
Internal Gear	120 mm + cutter diameter
Maximum Module	6
Maximum Machining Face Width	50 mm
Number of Spindle Strokes	200–1000 strokes/mm
Circumferential Feed Rate	5000 mm/min
Radial Cutting Feed	1000 mm/min
Radial Rapid Traverse Rate	10000 mm/min
Radial Travel	300 mm
Number of Passes	1–4 times
Cutter Spindle Diameter	100 mm
Table Diameter	330 mm
Main Motor Output	10 kW AC servo
Machine Weight	6500 kg
Floor Space	2325 x 2775 mm
Machine Total Electric Power	35 kVA

TABLE 2 — GEAR SPECIFICATIONS AND CUTTING CONDITIONS

Item	Dimension	Gear A	Gear B
Workpiece Dimensions	Module	1.75	2.25
	Helical Angle (°)	30	25
	Helical Direction	LH	RH
	Number of Teeth	23	23
	Face Width (mm)	10	15
	Outer Diameter (mm)	44.471	61.6
Cutter Dimensions	Outer Diameter (mm) Number of Teeth	115 54	150.7 58
Machining Conditions	Number of Strokes (strokes/mm)	600/600	800/800
	Circumferential Feed (strokes/mm)	1.5/1.5	1.58/1.58
	Radial Feed (mm/stroke)	0.01/0.006	0.01/0.006
	Cycle Time(s)	57	55

Workpiece Shape



oscillating motion are synchronously controlled by the CNC.

A Faster, Smarter CNC

To synchronously control three axes and produce gears with accuracies of higher than AGMA 10, for example, it was necessary for the CNC to operate at much higher speeds on the ST25CNC gear shaper than on its conventional predecessor, the SD25CNC. Simulation studies revealed that data transmission speeds on the order of under 1 ms would be required, in contrast to the 8 ms speed that was typical of the conventional system.

The ST25CNC's high-speed feed control focuses on extreme accuracy. Using a modified, inverse-transfer function data processing method, with virtually zero servo error, the system reads the NC data in advance of the servo amplifier to compensate for under- or over-torque at the same point in the next stroke. Again, enhanced accuracy is the result.

In Tables 1 and 2, major machine specifications and representative gear specifications and cutting conditions are given. In the example shown in Table 2, a two-stepped cutter with different helix angles was used to machine the workpiece in one chucking. Fig. 4 demonstrates the machining accuracy realized at 600 strokes/min for Gear A and 800 strokes/min for Gear B. This setup could not be done on a conventional machine. It is now possible to cut Gears A and B in setup times of less than 5 minutes.

Tell Us What You Think . . .
If you found this article of interest and/or useful, please circle **203**.

For more information about Mitsubishi, please circle **204**.

THE MACHINE USES SYNCHRONOUS, CNC-CONTROLLED RECIPROCAL AND OSCILLATING MOTION TO GET GREAT FLEXIBILITY AND MORE MANUFACTURING SPEED.

TECHNICAL CALENDAR

ASM CONTINUING EDUCATION PROGRAMS

Principles of Failure Analysis. Areas covered are Procedures for Analysis, Failure Mechanisms and Failure in Product Forms and Components. Offered **April 20–24, July 13–17 and Nov. 2–6**.

Heat Treatment of Steel. This is a comprehensive course that covers practical heat treating of carbon, alloy, stainless and tool steels. Offered **May 4–8, Aug. 10–14 and Nov. 9–13**.

For more information, call 800-336-5152, x5613. Outside the U.S., call 440-338-5151, x5900. Fax 440-338-4634 or e-mail *mem-serv@po.asm-intl.org*. ASM's Web address is *www.asm-intl.org*.

PFAUTER-MAAG GEAR SCHOOLS

Pfauter-Maag Cutting Tools offers two gear courses, Basic Fundamentals and Advanced Gear Process Dynamics, at its facility in Loves Park, IL, several times throughout the year. Basic Course: **March 16–19, April 20–23, May 18–21, June 15–18.** Advanced Course: **April 28–30**. For more information, contact Laurie Harshbarger at 815-282-3000, x313, fax 815-282-3075 or e-mail *sales@pfauter.com*.

March 12–14. AGMA Annual Meeting. Rio Mar Beach Resort, Rio Grande, Puerto Rico. Business meetings, seminars, recreation. For more information contact AGMA Headquarters. Ph: 708-684-0211; Fax: 703-684-0242; E-mail: *webmaster@agma.org*; Web: *www.agma.org*.

March 16–19, 1998. National Manufacturing Week. McCormick Place, Chicago, IL. This week-long exhibition and conference will feature over a half-million sq. ft. of exhibit space for some 65,000 visitors. For more information, contact Reed Exhibition Companies at 203-840-5878, fax 203-840-9879, e-mail *nmw@reedexpo.com* or log on to *http://nmw.reedexpo.com*.

March 25–26. Seminar, "Innovations Concerning the Bevel Wheel." Aachen Demonstration Laboratory for Integrated Production Engineering (ADITEC), Aachen, Germany. Reports on technology, current issues and trends in bevel gears. Application-oriented reports with focus on the layout, manufacturing, testing and operating performance of bevel gears. For more information call +49-242-836-91 or fax +49-241-837-69

March 30–April 1. The Great European Industrial Meeting-Place. Paris-Nord Villepinte, France. Over 3000 companies and 160,000 m^2 of exhibition space. All aspects of modern manufacturing are covered. For more information, call (33) 1-49-8-54-66, e-mail *machineoutil@cepexposium.fr* or log on to *www.meca98.com*.

April 21–22. Gear Manufacturing Through Powder Metallurgy. Arlington Heights Hilton, Arlington Heights, (Chicago) IL. Sponsored by the Metal Powder Industries Federation. Covers fundamentals of gear design and other aspects of manufacturing gears using powder metals. Contact Benny Sun at MPIF. Ph: 609-452-7700, fax 609-987-8523, e-mail *info@mpif.org* or log on to *www.mpif.org*.

April 22–27, 1998. Seoul International Machine Tool Show 98. Seoul Yoido Exhibition Center and Yoido Tongil

Exhibition Center. Organized by the Korea Machine Tool Manufacturers' Association and sponsored by the Korean Ministry of Trade, Industry & Energy, this show is designed to promote trade through the international exchange of information and technology. Both domestic and foreign machine tools and related items will be featured. For more information about exhibiting or attending, contact Korea Machine Tool Manufacturers' Association by phone at 82-2-565-2721 or fax 82-2-564-5639.

April 26–May 1. Plastics Gearing Technology. The Product Design & Development Division of the Society of Plastics Engineers and the Plastics Steering Committee of the Emerging Technologies of AGMA is planning sessions on Plastic Gearing Technology to be held at **ANTEC '98** in Atlanta, GA. For more information, contact Andrea Knapp at SPE Headquarters, 203-740-5458 or fax 203-775-8490.

May 18–20. Fundamentals of Parallel Axis Gear Manufacturing. Pheasant Run Resort, St. Charles, IL. Sponsored by Koepfer America, this seminar is designed for entry level gear manufacturing personnel. It will be of interest to manufacturing management, industrial engineers, supervisors, set-up personnel, operators and quality control personnel. To register, phone or fax Koepfer America. Phone: 847-931-4121; Fax 847-931-4192.

May 19. INFAC Industry Briefing. INFAC (The Instrumented Factory for Gears) will present its spring industry briefing at the Sheraton Washington in Washington, D.C. This briefing will update attendees on the status of on-going INFAC research projects and preview new developments. For more information, contact Terry Phillippi at 312-567-4264 or fax 312-567-4329.

May 28–30. Ultra-Hard Materials Conference. Sponsored by the Industrial Diamond Association in conjunction with the University of Windsor and the University of Toledo. Windsor Hilton Hotel, Windsor, Ontario, Canada. This conference will offer attendees exposure to the latest developments in diamond and cubic boron nitride technology. It will focus on the types of diamond and cubic boron nitride materials available and their applications. For more information phone 704-684-1986, fax 704-684-7372 or e-mail *gray3@juno.com.*

May 31–June 4. PM²TEC'98, The International Conference on Powder Metallurgy & Particulate Materials. Las Vegas, NV. Sponsored by the Metal Powder Industries Federation and APMI International. Technical sessions and poster presentations will report on new innovations in metal powders and advanced particulate materials, compaction technologies and processes, rapid prototyping, sintering, powder injection molding and more. For information, call MPIF at 609-452-7700, fax 609-987-8523 or log on to *www.mpif.org*.

Tell Us What You Think . . .
If you found this article of interest and/or useful, please circle **215**.

IMTS WEB SITE OPEN FOR BUSINESS

Information about IMTS 98, (McCormick Place, Chicago, Sept. 9–16) is available to exhibitors and attendees at *www.imts.org.* The site contains registration information, online registration capability with a secure electronic commerce system, exhibitor and pavilion listings, details on the concurrent Society of Manufacturing Engineers technical conference, and links to Chicago area sites.

MULTI-ARC ACQUIRED BY BERNA AG

Multi-Arc, Inc. of Rockaway, NJ, has been acquired by Berna AG, part of the Sauer Group. The acquistion is part of Berna's strategy to expand its thin film coating business. Multi-Arc, with 11 coating centers and four joint ventures in North America, Europe and Asia, as well as an equipment manufacturing facility in St. Paul, MN, will be a part of Berna's newly formed Thin Film Coating Division.

PROMOTIONS, MOVES, NEW HIRES

Carlos Carrasco has been named representative in Mexico of the **Welduction Corporation**, Farmington Hills, MI, a full-service induction heat treating equipment and system manufacturer. . . **Fred R. Specht** has been appointed national sales manager of **Pillar Industries,** Menomonee Falls, WI. Pillar is a worldwide supplier of induction heat treating supplies to the automotive, off-highway, aerospace, appliance and general metal working and forming industries . . . **Larry Habdas** has joined **Kluber Lubrication**'s Western Regional Group, which has sales responsibilities in Arizona, Colorado, Nevada, New Mexico and Utah. . . **Don F. Carlson** is the new president of **AMT—The Association for Manufacturing Technology**. He replaces **Albert W. Moore**, who is retiring. Carlson is past president/CEO of Acme Manufacturing Co., Madison Heights, MI . . . AMT has also elected officers and directors for 1997–98. The new chairman is **John Fedor**, president and CEO of **Masco Machine, Inc**. He replaces **James S. Gleason** of the **Gleason Corporation**, who will now serve as an ex-officio member of the board of directors . . . **Thomas E. Gross** has been named Vice President - Rochester Operations for **The Gleason Works.** His responsibilites will include managing manufacturing and engineering-related activies at the Rochester facility . . . **Mahr Corporation** has announced a restructuring of its management team. **Edgar Hochwart** is the new Executive Vice President and General Manager. **Paul Bruemmer** is the new CFO. **Donald Parker** is Sales & Product Manager, Hand Tools Division. **Douglas Brank, Danny Moss, Todd Golem** and **Bruce Cowley** are the new Product Managers for Form Metrology, Surface Metrology, Gage Calibration Metrology and Gear Metrology & PRIMAR, respectively. **David Rice** is now the Manager, Technical Service.

Tell Us What You Think . . .
If you found this article of interest and/or useful, please circle **209.**

Welcome to the Company Index of the 1998 *Gear Technology* Directory of Heat Treating Services. Use this list to locate the complete contact information for each company listed in the Services Index. *Gear Technology* advertisers are shown in boldface type. To find the pages on which their ads appear, see the Advertisers Index on page 48.

While we have made every effort to ensure that company names and addresses are correct, we cannot be held responsible for errors of fact or omission. If your company was not listed in this directory, and you would like to be included in 1999, please call 847-437-6604.

A

Abbott Furnace Company
1068 Trout Run Road
P. O. Box 967
Saint Marys, PA 15847
814-781-7355
Fax: 814-781-7334
E-mail: *abbottsales@ncentral.com*
Web: *http://dns.ncentral.com~abbott*

ABS Metallurgical Processors Inc.
4313 E. Magnolia St.
Phoenix, AZ 85034
602-437-3008
Fax: 602-470-0309

Accurate Ion Technology
10010 Miller Way
South Gate, CA 90280
562-928-1868
Fax: 562-927-8591

Accurate Steel Treating
10008 Miller Way
South Gate, CA 90280
562-927-6528
Fax: 310-927-8591

Advanced Heat Treat Corp.
1625 Rose St.
Monroe, MI 48162
734-243-0063
Fax: 734-243-4066
Web: *www.ahtweb.com*

Advanced Heat Treating Inc.
Trout Run Rd.
St. Marys, PA 15857
814-781-3744
Fax: 814-781-3230
E-mail: *cherry@ncentral.com*

Advanced Heat Treat Corp.
2839 Burton Ave.
Waterloo, IA 50703
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Fax: 319-232-4952
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Web: *www.ahtweb.com*

Advanced Metallurgical Technology
212 Page Ave.
Fort Worth, TX 76110
817-921-5100
Fax: 817-921-5372

Advanced Thermal Technologies, Inc.
P.O. Box 875
Kendallville, IN 46755
219-347-1203
Fax: 219-347-3568

Ajax Magnethermic Corp.
1745 Overland Ave.
Warren, OH 44483
216-372-8511
Fax: 216-372-8608

Albany Metal Treating
400 S. Dowden Ave.
Albany, IN 47320
317-789-6470
Fax: 317-789-6839

Alco Heat Treating Corp.
130 Verdi St.
Farmingdale, NY 11735
516-249-1660
Fax: 516-249-7889

Alliance Metal Treating
P.O. Box 68
Eola, IL 60519
630-851-5880
Fax: 630-851-0733
E-mail: *almt@ix.netcom.com*

Allread Products
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Terryville, CT 06786
860-589-3566
Fax: 860-589-3566

Alpha Heat Treaters
270 Emig Rd.
P.O. Box 23
York County Industrial Park
Emigsville, PA 17318
717-767-6757
Fax: 717-764-0129

American Brazing
Div. of Paulo Products Co.
4428 Hamann Pkwy.
Willoughby, OH 44094
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Fax: 440-946-3091
E-mail: *MEmerson@Paulo-us.com*

American Heat Treating
1346 Morris Ave.
Dayton, OH 45408
937-461-1121
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American Metal Processing Co.
22720 Nagel
Warren, MI 48089
810-757-7337
Fax: 810-757-8232

American Metal Treating Co.
1043 E. 62nd St.
Cleveland, OH 44103
216-431-4492
Fax: 216-431-1508

American Metal Treating Inc.
500 Manley St.
P.O. Box 4157
High Point, NC 27260
336-889-3277
Fax: 336-889-7950

AMT Monroe Inc.
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Monroe, MI 48162-5601
313-242-1733
Fax: 313-242-0993

AP Westshore, Inc.
4000 State Hwy. 91
Oshkosh, WI 54904-9217
920-235-2001
Fax: 920-235-2701
E-mail: *adiapw@aol.com*
Web: *www.appliedprocess.com*

Applied Cryogenics Inc.
1191 Chestnut St.
Newton, MA 02164
617-969-6490
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Web: *www.appliedprocess.com*

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B

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Benedict-Miller Inc.
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201-438-3000
Fax: 201-438-3137
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Fax: 201-589-6518

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Fort Worth, TX 76107
817-737-6651
Fax: 817-377-9601

Bomak Corp.
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Woburn, MA 01801
617-935-4100
Fax: 617-932-0542
E-mail: *bomak@industry.net*

Bonal Technologies Inc.
21178 Bridge St.
Southfield, MI 48034
248-353-2041
Fax: 248-353-2028
E-mail: *bonalth@aol.com*
Web: *www.bonal.com*

The Bowdil Co.
2030 Industrial Place S.E.
Canton, OH 44707
216-456-7176
Fax: 216-456-4625

Braddock Metallurgical
14600 Duval Place West
Jacksonville, FL 32218
904-741-4777
Fax: 904-741-4813

Braddock Metallurgical Alabama
3008 Red Morris Pkwy.
Anniston, AL 36207
205-831-5199
Fax: 205-831-5680

Brazing & Metal Treating
Div. of HI TecMetal Group
1101 E. 55th St.
Cleveland, OH 44103
216-881-8100
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Brazing & Metal Treating of KY
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1379 Jamike Ln.
Erlanger, KY 41018
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Brazing & Metal Treating of MN
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Albert Lea, MN 56007
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Fax: 507) 373-3771

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Fax: 216-341-4273

Bucyrus International, Inc.
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414-768-4000
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Burbank, CA 91502
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Cal-Doran Division
1804 Cleveland Ave.
National City, CA 91950
619-477-2121
Fax: 619-477-3219

California Surface Hardening Inc.
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P.O. Box 736
Compton, CA 90223
310-608-5576
Fax: 310-608-2072

Calumet Surface Hardening
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Hammond, IN 46323
219-844-5600
Fax: 219-845-1046

Carolina Commercial Heat Treating
P.O. Drawer 1368
Fountain Inn, SC 29644
803-862-3516
Fax: 803-862-4466

Caterpillar Industrial Products Inc.
100 N.E. Adams St.
Peoria, IL 61629-4375
309-675-5451
Fax: 309-675-6457
E-mail: *catgears@cat.e-mail.com*

Century Sun Metal Treating
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Fax: 616-941-2346
Web: *www.century-sun.com*

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937-461-2844
Fax: 937-461-4519

Certified Metal Craft Inc.
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El Cajon, CA 92020
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Fax: 619-593-3635
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219-397-6475
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Fax: 513-942-1414

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318-882-1800
Fax: 318-882-1821

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515-225-6565
Fax: 515-226-8772

Delphi Engineering & Contracting Inc.
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Sewell, NJ 08080
609-468-4839
Fax: 609-228-9354
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Web: *www.delphienginering.com*

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17644 Mt. Elliott
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313-891-2936
Fax: 313-891-3150
E-mail: *dfine@earthlink.net*
Web: *networkl1000.com/detflame*

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6795 State Rd.
Philadelphia, PA 19135
215-338-1200
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Dixie Heat Treating Co.
425 County Road 30
Florence, AL 35630
205-767-1752
Fax: 205-767-1573

Dixie Machine & Heat Treating Inc.
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Gastonia, NC 28054
704-864-5454
Fax: 704-864-5456

Drever Heat Treating
6201 Robinwood Rd.
Baltimore, MD 21225
410-789-6161
Fax: 410-789-6659

Dynamic Metal Treating
7784 Ronda Dr.
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313-459-8022
Fax: 313-459-7863

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Raleigh, NC 27603
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Fax: 919-833-1764
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32045 Dequindre
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248-585-1415
Fax: 248-585-3045
E-mail: *eastlind@aol.com*

Eckel Heat Treat
8035 W. County Rd.
Odessa, TX 79764
915-362-4336
Fax: 915-362-1827

Edwards Heat Treating
642 McCormick St.
San Leandro, CA 94577
510-638-4140
Fax: 510-638-1438

Elmira Heat Treating Inc.
407 S. Kinyon St.
Elmira, NY 14904
607-734-1577
Fax: 607-732-2572
E-mail: *eheattreat@aol.com*

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31271 Stephenson Hwy.
Madison Heights, MI 48071
248-588-5141
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E-mail: *ehtrp@aol.com*
Web: *eht-inc.com*

Erie Steel Treating Inc.
5540 Jackman Rd.
Toledo, OH 43613
419-478-3743
Fax: 419-478-0109
E-mail: *eriesteel@toledolink.com*
Web: *www.erie.com*

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1408 E. 222nd St.
Euclid, OH 44117
216-481-8444
800-962-2909
Fax: 216-481-3473

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Fairfield Mfg. Co.
P.O. Box 7940
Lafayette, IN 47903
765-474-3474
Fax: 317-477-7342

Feinblanking Ltd.
9461 LeSaint Dr.
Fairfield, OH 45014
513-860-2100
Fax: 513-870-5146

Fenton Heat Treating
3605 Homestead Duquesne Rd.
West Mifflin, PA 15122
412-466-3960
Fax: 412-466-7931

Flame Hardening Co. of California
6057 State St.
Huntington Park, CA 90255
213-589-5066
Fax: 213-589-5403

Flame Metals Processing Corp.
7317 W. Lake St.
Minneapolis, MN 55426-4396
612-929-7815
Fax: 612-925-0572

Fluxtrol Manufacturing Inc.
1388 Atlantic Blvd.
Auburn Hills, MI 48326
810-393-2000
Fax: 810-393-0277

Fox Steel Treating Co.
2220 Gratiot Ave
Detroit, MI 48207
888-818-0808
Fax: 313-568-0148

FPM Heat Treating
1501 S. Lively Blvd.
Elk Grove, IL 60007
847-228-2525
Fax: 847-228-9887

FPM Ipsen Heat Treating
666 Route 20
Cherry Valley, IL 61016
815-332-4961
Fax: 815-332-3022

FPM Milwaukee
8201 W. Calumet Rd.
Milwaukee, WI 53223
414-355-7900
Fax: 414-355-4719

Franklin Steel Treating Co.
1070 Ridge St.
Columbus, OH 43215-1190
614-488-2556
Fax: 614-486-9489

G

Gear Company of America
14300 Corgin Ave.
Cleveland, OH 44111
216-671-5400
Fax: 216-671-5825

General Heat Treating Corp.
6770 Benedict Rd.
East Syracuse, NY 13057
315-437-1117
Fax: 315-433-1194
Web: *www.GeneralHeatTreating.com*

General Metal Heat Treating Inc.
941 Addison Rd.
Cleveland, OH 44103
216-391-0886
Fax: 216-391-0890

Geo. H. Porter Steel Treating Co.
1273 E. 55th St.
Cleveland, OH 44103
216-431-6601
Fax: 216-431-0009
E-mail: *treating@aol.com*

Gibson Heat Treat Inc.
2037 Brookside Ln.
Kingsport, TN 37660
423-246-5542
Fax: 423-246-8629

The Gleason Works
1000 University Ave.
Rochester, NY 14692
716-461-8051
Fax: 716-461-1492

Global Heat Treat Inc.
54 Route 130
Yardville, NJ 08620
609-298-1200
Fax: 609-298-7958

Good Earth Tools, Inc.
Four Industrial Drive
Crystal City, MO 63019
314-937-3330
Fax: 314-937-3386
E-mail: goodearthtools@usa.net

Grand Rapids Heat Treating Co.
3832 Buchanan S.W.
Wyoming, MI 49548
616-243-0111
Fax: 616-243-4080

H

H & M Metal Processing
1850 Front St.
Cuyahoga Falls, OH 44221
800-304-2636
Fax: 216-928-5472

Hansen-Balk Steel Treating Co.
1230 Monroe N.W.
Grand Rapids, MI 49505
616-458-1414
Fax: 616-458-6868

Hauni Richmond Inc.
2800 Charles City Rd.
Richmond, VA 23231
804-236-5241
Fax: 804-236-5284

Heat Treat Corp. of America
1120 W. 119th St.
Chicago, IL 60643
773-264-1234
Fax: 773-264-4321

Heat-Treating Inc.
1807 W. Pleasant St.
Springfield, OH 45506
513-325-3121
Fax: 513-325-3117

Heat Treating Network
16600 W. Sprague Road, #275
Cleveland, OH 44130
440-243-8990
Fax: 440-243-8992
E-mail: *hsatnet@aol.com*

Heat Treating Services Corp.
217 Central Ave.
Pontiac, MI 48341
810-858-2230
Fax: 810-858-2242

HI TecMetal Group
1101 E. 55th St.
Cleveland, OH 44103
216-881-8100
Fax: 216-881-6811

Hinderliter Heat Treating Inc.
1025 N. Pauline St.
Anaheim, CA 92801
714-776-8312
Fax: 714-776-8446

Hinderliter Heat Treating Inc.
10530 Doric St.
Dallas, TX 75220
214-357-0394
Fax: 214-357-0195

Hinderliter Heat Treating Inc.
18600 Oxnard St.
Tarzana, CA 91356
818-344-0216
Fax: 818-609-9372

Hinderliter Heat Treating Inc.
1240 N. Harvard
Tulsa, OK 74115
918-834-0855
Fax: 918-836-4162

Hitech Metallurgical Co.
7384 Trade St.
San Diego, CA 92121
619-586-7272
Fax: 619-586-7598
E-mail: *aajb8@prodigy.com*

Hi-Tech Steel Treating Inc.
2720 Roberts St.
Saginaw, MI 48601
800-835-8294
Fax: 517-753-2368

Horizon Steel Treating Inc.
231 Jandus Rd.
Cary, IL 60013
847-639-4030
Fax: 847-639-1981

Horsburgh & Scott Co.
5114 Hamilton Ave.
Cleveland, OH 44114
216-431-3900
Fax: 216-432-5850
E-mail: *www.horsburgh-scott.com*

Houston Flame Hardening
215 N. Jenkins St.
Houston, TX 77003
713-926-8017
Fax: 713-926-8316

HTG Aerobraze
940 Redna Terrace
Woodlawn, OH 45215
513-772-1461
Fax: 513-772-0149

HTG–HiTech Aero
34800 Lakeland Blvd.
Eastlake, OH 44095
440-946-2280
Fax: 440-946-2283

Hudapack Metal Treating–Addison
824 South Kay Avenue
Addison, IL 60101-4976
630-543-6033
Fax: 630-543-8686

Hudapack Metal Treating–Elkhorn
979 Koopmen Lane
Elkhorn, WI 53121-2203
414-723-3345
Fax: 414-723-3752

Huron Metallurgical Inc.
12611 Haggerty Rd.
Belleville, MI 48111
313-699-6861
Fax: 313-699-6971

Hydro-Vac
1177 Marquette St.
Cleveland, OH 44114
216-881-8100
Fax: 216-881-6811

Hy-Vac Technologies Inc.
15701 Glendale Ave.
Detroit, MI 48227
313-838-2800
Fax: 313-838-2802

I

IHS, an Inductotherm Co.
5009 Rondo Drive
Ft. Worth, TX 76106
817-625-5577
Fax: 817-625-1872

Illiana Heat Treating Inc.
P.O. Box 1466
Danville, IL 61834-1466
217-443-5418
Fax: 217-443-5419

Impact Strategies Inc.
P.O. Box 5317
Clinton, NJ 08809
908-730-9163
Fax: 908-730-8334

Induction Heat Treating Corp.
775 Tek Drive
Crystal Lake, IL 60014
815-477-7788
Fax: 815-477-7784
E-mail: *ihtcorp@mc.net*

Induction Metal Treating Co.
P.O. Box 748
York, SC 29745
803-684-2548
Fax: 803-684-9387

Induction Services Inc.
24800 Mound Rd.
Warren, MI 48001
810-754-1640
Fax: 810-754-5402

Inductoheat Inc.
32251 N. Avis Dr.
Madison Heights, MI 48071
810-585-9393
Fax: 810-585-0429
E-mail: *moorhous@inductoheat.com*

Industrial Metal Treating Corp.
402 E. Front St.
Wilmington, DE 19801
800-445-7545
Fax: 302-656-4370
E-mail: *ribec@voicenet.com*

Industrial Steel Treating Co.
613 Carroll St.
P.O. Box 98
Jackson, MI 49202
517-787-6312
Fax: 517-787-5441
E-mail: *mlevy@indstl.com*
Web: www.*indstl.inter.net*

Industrial Steel Treating Inc.
3370 Benedict Way
Huntington Park, CA 90255
213-583-1231
Fax: 213-589-1255
Web: *www.industry.net/ist*

International Induction Inc.
1504 10th Ave.
Port Huron, MI 48060
810-984-3803
Fax: 810-984-3801

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Greensberg, PA 15601
412-834-7160
Fax: 412-834-4670
E-mail: *iai@westol.com*

J

Jasco Heat Treating Inc.
820 Turk Hill Road
Fairport, NY 14450
716-388-1040
Fax: 716-377-7226

JCS Engineering & Development
211 W. 22nd St.
Hialeah, FL 33010
305-888-7911
Fax: 305-888-9913

John V. Potero Co.
4225-35 Adams Ave.
Philadelphia, PA 19124
215-533-8988
Fax: 215-533-9210

K

Kowalski Heat Treating Co.
3611 Detroit Ave.
Cleveland, OH 44113
216-631-4411
Fax: 216-631-8921
E-mail: *khtheat@aol.com*

L

Lake County Steel Treating
960 Anita
Antioch, IL 60002
847-375-8174
Fax: 847-395-7638

Lawrence Industries Inc.
2720 S. Cornhusker Ave.
P.O. Box 1025
Hastings, NE 68901
402-463-3158
Fax: 402-463-4128

Lexington Heat Treat Inc.
657 E. 7th St.
Lexington, KY 40505
606-231-0236
Fax: 606-211-9464

Lindberg Heat Treating Co.
675 Christian Lane
Berlin, CT 06037
860-225-7691
Fax: 860-229-3891
E-mail: *berlin@lindbergct.com*

Lindberg Heat Treating Co.
8316 E. Freeway
Houston, TX 77229
713-672-6601
Fax: 713-672-5164

Lindberg Heat Treating Co.
1975 N. Ruby St.
Melrose Park, IL 60160
708-344-4080
Fax: 708-344-4010

Lindberg Heat Treating Co.
16167 W. Rogers Dr.
New Berlin, WI 53151
414-782-5553
Fax: 414-782-5660

Lindberg Heat Treating Co.
Harris Metals Division
4210 Douglas Ave.
Racine, WI 53402

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414-681-4280
Fax: 414-639-5719

Lindberg Heat Treating Co.
620 Buffalo Rd.
Rochester, NY 14611
716-436-7876
Fax: 716-436-5276
E-mail: *troverts@frontiernet.net*
Web: *www.ceramics.com/linduers*

Lindberg Heat Treating Co.
650 E. Taylor Ave.
St. Louis, MO 63147
314-382-6200
Fax: 314-382-3741

M

M & M Heat Treat
1309 Main St.
Essexville, MI 48732
517-893-3677
Fax: 517-893-4423

Magnum Metal Treating
4400 N. Frazier St.
Conroe, TX 77303
713-353-8615
Fax: 409-856-6607

Mannings U.S.A.
200 Richards Ave.
Dover, NJ 07801
800-447-4473
Fax: 973-537-1581
E-mail: *MANNINGS@worldnett.att.net or Mannings@aol.com*
Web: *manningsusa.com*

Master Heat Treating Inc.
51 Brown Ave.
Springfield, NJ 07081
201-379-7320
Fax: 201-379-3214

Merit Gear Corp.
810 Hudson St.
Antigo, WI 54409
800-756-3748
Fax: 715-627-2558
E-mail: *meritgear@wi.net*

Metal Improvement Co.
1515 Universal Rd.
Columbus, OH 43207
614-444-1181
Fax: 614-444-0421

Metal Improvement Co.
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Lafayette, LA 70508
318-837-9273
Fax: 318-837-2505

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1618 Ida
Wichita, KS 67211
316-267-8201
Fax: 316-267-5735

Metal Improvement Co.
1019 S. McLean Blvd.
Wichita, KS 67213
316-267-8201
Fax: 316-267-7904

Metal Methods
260 Chenault Rd.
Frankfort, KY 40601
502-695-5700
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Milwaukee, WI 53216
414-871-9010
Fax: 414-871-3910

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St. Paul, MN 55104
612-646-1317
Fax: 612-646-7705

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Denver, CO 80229
303-286-9338
Fax: 303-286-9366
E-mail: *annamtr@dimensional.com*

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1575 Pierce St.
Milwaukee, WI 53204
414-645-2226
Fax: 414-645-9118

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Minneapolis, MN 55414
612-378-1500
Fax: 612-378-0462

Metallurgical Processing Inc.
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Fort Wayne, IN 46854
219-423-1691
Fax: 219-422-2656

Metals Engineering Inc.
1800 South Broadway
Green Bay, WI 54304
414-437-7686
Fax: 414-437-7687

Metals Technology Corp.
120 North Schmale Rd.
Carol Stream, IL 60188
630-221-2500
Fax: 630-221-0120

Metal-Tec Heat Treating Inc.
4723 W. Station St.
Eight Mile, AL 36613
334-456-1133
Fax: 334-456-1134

Metlab Co.
1000 E. Mermaid Ln.
Glenside, PA 19038
215-233-2600
Fax: 215-233-5653

Metro Steel Treating
9792 Grinnell
Detroit, MI 48213
313-921-5522
Fax: 313-921-0363

Met-Tek Inc.
15651 S.E. 125th St.
Clackamas, OR 97015
503-636-3203
Fax: 503-655-6898

Met-Tek Inc.
1800 Melvin Ave.
Racine, WI 53404
414-639-8357
Fax: 414-639-7152

Michigan Flame Hardening Co.
2241 Bellingham
Troy, MI 48083
810-689-3737
Fax: 810-689-0680

Paulo Products Co.
4827 Chelsea
Kansas City, MO 64130
816-861-7500
Fax: 816-924-7300
E-mail: *DCoulis@paulo-us.com*

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1540 Channel Ave.
Memphis, TN 38113
901-948-5523
Fax: 901-948-7501
E-mail: *DKermick@paulo-us.com*

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1307 Rutledge Ave.
Murfreesboro, TN 37129
615-896-1385
Fax: 615-895-9613
E-mail: *JJenkins@paulo-us.com*

Paulo Products Co.
3206 Ambrose
Nashville, TN 37207-3206
615-228-2526
Fax: 615-228-2734
E-mail: *EPfrommer@paulo-us.com*

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St. Louis, MO 63110
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Fax: 314-647-7518
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RR#3 Box 14B
Zelienople, PA 16063
412-452-8750
Fax: 412-452-0484
E-mail: *jorr@pennaflame.com*
Web: www.*pennaflame.com*

Pennsylvania Metallurgical Inc.
315 Columbia St.
Bethlehem, PA 18017
610-691-1313
Fax: 610-691-2662

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Meadville, PA 16335
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Fax: 814-333-2533

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Fax: 815-282-0264

Phoenix Heat Treating Inc.
2405 W. Mohave
Phoenix, AZ 85009
602-258-7751
Fax: 602-258-7767
E-mail: *info@phxheatreat.com*
Web: *www.phxheatreat.com*

Pitt-Tex Inc.
P.O. Box 109
Latrobe, PA 15650
412-537-2009
Fax: 412-537-2140
E-mail: *Pitt-Tex@prodigy.net*

Precision Heat Treating Corp.
2711 Adams Center Rd.
Fort Wayne, IN 46803
219-749-5125
Fax: 219-749-0108

Progressive Engineering Co.
2010 E. Main St.
Richmond, VA 23223
804-648-7221
Fax: 804-780-2230

Progressive Steel Treating Inc.
922 Lawn Drive
Rockford, IL 61111
815-877-2571
Fax: 815-877-7922

R

Racine Heat Treating Co.
1215 8th St.
Racine, WI 53403
414-637-9893
Fax: 414-637-9854

Rebco/Rolock/Mtech
P.O. Box 375
Jefferson, OH 44047
440-275-3075
Fax: 440-275-3075

Revas Engineering Co.
555 W. 16th St.
Indianapolis, IN 46202
317-635-6311

Richter Precision Inc.
1021 Commercial Ave.
East Petersburg, PA 17520
717-560-9990
Fax: 717-560-8741

Roboduction Thermal Processing
P.O. Box 5090
Southfield, MI 48086
810-356-2577
Fax: 810-356-3989

Rochester Steel Treating Works
962 East Main St.
Rochester, NY 14605
716-546-3348
Fax: 716-546-1684

Rotation Products Corp.
2849 N. Catherwood Ave.
Indianapolis, IN 46219
317-542-8563
Fax: 317-542-1171

S

Scot Forge
8001 Winn Rd. Box 8
Spring Grove, IL 60081
847-587-1000
Fax: 847-587-2000
E-mail: *sales@scotforge.com*
Web: *scotforge.com*

Shanafelt Mfg. Co.
2633 Winfield Way N.E.
Canton, OH 44705
216-455-0315
Fax: 216-455-4487

Shore Metal Treating Technology Inc.
5475 Avion Park Dr.
Cleveland, OH 44143
216-473-2020
Fax: 216-473-0947

S.K.S. Heat Treating Inc.
3286 Industrial Dr.
Saginaw, MI 48601
517-777-0270
Fax: 517-777-0273

Solar Atmospheres Inc.
1969 Clearview Dr.
Souderton, PA 18964
800-347-3236
Fax: 215-723-6460
E-mail: *info@solaratm.com*
E-mail: *www.solaratm.com*

Sonee Heat Treating Corp.
3900 N. 31st Ave.
Phoenix, AZ 85017
602-277-4757
Fax: 602-230-7811

Southeastern Heat Treating Inc.
10 Old Shoals Rd.
Arden, NC 28704
704-684-4572
Fax: 704-684-5982

Specialty Heat Treating Inc.
105 W. Sanderfer Rd.
Athens, AL 35611
205-233-1147
Fax: 205-232-5595

Specialty Heat Treating
55226 C.R. 1 N.
Elkhart, IN 46514
219-295-2491
Fax: 219-295-1752

Specialty Heat Treating Inc.
3700 Eastern Ave. SE
Grand Rapids, MI 49508
616-245-0465
Fax: 616-245-3060

Specialty Heat Treating of Holland, Inc.
3270 John F. Donnelly Dr.
Holland, MI 49424
616-399-6880
Fax: 616-399-7504

Specialty Steel Treating
31610 W. Eight Mile Rd.
Farmington Hills, MI 48336
810-478-5900
Fax: 810-478-9626

Specialty Steel Treating
34501 Commerce Rd.
Fraser, MI 48026
810-293-5355
Fax: 810-293-5390

State Heat Treat Inc.
520 32nd St. S.E.
Grand Rapids, MI 49548-2304
616-243-0178
Fax: 616-243-6337
E-mail: rharvey@iserv.net

Steel Treaters, Inc.
100 Furnace St.
Oriskany, NY 13424
315-736-3081
Fax: 315-736-8849

Sun Steel Treating Inc.
550 Mill St.
S. Lyon, MI 48178
248-471-0844
Fax: 248-437-3140

Suncoast Heat Treating
316 S. Hughey Ave.
Orlando, FL 32801
407-843-7145
Fax: 407-422-3276

Suncoast Heat Treating
3181 SW 15th St.
Pompano Beach, FL 33069
305-968-6200
Fax: 305-972-0970

Suncoast Heat Treating
4704 W. South Ave.
Tampa, FL 33614
813-870-1510
Fax: 813-871-3792

Superior Metal Treating
2540 Indiana Ave.
Kansas City, MO 64127
816-924-1966
Fax: 816-924-3199

Syracuse Heat Treating Corp.
7055 Interstate Island Rd.
Syracuse, NY 13209
315-451-0000
Fax: 315-451-3895
E-mail: *www.SyracuseHeatTreating.com*

T

T. N. Woodworth Inc.
1600 Farrow St.
Ferndale, MI 48220
810-541-1960
Fax: 810-541-3864

Therm Tech of Waukesha, Inc.
301 Travis Ln.
Waukesha, WI 53186
414-549-1878
Fax: 414-549-4320

Thermal Braze Inc.
230 Juno St.
Jupiter, FL 33458
561-746-6640
Fax: 561-746-7452

Thermal Metal Treating Inc.
314 S. Pine St.
Aberdeen, NC 28315
910-944-3636
Fax: 910-944-3280

Thermal Treatment Center
28910 Lakeland Blvd.
Wickliffe, OH 44092
216-881-8100
Fax: 216-881-6811

Thermet Inc.
203 Travis Lane
Waukesha, WI 53186
414-544-9800
Fax: 414-544-5959
E-mail: *thermet@aol.com*

Thermo Electron Metal Treating Div.
1575 W. Pierce St.
Milwaukee, WI 53204
414-645-2226
Fax: 414-645-9118

Thermo Treaters Ltd.
101 McCoy Creek Dr.
Buchanan, MI 49107
616-695-6700
Fax: 616-695-6737

Tocco, Inc.
30100 Stephenson Hwy.
Madison Heights, MI 48071
810-399-8601
Fax: 810-399-8603

TracTech Inc.
11405 Stephens Dr.
Warren, MI 48090
810-759-3880
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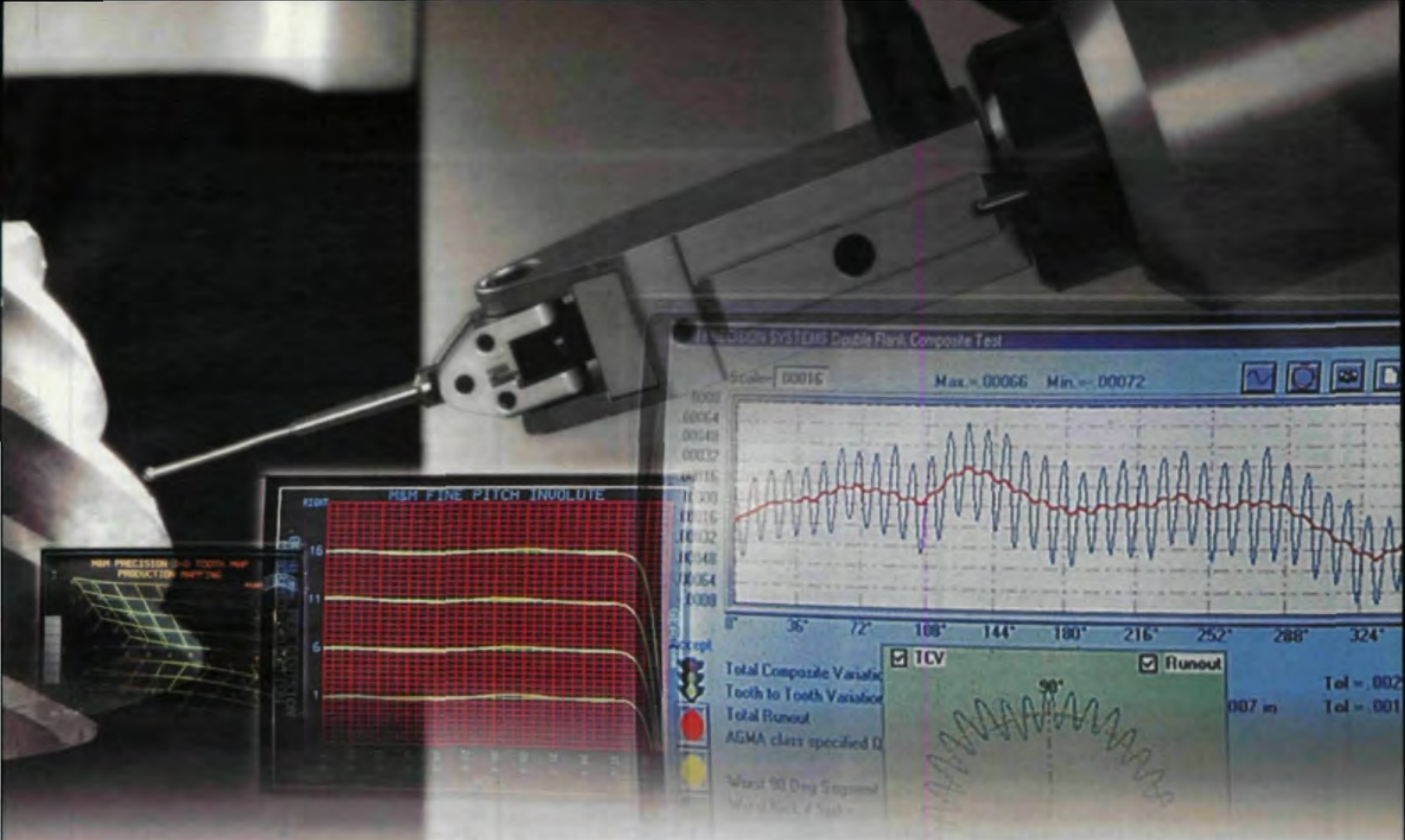
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While we have made every effort to ensure that company names and addresses are correct, we cannot be held responsible for errors of fact or omission. If your company was not listed in this directory, and you would like to be included in 1999, please call 847-437-6604.

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- Century Sun Metal Treating
- Certified Metal Craft
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- General Heat Treating
- Gibson Heat Treat
- Hansen-Balk Steel Treating
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- Hinderliter — Anaheim
- Hitech Metallurgical Co.
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- **Hudapack — Elkhorn**
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- Lindberg Heat Treating Co. — Houston
- Lindberg Heat Treating Co. — Rochester
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- Metal Improvement Co. — Columbus
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- Metal Treaters Inc.
- Metal Treating Inc.
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- Metallurgical Inc.
- Metlab Co.
- Midwestern Machinery Co.
- Modern Metal Processing
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- Paulo Products Co. — Nashville
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- Phoenix Heat Treating
- Pitt-Tex Inc.
- Progressive Steel Treating
- Racine Heat Treating Co.
- Richter Precision Inc.
- Rotation Products Corp.
- Solar Atmospheres Inc.
- Speciality Heat Treating —Grand Rapids
- Superior Metal Treating
- Syracuse Heat Treating
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- Cincinnati Steel Treating
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- Delphi Engineering
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- Dixie Machine & Heat Treating Inc.
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- Edwards Heat Treating
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- General Heat Treating
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- Metal Treating Inc.
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- Pennsylvania Metallurgical
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- Advanced Heat Treat Corp. —Waterloo
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- Century Sun Metal Treating
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- Chicago Flame Hardening
- Chicago Induction
- Cincinnati Flame Hardening Co.
- Cincinnati Gear Co.
- Cincinnati Steel Treating
- City Steel Treating Inc.
- Cleveland Flame Hardening Co.
- Coleman Commercial Heat Treating
- Commercial Induction
- Commercial Steel Treating
- Custom Heat Treating Co.
- Delavan Steel Treating
- Delphi Engineering
- Detroit Steel Treating Co.
- Diamond Heat Treating Co.
- Dixie Heat Treating Co.
- Dixie Machine & Heat Treating Inc.
- Drever Heat Treating
- Dynamic Metal Treating
- East Carolina Metal Treating Inc.
- East-Lind Heat Treat
- Eckel Heat Treat
- Edwards Heat Treating
- Elmira Heat Treating
- Engineered Heat Treat Inc.
- Erie Steel Treating Inc.
- Euclid Heat Treating Co.
- **Fairfield Mfg. Co.**
- Feinblanking Ltd.
- Fenton Heat Treating
- Flame Hardening Co. of California
- Flame Metals Processing
- Fluxtrol Manufacturing Inc.
- Fox Steel Treating Co.
- FPM Heat Treating—Elk Grove
- FPM Ipsen Heat Treating
- FPM Milwaukee
- Franklin Steel Treating Co.
- Gear Company of America
- General Heat Treating
- **General Metal Heat Treating Inc.**
- Geo. H. Porter Steel Treating Co.
- Gibson Heat Treat Inc.
- Grand Rapids Heat Treating Co.
- H & M Metal Processing
- Hansen-Balk Steel Treating
- Hauni Richmond Inc.
- Heat Treat Corp. of America
- Heat Treating Services
- HI TecMetal Group—Cleveland
- Hitech Metallurgical Co.
- Hi-Tech Steel Treating Inc.
- Hinderliter Heat Treating Inc.—Anaheim
- Hinderliter Heat Treating Inc.—Dallas
- Hinderliter Heat Treating Inc.—Tarzana
- Hinderliter Heat Treating Inc.—Tulsa
- Hitech Metallurgical Co.
- Horizon Steel Treating Inc.
- Horsburgh & Scott Co.
- Houston Flame Hardening
- HTG-HiTech Aero
- **Hudapack — Elkhorn**
- Huron Metallurgical
- Hydro-Vac
- Hy-Vac Technologies Inc.
- Illiana Heat Treating Inc.
- Impact Strategies Inc.
- Induction Metal Treating
- Induction Services Inc.
- Inductoheat Inc.
- Industrial Metal Treating
- Industrial Steel Treating Co.
- Industrial Steel Treating Inc.
- Ironbound Heat Treating
- Irwin Automation Inc.
- Jasco Heat Treating Inc.
- JCS Engineering & Development
- John V. Potero Co.
- Kowalski Heat Treating Co.
- Lake County Steel Treating
- Lawrence Industries Inc.
- Lexington Heat Treat Inc.
- Lindberg Heat Treating Co.—Berlin
- Lindberg Heat Treating Co.—Houston
- Lindberg Heat Treating Co.—Melrose Park
- Lindberg Heat Treating Co.—Racine
- Lindberg Heat Treating Co.—St. Louis
- M & M Heat Treat
- Magnum Metal Treating Inc.
- Master Heat Treating Inc.
- Merit Gear Corp.
- Metal Improvement Co.—Columbus
- Metal Improvement Co.—Lafayette
- Metal Improvement Co.—McLean/Wichita
- Metal Methods
- Metal Treaters Inc.
- Metal Treating & Research
- Metal Treating Inc.
- Metallurgical Inc.
- Metallurgical Processing
- Metals Engineering Inc.
- Metals Technology
- Metlab Co.
- Metro Steel Treating
- Met-Tek Inc.—Clackamas
- Met-Tek Inc.—Racine
- Michigan Induction Inc.
- Midland Metal Treating Inc.
- Mid-West Flame Hardening
- Midwestern Machinery Co.
- Modern Industries Inc.
- Modern Metal Processing
- Mountain Metallurgical
- National Induction Heating
- **National Broach**
- National Metal Processing
- Nettleson Steel Treating
- Nitro-Vac Heat Treating
- O & W Heat Treat Inc.
- Oakland Metal Treating Co.
- Ohio Metallurgical Service
- P & L Heat Treating & Grinding
- Partek Laboratories Inc.
- Paulo Products Co.—Bessemer
- Paulo Products Co.—Kansas City
- Paulo Products Co.—Nashville
- Paulo Products Co.—St. Louis
- Pennsylvania Metallurgical
- Peters Heat Treating Inc.
- **Pfauter-Maag Cutting Tools**
- Phoenix Heat Treating Inc.
- Pitt-Tex Inc.
- Precision Heat Treating
- Progressive Steel Treating
- Racine Heat Treating Co.
- Richter Precision Inc.
- Rochester Steel Treating
- Rotation Products Corp.
- S.K.S. Heat Treating Inc.
- Scot Forge
- Shore Metal Technology Inc.
- Solar Atmospheres Inc.
- Sonee Heat Treating Corp.
- Southeastern Heat Treating
- Specialty Heat Treating Inc.—Athens
- Specialty Heat Treating Inc.—Elkhart
- Specialty Heat Treating Inc.—Grand Rapids
- Specialty Heat Treating Inc.—Holland
- Specialty Steel Treating—Farmington Hills
- Specialty Steel Treating—Fraser
- State Heat Treat Inc.
- Steel Treaters, Inc.
- Steel Treating
- Sun Steel Treating
- Suncoast Heat Treating—Orlando
- Suncoast Heat Treating—Pompano Beach
- Suncoast Heat Treating—Tampa
- Superior Metal Treating
- Syracuse Heat Treating
- Therm Tech of Waukesha
- Thermal Braze Inc.
- Thermal Metal Treating Inc.
- Thermal Treatment Center
- Thermo Electron Metal Treating Div.
- Thermo Treaters Ltd.
- Tocco, Inc.
- TracTech
- Treat All Metals Inc.
- Trojan Heat Treat Inc.
- Universal Heat Treating
- Vacu Braze
- Walker Heat Treating
- Wall Colmonoy Corp.
- Washington Metallurgical Services
- Weiss Industries Inc.
- Westside Flame Hardening

AUSFORMING

- ABS Metallurgical Processors Inc.
- Certified Metal Craft Inc.
- Cincinnati Gear Co.
- Kowalski Heat Treating Co.
- Metals Technology
- Met-Tek Inc.—Clackamas

AUSTEMPERING

- Abbott Furnace
- Accurate Steel Treating
- Advanced Metallurgical Technology
- Alco Heat Treating Corp.
- Am. Met. Treating Inc.
- AP Westshore
- Applied Process Inc.
- Beehive Heat Treating
- Bodycote/Hinderliter
- Burbank Steel Treating Inc.
- Century Sun Metal Treating
- Certified Metal Craft Inc.
- Edwards Heat Treating
- Elmira Heat Treating
- **Engineered Heat Treat, Inc.**
- Euclid Heat Treating Co.
- Flame Metals Processing
- Fox Steel Treating Co.
- FPM Heat Treating—Elk Grove
- Franklin Steel Treating Co.
- **General Metal Heat Treating Inc.**
- Gibson Heat Treat, Inc.
- HI TecMetal Group—Cleveland
- Horizon Steel Treating Inc.
- **Hudapack — Addison**
- Hy-Vac Technologies Inc.
- Illiana Heat Treating Inc.
- Impact Strategies Inc.
- Industrial Steel Treating Inc.
- Ironbound Heat Treating
- Irwin Automation Inc.
- Jasco Heat Treating Inc.
- Kowalski Heat Treating Co.
- Lexington Heat Treat Inc.
- Lindberg Heat Treating Co.—New Berlin
- Lindberg Heat Treating Co.—Racine
- Metal Improvement Co.—McLean/Wichita
- Metal Treating Inc.
- Metallurgical Inc.
- Metals Technology
- Metro Steel Treating
- Midwestern Machinery Co.
- National Metal Processing
- Paulo Products Co.—Kansas City
- Paulo Products Co.—Murfreesboro
- Phoenix Heat Treating Inc.
- Sonee Heat Treating Corp.
- Southeastern Heat Treating
- Steel Treaters, Inc.
- Superior Metal Treating
- Therm Tech of Waukesha
- Thermo Electron Metal Treating Div.

BLACK OXIDING

- Abbott Furnace
- Advanced Heat Treat Corp. — Monroe
- Advanced Heat Treat Corp. — Waterloo
- Advanced Heat Treating Inc.
- Alco Heat Treating Corp.
- Alpha Heat Treaters
- Benedict-Miller
- Detroit Steel Treating Co.
- Gibson Heat Treat
- Hauni Richmond Inc.
- Hi-Tech Steel Treating
- Horsburg & Scott
- Impact Strategies, Inc.

Ironbound Heat Treating
Kowalski Heat Treating
Midwestern Machinery Co.
Paulo Products Co. — Kansas City
Paulo Products Co. — Memphis
Paolo Products Co. — St. Louis
Phoenix Heat Treating
Superior Metal Treating
Syracuse Heat Treating
Universal Heat Treating

BLAST CLEANING

Alliance Metal Treating
Alpha Heat Treaters
American Heat Treating
Am. Met. Treating Inc.
Beehive Heat Treating
Benedict-Miller
Burbank Steel Treating, Inc.
Century Sun Metal Treating
Certified Metal Craft
Cincinnati Steel Treating
Detroit Steel Treating Co.
Dixie Heat Treating
Drever Heat Treating
East-Lind Heat Treat
Edwards Heat Treating
Elmira Heat Treating
Erie Steel Treating Inc.
Euclid Heat Treating
Fenton Heat Treating
Flame Metals Processing
FPM Ipsen Heat Treating
General Heat Treating
Gibson Heat Treat
Hanson-Balk Steel Treating
Hauni Richmond Inc.
Hi-Tech Steel Treating
Industrial Metal Treating
Industrial Steel Treating Inc.
Kowalski Heat Treating
Lindberg Heat Treating Co. — Houston
Merit Gear Corp.
Metal Improvement Co. — Columbus
Metal Treaters Inc.
Metal Treating Inc.
Metallurgical Inc.
Metlab Co.
Midwest Flame Hardening
Midwestern Machinery Co.
Oakland Metal Treating
Paulo Products Co. — Nashville
Pennsylvania Metallurgical
Phoenix Heat Treating
Progressive Steel Treating
Racine Heat Treating Co.
Solar Atmospheres Inc.
Superior Metal Treating
Syracuse Heat Treating
TracTech
Treat All Metals
Universal Heat Treating
Westside Flame Hardening

BORONIZING

Lindberg Heat Treating Co. — Houston
Lindberg Heat Treating Co. — Rochester

BRAZING

Abbott Furnace
Alco Heat Treating Corp.
Allread Products
American Brazing
Am. Met. Treating Inc.
Bodycote/Hinderliter
Brazing & Metal Treating of KY
Brazing & Metal Treating of MN
Certified Heat Treating Inc.
Certified Metal Craft
Chicago Induction
Coleman Commercial Heat Treating
Delavan Steel Treating
Drever Heat Treating
Dynamic Metal Treting
East Carolina Metal Treating Inc.
Edwards Heat Treating
Elmira Heat Treating
Fenton Heat Treating
Flame Metals Processing
Fluxtrol Manufacturing, Inc.
FPM Heat Treating— Elk Grove
FPM Ipsen Heat Treating
Franklin Steel Treating Co.
General Heat Treating Corp.
Gibson Heat Treat Inc.
Good Earth Tools, Inc.
Hauni Richmond Inc.
HI TecMetal Group— Cleveland
Hinderliter Heat Treating Inc.—Anaheim
Hinderliter Heat Treating Inc.—Dallas
Hinderliter Heat Treating Inc.—Tarzana
Hitech Metallurgical Co.
Hi-Tech Steel Treating Inc.
Horizon Steel Treating Inc.
HTG—HiTech Aero
Hy-Vac Technologies Inc.
Induction Metal Treating Co.
Inductoheat Inc.
Industrial Metal Treating
Industrial Steel Treating
Lindberg Heat Treating Co.—Berlin
Lindberg Heat Treating Co.—St. Louis
Magnum Metal Treating
Mannings U.S.A.
Merit Gear Corp.
Metal Improvement Co.— McLean/Wichita
Metal Treating & Research
Metal Treating Inc.
Metallurgical Inc.
Metals Technology
Modern Industries Inc.
Modern Metal Processing
National Induction Heating
Nitro-Vac Heat Treating
O & W Heat Treat Inc.
Paulo Products Co.— St. Louis
Pennsylvania Metallurgical
Precision Heat Treating
Progressive Steel Treating
Racine Heat Treating Co.
Solar Atmospheres Inc.
Sonee Heat Treating Corp.
Specialty Heat Treating Inc.—Athens
Specialty Heat Treating Inc.—Elkhart
Specialty Heat Treating Inc.—Grand Rapids
Specialty Heat Treating Inc.—Holland
Specialty Steel Treating— Farmington Hills
Steel Treating
Suncoast Heat Treating— Tampa
Superior Metal Treating
Syracuse Heat Treating
Thermal Braze Inc.
Thermal Treatment Center
Thermo Electron Metal Treating Div.
Wall Colmonoy Corp.

CARBONITRIDING

Abbott Furnace
ABS Metallurgical Processors Inc.
Accurate Steel Treating
Advanced Heat Treating Inc.
Advanced Thermal Technologies Inc.
Albany Metal Treating
Alco Heat Treating Corp.
Alliance Metal Treating
Alpha Heat Treaters
American Heat Treating
American Metal Processing
Am. Met. Treating Inc.
Beehive Heat Treating Inc.
Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Bodycote/Hinderliter
Braddock Metallurgical
Braddock Metallurgical Alabama
Brite Metal Treating Inc.
Burbank Steel Treating, Inc.
Cal-Doran Division
Carolina Commercial Heat
Caterpillar Industrial Products Inc.
Century Sun Metal Treating
Certified Heat Treating Inc.
Cincinnati Gear Co.
Cincinnati Steel Treating
City Steel Treating Inc.
Coleman Commercial Heat
Commercial Steel Treating
Delavan Steel Treating
Detroit Steel Treating Co.
Diamond Heat Treating Co.
Dixie Heat Treating Co.
Dixie Machine & Heat Treating Inc.
Drever Heat Treating
East-Lind Heat Treat
East Carolina Metal Treating Inc.
Edwards Heat Treating
Elmira Heat Treating
Engineered Heat Treat Inc.
Erie Steel Treating Inc.
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Feinblanking Ltd.
Flame Metals Processing
FPM Heat Treating— Elk Grove
FPM Ipsen Heat Treating
FPM Milwaukee
Franklin Steel Treating Co.
General Heat Treating
General Metal Heat Treating Inc.
Grand Rapids Heat Treating Co.
Hauni Richmond Inc.
Heat Treat Corp. of America
Heat-Treating Inc.
HI TecMetal Group— Cleveland
Hinderliter Heat Treating Inc.—Anaheim
Hinderliter Heat Treating Inc.—Dallas
Hinderliter Heat Treating Inc.—Tarzana
Hinderliter Heat Treating Inc.—Tulsa
Hi-Tech Steel Treating Inc.
Horizon Steel Treating Inc.
Hudapack — Elkhorn
Huron Metallurgical Inc.
Illiana Heat Treating Inc.
Impact Strategies Inc.
Induction Metal Treating
Industrial Metal Treating
Industrial Steel Treating Co.
Industrial Steel Treating Inc.
Ironbound Heat Treating
Jasco Heat Treating Inc.
Lake County Steel Treating
Lawrence Industries Inc.
Lexington Heat Treat Inc.
Lindberg Heat Treating Co. —Berlin
Lindberg Heat Treating Co. —Houston
Lindberg Heat Treating Co. —Melrose Park
Lindberg Heat Treating Co. —Racine
Lindberg Heat Treating Co. —Rochester
Lindberg Heat Treating Co. —St. Louis
Magnum Metal Treating
Merit Gear Corp.
Metal Improvement Co.— Columbus
Metal Improvement Co.— Lafayette
Metal Improvement Co.— McLean/Wichita
Metal Treaters Inc.
Metal Treating Inc.
Metal Treating & Research
Metallurgical Inc.
Metallurgical Processing
Metals Engineering Inc.
Metals Technology
Metlab Co.
Metro Steel Treating
Met-Tek Inc.—Clackamas
Met-Tek Inc.—Racine
Midland Metal Treating Inc.
Midwestern Machinery Co.
Modern Industries Inc.
Mountain Metallurgical
National Broach
National Metal Processing
Oakland Metal Treating Co.
Ohio Metallurgical Service
Paulo Products Co.— Bessemer
Paulo Products Co.— Kansas City
Paulo Products Co.— Memphis
Paulo Products Co.— Murfreesboro
Paulo Products Co.— Nashville
Paulo Products Co.— St. Louis
Pennsylvania Metallurgical
Peters Heat Treating Inc.
Phoenix Heat Treating Inc.
Precision Heat Treating
Progressive Steel Treating
Racine Heat Treating Co.
Rochester Steel Treating
Rotation Products Corp.
S.K.S. Heat Treating Inc.
Shore Metal Technology
Southeastern Heat Treating
Specialty Heat Treating Inc. —Athens
Specialty Heat Treating Inc. —Elkhart
Specialty Heat Treating Inc. —Grand Rapids
Specialty Heat Treating Inc. —Holland
Specialty Steel Treating— Farmington Hills
Specialty Steel Treating— Fraser
State Heat Treat Inc.
Steel Treaters, Inc.
Steel Treating
Suncoast Heat Treating— Orlando
Suncoast Heat Treating— Pompano Beach
Suncoast Heat Treating— Tampa

- Superior Metal Treating
- Syracuse Heat Treating
- T. N. Woodworth Inc.
- Therm Tech of Waukesha
- Thermal Metal Treating
- Thermal Treatment Center
- Thermo Electron Metal Treating Div.
- Thermo Treaters Ltd.
- TracTech
- Treat All Metals Inc.
- Trutec Industries
- Universal Heat Treating
- Washington Metallurgical Services
- Weiss Industries Inc.

CARBURIZING

- Abbott Furnace
- ABS Metallurgical Processors Inc.
- Accurate Steel Treating
- Advanced Heat Treating
- Advanced Metallurgical Technology
- Advanced Thermal Technologies Inc.
- Albany Metal Treating
- Alco Heat Treating Corp.
- Alliance Metal Treating
- Alpha Heat Treaters Div.
- American Heat Treating
- American Metal Processing
- Am. Met. Treating Inc.
- AP Westshore
- Beehive Heat Treating Inc.
- Benedict-Miller Inc.
- Bennett Heat Treating & Brazing Co.
- Bodycote/Hinderliter
- Bomak Corp.
- The Bowdil Co.
- Braddock Metallurgical
- Braddock Metallurgical Alabama
- Brite Metal Treating Inc.
- Burbank Steel Treating Inc.
- Cal-Doran Division
- Carolina Commercial Heat Treating
- Caterpillar Industrial Products Inc.
- Century Sun Metal Treating
- Certified Heat Treating Inc.
- Certified Metal Craft
- Cincinnati Gear Co.
- Cincinnati Steel Treating
- City Steel Treating Inc.
- Coleman Commercial Heat Treating
- Commercial Steel Treating
- *Custom Heat Treating Co.*
- Delavan Steel Treating
- Detroit Steel Treating Co.
- Diamond Heat Treating Co.
- Dixie Heat Treating Co
- Dixie Machine & Heat Treating Inc.
- Drever Heat Treating
- East Carolina Metal Treating Inc.
- East-Lind Heat Treat
- Eckel Heat Treat
- Edwards Heat Treating
- Elmira Heat Treating
- **Engineered Heat Treat Inc.**
- Erie Steel Treating Inc.
- Euclid Heat Treating Co.
- **Fairfield Mfg. Co.**
- Feinblanking Ltd.
- Fenton Heat Treating
- Flame Metals Processing
- Fox Steel Treating Co.
- FPM Heat Treating—Elk Grove
- FPM Ipsen Heat Treating
- FPM Milwaukee
- Franklin Steel Treating Co.
- Gear Company of America
- General Heat Treating Corp.
- **General Metal Heat Treating Inc.**
- Geo. H. Porter Steel Treating Co.
- Gibson Heat Treat Inc.
- Grand Rapids Heat Treating Co.
- Hanson-Balk Steel Treating
- Hauni Richmond Inc.
- Heat Treat Corp. of America
- Heat-Treating Inc.
- HI TecMetal Group —Cleveland
- Hinderliter Heat Treating Inc.—Anaheim
- Hinderliter Heat Treating Inc.—Dallas
- Hinderliter Heat Treating Inc.—Tarzana
- Hinderliter Heat Treating Inc.—Tulsa
- Hi-Tech Steel Treating Inc.
- Horizon Steel Treating Inc.
- Horsburgh & Scott Co.
- **Hudapack — Elkhorn**
- Huron Metallurgical Inc.
- Illiana Heat Treating Inc.
- Impact Strategies Inc.
- Induction Metal Treating
- Industrial Metal Treating
- Industrial Steel Treating Co.
- Industrial Steel Treating Inc.
- Ironbound Heat Treating
- Irwin Automation Inc.
- Jasco Heat Treating Inc.
- JCS Engineering & Development
- Lake County Steel Treating
- Lawrence Industries Inc.
- Lexington Heat Treat Inc.
- Lindberg Heat Treating Co. —Berlin
- Lindberg Heat Treating Co. —Houston
- Lindberg Heat Treating Co. —Melrose Park
- Lindberg Heat Treating Co. —New Berlin
- Lindberg Heat Treating Co. —Racine
- Lindberg Heat Treating Co. —Rochester
- Lindberg Heat Treating Co. —St. Louis
- Magnum Metal Treating Inc.
- Master Heat Treating Inc.
- Merit Gear Corp.
- Metal Improvement Co.—*Columbus*
- Metal Improvement Co.—Lafayette
- Metal Improvement Co.—McLean/Wichita
- Metal Treaters Inc.
- Metal Treating & Research
- Metal Treating Inc.
- Metallurgical Inc.
- Metallurgical Processing Inc.
- Metals Engineering Inc.
- Metals Technology
- Metlab Co.
- Metro Steel Treating
- Met-Tek Inc.—Racine
- Midland Metal Treating Inc.
- Midwestern Machinery Co.
- Modern Industries Inc.
- Mountain Metallurgical
- **National Broach**
- National Metal Processing
- Oakland Metal Treating Co.
- Ohio Metallurgical Service
- P & L Heat Treating & Grinding
- Partek Laboratories Inc.
- Paulo Products Co.—Bessemer
- Paulo Products Co.—Kansas City
- Paulo Products Co.—Memphis
- Paulo Products Co.—Murfreesboro
- Paulo Products Co.—Nashville
- Paulo Products Co.—St. Louis
- Pennsylvania Metallurgical
- Peters Heat Treating Inc.
- Phoenix Heat Treating Inc.
- Pitt-Tex Inc.
- Precision Heat Treating
- Progressive Steel Treating
- Racine Heat Treating Co.
- Rochester Steel Treating
- Rotation Products Corp.
- Shore Metal Technology
- Sonee Heat Treating Corp.
- Southeastern Heat Treating
- Specialty Heat Treating Inc.—Athens
- Specialty Heat Treating Inc.—Elkhart
- Specialty Heat Treating Inc.—Grand Rapids
- Specialty Heat Treating Inc.—Holland
- Specialty Steel Treating—Farmington Hills
- Specialty Steel Treating—Fraser
- State Heat Treat Inc.
- Steel Treaters, Inc.
- Steel Treating
- Suncoast Heat Treating—Orlando
- Suncoast Heat Treating—Pompano Beach
- Suncoast Heat Treating—Tampa
- Superior Metal Treating
- Syracuse Heat Treating
- T. N. Woodworth Inc.
- Therm Tech of Waukesha
- Thermal Metal Treating Inc.
- Thermal Treatment Center
- Thermo Electron Metal Treating Div.
- Thermo Treaters Ltd.
- TracTech
- Treat All Metals Inc.
- Trutec Industries
- Universal Heat Treating
- Washington Metallurgical Services
- Weiss Industries Inc.
- Westside Flame Hardening

CRYOGENICS

- ABS Metallurgical Processors Inc.
- Accurate Steel Treating
- Advanced Thermal Technologies Inc.
- Alco Heat Treating Corp.
- Alliance Metal Treating
- Alpha Heat Treaters
- American Brazing
- American Heat Treating
- Am. Met. Treating Inc.
- Applied Cryogenics Inc.
- Beehive Heat Treating Inc.
- Benedict-Miller Inc.
- Bennett Heat Treating & Brazing Co.
- Bodycote/Hinderliter
- Braddock Metallurgical
- Braddock Metallurgical Alabama
- Burbank Steel Treating Inc.
- Cal-Doran Division
- Carolina Commercial Heat Treating
- Century Sun Metal Treating
- Certified Heat Treating Inc.
- Certified Metal Craft
- Cincinnati Flame Hardening Co.
- Cincinnati Gear Co.
- Cincinnati Steel Treating
- City Steel Treating Inc.
- Delavan Steel Treating
- Detroit Flame Hardening
- Detroit Steel Treating Co.
- Dixie Heat Treating
- Drever Heat Treating
- East Carolina Metal Treating Inc.
- East-Lind Heat Treat
- Edwards Heat Treating
- Elmira Heat Treating
- **Engineered Heat Treat Inc.**
- Erie Steel Treating Inc.
- Fenton Heat Treating
- Flame Metals Processing
- Fox Steel Treating Co.
- FPM Heat Treating—Elk Grove
- FPM Ipsen Heat Treating
- FPM Milwaukee
- General Heat Treating Corp.
- **General Metal Heat Treating Inc.**
- Geo. H. Porter Steel Treating Co.
- Gibson Heat Treat Inc.
- Hanson-Balk Steel Treating
- Hauni Richmond Inc.
- Heat-Treating Inc.
- Heat Treat Corp. of America
- HI TecMetal Group—Cleveland
- Hinderliter Heat Treating Inc.—Anaheim
- Hinderliter Heat Treating Inc.—Dallas
- Hinderliter Heat Treating Inc.—Tarzana
- Hinderliter Heat Treating Inc.—Tulsa
- Hi-Tech Steel Treating Inc.
- Horsburgh & Scott
- HTG-HiTech Aero
- **Hudapack — Elkhorn**
- Hydro-Vac
- Hy-Vac Technologies Inc.
- Illiana Heat Treating Inc.
- Impact Strategies Inc.
- Induction Metal Treating
- Industrial Metal Treating
- Industrial Steel Treating Inc.
- Ironbound Heat Treating
- Irwin Automation Inc.
- Jasco Heat Treating Inc.
- *Kowalski Heat Treating Co.*
- Lexington Heat Treat Inc.
- Lindberg Heat Treating Co. —Berlin
- Lindberg Heat Treating Co. —Houston
- Lindberg Heat Treating Co. —Melrose Park
- Lindberg Heat Treating Co. —Racine
- Magnum Metal Treating
- Master Heat Treating Inc.
- Metal Improvement Co.—Columbus
- Metal Improvement Co.—McLean/Wichita
- Metal Treaters Inc.
- Metal Treating Inc.
- Metallurgical Inc.
- Metals Engineering Inc.
- Metals Technology
- Metro Steel Treating
- Met-Tek Inc.—Clackamas
- Midland Metal Treating Inc.
- Modern Industries Inc.
- Mountain Metallurgical
- National Metal Processing
- Nitro-Vac Heat Treating
- Ohio Metallurgical Service
- Paulo Products Co.—Bessemer
- Paulo Products Co.—Kansas City
- Paulo Products Co.—Memphis
- Paulo Products Co.—Murphreesboro
- Paulo Products Co.—Nashville
- Paulo Products Co.—St. Louis
- Penna Flame Industries Inc.
- Pennsylvania Metallurgical
- Peters Heat Treating Inc.
- Phoenix Heat Treating Inc.
- Pitt-Tex Inc.
- Progressive Steel Treating
- Racine Heat Treating Co.
- Rochester Steel Treating
- Rotation Products Corp.
- S.K.S. Heat Treating Inc.
- Shore Metal Technology
- Solar Atmospheres Inc.
- Sonee Heat Treating Corp.
- Southeastern Heat Treating
- Specialty Heat Treating Inc. —Athens
- Specialty Heat Treating Inc. —Elkhart
- Specialty Heat Treating Inc. —Grand Rapids
- Specialty Heat Treating Inc. —Holland
- Specialty Steel Treating—Fraser
- Steel Treaters, Inc.
- Steel Treating
- Sun Steel Treating
- Suncoast Heat Treating—Orlando
- Suncoast Heat Treating—Pompano Beach
- Suncoast Heat Treating—Tampa
- Superior Metal Treating
- Syracuse Heat Treating
- T. N. Woodworth Inc.
- Therm Tech of Waukesha
- Thermal Braze Inc.
- Thermal Treatment Center
- Thermo Electron Metal Treating Div.
- TracTech
- Treat All Metals Inc.
- Trutec Industries
- Universal Heat Treating
- Walker Heat Treating
- Washington Metallurgical Services
- Westside Flame Hardening

DIE QUENCHING

- American Brazing
- Beehive Heat Treating
- Benedict-Miller Inc.
- Bennett Heat Treating & Brazing Co.
- Burbank Steel Treating Inc.
- Caterpillar Industrial Products Inc.
- Certified Metal Craft
- Cincinnati Gear Co.
- Cincinnati Steel Treating
- Detroit Steel Treating Co.
- **Engineered Heat Treat Inc.**
- Euclid Heat Treating Co.
- **Fairfield Mfg. Co.**
- Fenton Heat Treating
- Fox Steel Treating Co.
- Franklin Steel Treating Co.
- **General Metal Heat Treating Inc.**
- Gibson Heat Teating
- The Gleason Works
- Grand Rapids Heat Treating Co.
- Heat Treat Corp. of America
- Hy-Vac Technologies Inc.
- Illiana Heat Treating Inc.
- Impact Strategies Inc.
- Industrial Steel Treating Inc.
- Ironbound Heat Treating
- Jasco Heat Treating Inc.
- John V. Potero Co.
- Kowalski Heat Treating Co.
- Lindberg Heat Treating Co.—Racine
- Metallurgical Inc.
- Metals Technology
- Ohio Metallurgical Service
- Paulo Products Co.—Bessemer
- Paulo Products Co.—Kansas City
- Paulo Products Co.—Memphis
- Paulo Products Co.—Nashville
- Paulo Products Co.—St. Louis
- Phoenix Heat Treating Inc.
- Progressive Steel Treating
- Roboduction Thermal Processing
- Rotation Products Corp.
- Solar Atmospheres Inc.
- Specialy Steel Treating—Farmington Hills
- Specialty Steel Treating—Fraser
- Sun Steel Treating
- Therm Tech of Waukesha
- Thermal Metal Treating Inc.
- Treat All Metals Inc.

FLAME HARDENING

- Alco Heat Treating Corp.
- American Heat Treating
- Beehive Heat Treating Inc.
- Benedict-Miller Inc.
- Bennett Heat Treating & Brazing Co.
- Bodycote/Hinderliter
- The Bowdil Co.
- Bucyrus International Inc.
- California Surface Hardening Inc.
- Calumet Surface Hardening
- Certified Heat Treating Inc.
- Chicago Flame Hardening
- Chicago Induction
- Cincinnati Flame Hardening Co.
- Cincinnati Gear Co.
- Cincinnati Steel Treating
- Cleveland Flame Hardening Co.
- Coleman Commercial Heat Treating
- Detroit Steel Treating Co.
- Detroit Flame Hardening
- Drever Heat Treating
- East-Lind Heat Treat
- Edwards Heat Treating
- Erie Steel Treating Inc.
- Flame Hardening Co. of California
- Fox Steel Treating Co.
- Franklin Steel Treating Co.
- Gibson Heat Treat Inc.
- Good Earth Tools
- Hansen-Balk Steel Treating
- Hauni Richmond Inc.
- Heat-Treating Inc.
- Hinderliter Heat Treating Inc.—Tulsa
- Hi-Tech Steel Treating Inc.
- Horizon Steel Treating Inc.
- Houston Flame Hardening
- Illiana Heat Treating Inc.
- Induction Metal Treating Co.
- John V. Potero Co.

Building Relationships Means:

SETTING STANDARDS OF VALUE

WITH CUSTOMERS - FOR CUSTOMERS

TECHNOLOGY ▲ RELATIONSHIPS ▲ SUPPORT

Surface has excelled for more than 80 years in applying its broad thermal processing technical abilities to new and unusual customer processing applications. These applications reach the full spectrum of vacuum, atmosphere, and non-atmosphere process demands. Surface technology is developed with customers for use in every day processing requirements.

The strength of Surface comes from the customer relationships built and maintained throughout our long history. Customer satisfaction and growth continues to be the key to our success. Surface combines tradition, integrity, and technology to help our customers achieve long-term success. Surface is truly in business with customers, for customers.

Surface dedicates a wide range of resources in support of our customers. When you commit to Surface products, you gain the support of a large field service force, an equipment retrofit & up-grade department, a strong technical services group, a full R&D department, and one of the largest parts inventories in the industry.

Surface® Combustion

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION IHEA

SURFACE COMBUSTION, INC. ▲ 1700 INDIAN WOOD CIRCLE ▲ MAUMEE, OH 43537 ▲ PH. (800) 537-8980, (419) 891-7150 ▲ FAX (419) 891-7151

CIRCLE 115

FLAME HARDENING (Cont.)

Kowalski Heat Treating Co.
M & M Heat Treat
Metal Improvement Co.—Columbus
Metal Improvement Co.—McLean/Wichita
Metal Treating Inc.
Metallurgical Inc.
Met-Tek Inc.—Racine
Michigan Flame Hardening
Mid-West Flame Hardening
Midwestern Machinery Co.
National Induction Heating
Ohio Metallurgical Service
Penna Flame Industries Inc.
Pennsylvania Metallurgical
Revas Engineering Co.
Specialty Heat Treating Inc.—Athens
Steel Treaters, Inc.
Suncoast Heat Treating—Orlando
Suncoast Heat Treating—Pompano Beach
Suncoast Heat Treating—Tampa
Superior Metal Treating
Syracuse Heat Treating
Therm Tech of Waukesha
Thermo Electron Metal Treating Div.
Thermo Treaters Ltd.
Washington Metallurgical Services
Westside Flame Hardening
Wohlert Corp.

FREE QUENCHING

ABS Metallurgical Processors Inc.
Advanced Thermal Technologies Inc.
Alliance Metal Treating
AP Westshore
Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Bodycote/Hinderliter
Braddock Metallurgical
Burbank Steel Treating Inc.
Cal-Doran Division
Carolina Commercial Heat Treating
Caterpillar Industrial Products Inc.
Certified Heat Treating Inc.
Certified Metal Craft
Cincinnati Gear Co.
Cincinnati Steel Treating
City Steel Treating Inc.
Commercial Induction
Commercial Steel Treating
Detroit Steel Treating Co.
Diamond Heat Treating Co.
East Carolina Metal Treating Inc.
Elmira Heat Treating
Engineered Heat Treat Inc.
Erie Steel Treating Inc.
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Fenton Heat Treating
FPM Heat Treating—Elk Grove
FPM Milwaukee
Franklin Steel Treating Co.
General Metal Heat Treating Inc.
Gibson Heat Treat Inc.
Hanson-Balk Steel Treating
Heat Treat Corp. of America
Heat-Treating Inc.
Hinderliter Heat Treating Inc.—Anaheim
Hinderliter Heat Treating Inc.—Tarzana
Horizon Steel Treating Inc.
Illiana Heat Treating Inc.
Induction Metal Treating Co.
Industrial Metal Treating
Industrial Steel Treating Inc.
Jasco Heat Treating Inc.
Kowalski Heat Treating Co.
Lake County Steel Treating
Lawrence Industries Inc.
Lindberg Heat Treating Co.—Berlin
Lindberg Heat Treating Co.—Houston
Lindberg Heat Treating Co.—Melrose Park
Lindberg Heat Treating Co.—Racine
Metal Improvement Co.—Lafayette
Metal Improvement Co.—McLean/Wichita
Metal Treating Inc.
Metallurgical Inc.
Metals Technology
Metlab Co.
Met-Tek Inc.—Racine
Midland Metal Treating Inc.
Mid-West Flame Hardening
National Broach
National Induction Heating
Nettleson Steel Treating
Ohio Metallurgical Service
P & L Heat Treating & Grinding
Pfauter-Maag Cutting Tools
Phoenix Heat Treating Inc.
Pitt-Tex Inc.
Racine Heat Treating Co.
Rotation Products Corp.
S.K.S. Heat Treating Inc.
Scot Forge
Sonee Heat Treating Corp.
Specialty Steel Treating—Farmington Hills
Specialty Steel Treating—Fraser
State Heat Treat Inc.
Sun Steel Treating
Suncoast Heat Treating—Orlando
Suncoast Heat Treating—Pompano Beach
Superior Metal Treating
Syracuse Heat Treating
T. N. Woodworth Inc.
Thermal Treatment Center
Thermo Electron Metal Treating Div.
Treat All Metals Inc.
Walker Heat Treating
Washington Metallurgical Services
Westside Flame Hardening
Wohlert Corp.

HOT OIL QUENCHING

Abbott Furnace
ABS Metallurgical Processors Inc.
Advanced Metallurgical
Alco Heat Treating Corp.
Alpha Heat Treaters
American Heat Treating
Am. Met. Treating Inc.
Atmosphere Annealing Inc.
Beehive Heat Treating Inc.
Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Bodycote/Hinderliter
Bomak Corp.
Burbank Steel Treating Inc.
Carolina Commercial Heat Treating
Century Sun Metal Treating
Certified Heat Treating Inc.
Certified Metal Craft
Cincinnati Gear Co.
Cincinnati Steel Treating
City Steel Treating Inc.
Cleveland Flame Hardening Co.
Commercial Steel Treating
Custom Heat Treating Co.
Detroit Steel Treating Co.
Disston Precision Inc.
Dixie Machine & Heat Treating Inc.
Drever Heat Treating
East Carolina Metal Treating Inc.
Eckel Heat Treat
Elmira Heat Treating
Engineered Heat Treat Inc.
Erie Steel Treating Inc.
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Feinblanking Ltd.
Fenton Heat Treating
Fox Steel Treating Co.
FPM Heat Treating—Elk Grove
FPM Ipsen Heat Treating
FPM Milwaukee
Franklin Steel Treating Co.
General Heat Treating
General Metal Heat Treating Inc.
Gibson Heat Treat Inc.
Hansen-Balk Steel Treating
Hauni Richmond Inc.
Heat Treat Corp. of America
Heat-Treating Inc.
HI TecMetal Group—Cleveland
Hinderliter Heat Treating Inc. —Tulsa
Hi-Tech Steel Treating Inc.
Horizon Steel Treating Inc.
Horsburgh & Scott
Huron Metallurgical Inc.
Illiana Heat Treating Inc.
Induction Metal Treating Co.
Industrial Metal Treating
Industrial Steel Treating Co.
Industrial Steel Treating Inc.
Irwin Automation Inc.
Jasco Heat Treating Inc.
John V. Potero Co.
Kowalski Heat Treating Co.
Lexington Heat Treat Inc.
Lindberg Heat Treating Co.—New Berlin
Lindberg Heat Treating Co.—Racine
M & M Heat Treat
Magnum Metal Treating
Merit Gear Corp.
Metal Treating & Research
Metal Improvement Co.—Columbus
Metal Improvement Co.—McLean/Wichita
Metal Treaters Inc.
Metallurgical Inc.
Metallurgical Processing
Metals Engineering Inc.
Metals Technology
Metlab Co.
Metro Steel Treating
Met-Tek Inc.—Clackamas
Met-Tek Inc.—Racine
Mid-West Flame Hardening
Midwestern Machinery Co.
Modern Industries Inc.
Ohio Metallurgical Service
Paulo Products Co.—Bessemer
Paulo Products Co.—Nashville
Paulo Products Co.—St. Louis
Pennsylvania Metallurgical
Pitt-Tex Inc.
Progressive Steel Treating
Racine Heat Treating Co.
Rochester Steel Treating
Rotation Products Corp.
S.K.S. Heat Treating Inc.
Sonee Heat Treating Corp.
Southeastern Heat Treating
Specialty Steel Treating—Farmington Hills
Specialty Steel Treating—Fraser
Sun Steel Treating
Suncoast Heat Treating—Orlando
Suncoast Heat Treating—Pompano Beach
Superior Metal Treating
Syracuse Heat Treating
Therm Tech of Waukesha
Thermal Treatment Center
Thermo Treaters Ltd.
Treat All Metals Inc.
Weiss Industries, Inc.
Washington Metallurgical Services
Westside Flame Hardening

INDUCTION HARDENING

Advanced Heat Treat Corp.—Monroe
Advanced Heat Treat Corp.—Waterloo
Advanced Heat Treating
Ajax Magnethermic Corp.
Alco Heat Treating Corp.
Alpha Heat Treaters
Amer. Met. Treating Co.
Beehive Heat Treating Inc.
Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Bodycote/Hinderliter
Braddock Metallurgical
Bucyrus International Inc.
Carolina Commercial Heat Treating
Caterpillar Industrial Products Inc.
Century Sun Metal Treating
Certified Heat Treating Inc.
Chicago Induction
Cincinnati Gear Co.
Cincinnati Steel Treating
Coleman Commercial Heat Treating
Commercial Induction
Contour Hardening Inc.
Delavan Steel Treating
Dixie Machine & Heat Treating Inc.
Drever Heat Treating
East Carolina Metal Treating Inc.
Edwards Heat Treating
Elmira Heat Treating
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Flame Metals Processing
Fluxtrol Manufacturing Inc.
Franklin Steel Treating Co.
Gear Company of America
General Heat Treating
Gibson Heat Treat Inc.
Good Earth Tools, Inc.
Hauni Richmond Inc.
Heat Treat Corp. of America
Heat-Treating Inc.
Hi-Tech Steel Treating Inc.
HI TecMetal Group—Cleveland
Hinderliter Heat Treating Inc.—Anaheim,
Hinderliter Heat Treating Inc.—Tulsa
Horizon Steel Treating Inc.
Hudapack — Elkhorn
Illiana Heat Treating Inc.

Impact Strategies Inc.
Induction Services Inc.
Induction Metal Treating Co.
Induction Heat Treating
Inductoheat Inc.
Industrial Metal Treating
Industrial Steel Treating Co.
International Induction Inc.
Ironbound Heat Treating
Jasco Heat Treating Inc.
John V. Potero Co.
Lawrence Industries Inc.
Lexington Heat Treat Inc.
Lindberg Heat Treating Co. —Houston
Lindberg Heat Treating Co. —Melrose Park
Lindberg Heat Treating Co. —Racine
Lindberg Heat Treating Co. —St. Louis
Mannings U.S.A.
Master Heat Treating Inc.
Merit Gear Corp.
Metal Treating & Research
Metal Improvement Co.— Columbus
Metal Improvement Co.— McLean/Wichita
Metal Processing Co.
Metal Treaters Inc.
Metal Treating & Research
Metal Treating Inc.
Metallurgical Inc.
Metals Engineering Inc.
Met-Tek Inc.—Clackamas
Met-Tek Inc.—Racine
Michigan Induction Inc.
Midland Metal Treating Inc.
Modern Industries Inc.
Molon Gear & Shaft
National Induction Heating
National Metal Processing
O & W Heat Treat Inc.
Ohio Metallurgical Service
Paulo Products Co. —Kansas City
Paulo Products Co. —Memphis
Paulo Products Co. —Nashville
Paulo Products Co. —St. Louis
Pennsylvania Metallurgical
Pitt-Tex Inc.
Precision Heat Treating
Racine Heat Treating Co.
Revas Engineering Co.
Roboduction Thermal Processing
S.K.S. Heat Treating Inc.
Southeastern Heat Treating
Specialty Heat Treating Inc. —Elkhart
Specialty Heat Treating Inc. —Grand Rapids
Specialty Heat Treating Inc. —Holland
State Heat Treat Inc.
Steel Treaters, Inc.
Steel Treating
Suncoast Heat Treating— Pompano Beach
Suncoast Heat Treating— Tampa
Superior Metal Treating
Syracuse Heat Treating
Thermal Braze Inc.
Thermal Treatment Center
Thermet Inc.
Thermo Electron Metal Treating Div.
Tocco, Inc.
Treat All Metals Inc.
Washington Metallurgical
Westside Flame Hardening
Wohlert Corp.
Zion Industries

ION NITRIDING

Accurate Ion Technologies
Advanced Heat Treat Corp. —Monroe
Advanced Heat Treat Corp. —Waterloo
Advanced Metallurgical
AMT Monroe Inc.
Century Sun Metal Treating
Cincinnati Gear Co.
Fox Steel Treating Co.
FPM Heat Treating— Elk Grove
FPM Ipsen Heat Treating
Hansen-Balk Steel Treating
Hauni Richmond Inc.
HI TecMetal Group— Cleveland
Magnum Metal Treating
MPT America
Progressive Engineering Co.
Solar Atmospheres Inc.
Sonee Heat Treating Corp.
Sun Steel Treating
Thermal Treatment Center

LASER HARDENING

Cincinnati Gear Co.
National Metal Processing
Weiss Industries Inc.

METALLURGICAL TESTING

Accurate Ion Technologies
Advanced Heat Treat Corp. — Monroe
Advanced Heat Treat Corp. — Waterloo
Advanced Heat Treating
Advanced Metallurgical
Alliance Metal Treating
Alpha Heat Treaters
Benedict-Miller
Bodycote-Hinderliter
Burbank Steel Treating
Century Sun Metal Treating
Certified Metal Craft
Cincinnati Steel Treating
Delevan Steel Treating
Detroit Steel Treating Co.
Dixie Heat Treating
Dynamic Metal Treating
East-Lind Heat Treat
Elmira Heat Treating
Engineered Heat Treat, Inc.
Erie Steel Treating Inc.
Euclid Heat Treating
Flame Metals Processing
General Heat Treating
Hauni Richmond Inc.
Hitech Metallurgical Co.
Hi-Tech Steel Treating
Hudapack — Elkhorn
Impact Strategies Inc.
Industrial Steel Treating Co.
Industrial Steel Treating Inc.
Ironbound Heat Treating
Irwin Automation Inc.
Kowalski Heat Treating
Lindberg Heat Treating Co. — Houston
Lindberg Heat Treating Co. — Rochester
Merit Gear Corp.
Metal Improvement Co. — Columbus
Metal Treating Inc.
Metallurgical Inc.
Michigan Induction Inc.
National Metal Processing
Pennsylvania Metallurgical
Phoenix Heat Treating
Pitt-Tex Inc.
Progressive Steel Treating
Racine Heat Treating Co.
Richter Presiaion Inc.
Rotation Products Corp.
Sonee Heat Treting Corp.
Specialty Heat Treating — Grand Rapids
Superior Metal Treating
Syracuse Heat Treating
Thermet Inc.
TracTech
Universal Heat Treating
Weiss Industries Inc.

NITRIDING

Abbott Furnace
Accurate Steel Treating
Advanced Metallurgical
Albany Metal Treating
Alco Heat Treating Corp.
Am. Met. Treating Inc.
Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Bodycote/Hinderliter
Braddock Metallurgical
Burbank Steel Treating Inc.
Cal-Doran Division
Caterpillar Industrial Products Inc.
Cincinnati Gear Co.
Cincinnati Steel Treating
City Steel Treating Inc.
Commercial Steel Treating
Custom Heat Treating Co.
Drever Heat Treating
Dynamic Metal Treating
East Carolina Metal Treating Inc.
Elmira Heat Treating
Engineered Heat Treat Inc.
Erie Steel Treating Inc.
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Fenton Heat Treating
Fox Steel Treating Co.
FPM Heat Treating— Elk Grove
FPM Ipsen Heat Treating
FPM Milwaukee
General Metal Heat Treating Inc.
Grand Rapids Heat Treating Co.
H & M Metal Processing
Hansen-Balk Steel Treating
HI TecMetal Group— Cleveland
Hinderliter Heat Treating Inc.—Anaheim
Hinderliter Heat Treating Inc.—Dallas
Hinderliter Heat Treating Inc.—Tarzana
Hinderliter Heat Treating Inc.—Tulsa
Horizon Steel Treating Inc.
Hydro-Vac
Illiana Heat Treating Inc.
Impact Strategies Inc.
Induction Metal Treating Co.
Industrial Metal Treating
Industrial Steel Treating Inc.
Ironbound Heat Treating
Jasco Heat Treating Inc.
Lake County Steel Treating
Lindberg Heat Treating Co. —Houston
Lindberg Heat Treating Co. —Melrose Park
Lindberg Heat Treating Co. —Racine
Lindberg Heat Treating Co. —St. Louis
Merit Gear Corp.
Metal Improvement Co.
Metallurgical Inc.
Metal-Tec Heat Treating Inc.
Metals Technology
Metlab Co.
Metro Steel Treating
Met-Tek Inc.—Clackamas
Modern Industries Inc.
Modern Steel Treating
Nitrex Metal Tech— Burlington
Nitrex Metal Tech— Mason
Nitrex Metal Tech— St. Laurent
Nitron Inc.
Nitro-Vac Heat Treating
O & W Heat Treat Inc.
P & L Heat Treating & Grinding
Peters Heat Treating Inc.
Phoenix Heat Treating Inc.
Precision Heat Treating
Progressive Engineering
Rochester Steel Treating
Rotation Products Corp.
Scot Forge
Shore Metal Technology Inc.
Specialty Heat Treating Inc. —Elkhart
Specialty Heat Treating Inc. —Grand Rapids
Specialty Heat Treating Inc. —Holland
Specialty Steel Treating— Farmington Hills
Specialty Steel Treating— Fraser
Steel Treaters, Inc.
Sun Steel Treating
Suncoast Heat Treating— Orlando
Suncoast Heat Treating— Pompano Beach
Suncoast Heat Treating— Tampa
Syracuse Heat Treating
T. N. Woodworth Inc.
Therm Tech of Waukesha
Thermal Treatment Center
Treat All Metals Inc.
Trutec Industries
Universal Heat Treating
Walker Heat Treating

NITROCARBURIZING

Abbott Furnace
Alliance Meatl Treating
Alco Heat Treating Corp.
Am. Met. Treating Inc.
Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Bodycote/Hinderliter
Carolina Commercial Heat Treating
Cincinnati Gear Co.
Cincinnati Steel Treating
City Steel Treating Inc.
Coleman Commerical Heat Treating
Commercial Steel Treating
Dixie Heat Treating
Dynamic Metal Treating
Erie Steel Treating Inc.
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Flame Metals Processing
Fox Steel Treating Co.
FPM Heat Treating— Elk Grove
FPM Ipsen Heat Treating
FPM Milwaukee
Gear Company of America
Hauni Richmond Inc.
Hinderliter Heat Treating Inc.—Anaheim
Hinderliter Heat Treating Inc.—Tarzana
Hinderliter Heat Treating Inc.—Tulsa
Hudapack — Elkhorn
Illiana Heat Treating Inc.
Impact Strategies Inc.
Induction Metal Treating Co.
Industrial Metal Treating
Industrial Steel Treating
Ironbound Heat Treating
Jasco Heat Treating Inc.
Lindberg Heat Treating Co. —Houston
Lindberg Heat Treating Co. —Melrose Park
Lindberg Heat Treating Co. —New Berlin
Lindberg Heat Treating Co. —Racine
Lindberg Heat Treating Co. —Rochester
Lindberg Heat Treating Co. —St. Louis
Merit Gear Corp.
Metallurgical Inc.
Metals Technology
Metal-Tec Heat Treating
Metlab Co.
Metro Steel Treating
Met-Tek Inc.—Clackamas
Modern Industries Inc.
Nitrex Metal Tech. —Burlington
Nitrex Metal Tech. —Mason
Nitrex Metal Tech. —St. Laurent
Paulo Products Co.— Bessemer
Paulo Products Co.— Kansas City
Paulo Products Co.— Memphis
Paulo Products Co.— Murfreesboro
Paulo Products Co.— Nashville
Paulo Products Co.— St. Louis
Peters Heat Treating Inc.
Phoenix Heat Treating Inc.
Rochester Steel Treating
Rotation Products Corp.
Shore Metal Technology
Specialty Heat Treating Inc. —Athens
Specialty Heat Treating Inc. —Elkhart
Specialty Heat Treating Inc. —Grand Rapids
Specialty Heat Treating Inc. —Holland
Suncoast Heat Treating— Pompano Beach
Syracuse Heat Treating
Therm Tech of Waukesha
Thermal Treatment Center
Trutec Industries

NORMALIZING

Abbott Furnace
ABS Metallurgical Processors Inc.
Accurate Steel Treating
Advanced Heat Treating Inc.
Advanced Metallurgical Technology
Advanced Thermal Technologies
Albany Metal Treating
Alco Heat Treating Corp.
Alliance Metal Treating
Alpha Heat Treaters
American Brazing
American Heat Treating
Am. Met. Treating Inc.
Atmosphere Annealing Inc.
Beehive Heat Treating Inc.
Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Bodycote/Hinderliter
Bomak Corp.
The Bowdil Co.
Braddock Metallurgical
Braddock Metallurgical Alabama
Brazing & Metal Treating —Cleveland
Brazing & Metal Treating of KY
Brazing & Metal Treating of MN
Brite Brazing
Burbank Steel Treating Inc.
Cal-Doran Division
Carolina Commercial Heat Treating
Caterpillar Industrial Products
Century Sun Metal Treating
Certified Metal Craft Inc.
Certified Heat Treating Inc.
Cincinnati Flame Hardening
Cincinnati Gear Co.
Cincinnati Steel Treating
City Steel Treating Inc.
Coleman Commercial Heat Treating
Commercial Induction
Commercial Steel Treating
Custom Heat Treating Co.
Delavan Steel Treating
Delphi Engineering
Detroit Steel Treating Co.
Diamond Heat Treating Co.
Disston Precision Inc.
Dixie Heat Treating Co.
Dixie Machine & Heat Treating Inc.
Drever Heat Treating
East Carolina Metal Treating Inc.
East-Lind Heat Treat
Eckel Heat Treat
Edwards Heat Treating
Elmira Heat Treating
Engineered Heat Treat Inc.
Erie Steel Treating Inc.
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Feinblanking Ltd.
Fenton Heat Treating
Flame Metals Processing
Fox Steel Treating Co.
FPM Heat Treating— Elk Grove
FPM Ipsen Heat Treating
FPM Milwaukee
Franklin Steel Treating Co.
Gear Company of America
General Heat Treating Corp.
General Metal Heat Treating Inc.
Geo. H. Porter Steel Treating Co.
Gibson Heat Treat Inc.
Grand Rapids Heat Treating Co.
Hansen-Balk Steel Treating
Hauni Richmond Inc.
Heat Treat Corp. of America
Heat Treating Services
Heat-Treating Inc.
HI TecMetal Group— Cleveland
Hinderliter Heat Treating Inc.—Anaheim
Hinderliter Heat Treating Inc.—Dallas
Hinderliter Heat Treating Inc.—Tarzana
Hinderliter Heat Treating Inc.—Tulsa
Hi-Tech Steel Treating Inc.
Horizon Steel Treating Inc.
Horsburgh & Scott Co.
HTG-HiTech Aero
Hudapack — Elkhorn
Huron Metallurgical
Hydro-Vac
Hy-Vac Technologies Inc.

NORMALIZING (Cont.)

Illiana Heat Treating Inc.
Impact Strategies Inc.
Induction Metal Treating Co.
Industrial Metal Treating
Industrial Steel Treating Co.
Industrial Steel Treating Inc.
Ironbound Heat Treating
Irwin Automation Inc.
Jasco Heat Treating Inc.
John V. Potero Co.
Kowalski Heat Treating Co.
Lake County Steel Treating
Lawrence Industries Inc.
Lexington Heat Treat Inc.
Lindberg Heat Treating Co. —Berlin
Lindberg Heat Treating Co. —Houston
Lindberg Heat Treating Co. —Melrose Park
Lindberg Heat Treating Co. —Racine
Lindberg Heat Treating Co. —St. Louis
M & M Heat Treat
Magnum Metal Treating
Master Heat Treating Inc.
Merit Gear Corp.
Metal Improvement Co. —Columbus
Metal Improvement Co. —Lafayette
Metal Improvement Co.—McLean/Wichita
Metal Methods
Metal Treating & Research
Metal Treating Inc.
Metallurgical Inc.
Metallurgical Processing Inc.
Metals Engineering Inc.
Metals Technology
Metlab Co.
Metro Steel Treating
Met-Tek Inc.—Clackamas
Met-Tek Inc.—Racine
Midland Metal Treating Inc.
Modern Industries Inc.
Modern Metal Processing
Mountain Metallurgical
National Broach
National Metal Processing
Nettleson Steel Treating
Nitro-Vac Heat Treating
O & W Heat Treat Inc.
Oakland Metal Treating Co.
Ohio Metallurgical Service
P & L Heat Treating & Grinding
Partek Laboratories Inc.
Paulo Products Co.—Bessemer
Paulo Products Co.—Kansas City
Paulo Products Co.—Memphis
Paulo Products Co.—Nashville
Paulo Products Co.—St. Louis
Pennsylvania Metallurgical
Peters Heat Treating Inc.
Phoenix Heat Treating Inc.
Pitt-Tex Inc.
Precision Heat Treating
Progressive Steel Treating
Racine Heat Treating Co.
Rochester Steel Treating
Rotation Products Corp.
S.K.S. Heat Treating Inc.
Scot Forge
Shore Metal Technology
Solar Atmospheres Inc.
Sonee Heat Treating Corp.
Southeastern Heat Treating
Specialty Heat Treating Inc. —Athens
Specialty Heat Treating Inc. —Elkhart
Specialty Heat Treating Inc. —Grand Rapids
Specialty Heat Treating Inc. —Holland
Specialty Heat Treating Inc. —Farmington Hills
Specialty Steel Treating—Fraser
State Heat Treat Inc.
Steel Treaters, Inc.
Sun Steel Treating
Suncoast Heat Treating—Orlando
Suncoast Heat Treating—Pompano Beach
Suncoast Heat Treating—Tampa
Superior Metal Treating
Syracuse Heat Treating
T. N. Woodworth Inc.
Therm Tech of Waukesha
Thermal Metal Treating
Thermal Treatment Center
Thermo Electron Metal Treating Div.
Thermo Treaters Ltd.
TracTech
Treat All Metals Inc.
Trojan Heat Treat Inc.
Universal Heat Treating
Vacu Braze
Walker Heat Treating
Wall Colmonoy Corp.
Washington Metallurgical Services
Weiss Industries Inc.
Wohlert Corp.

PLASMA CARBURIZING

Cincinnati Gear Co.
HI TecMetal Group—Cleveland

PRESS QUENCHING

Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Caterpillar Industrial Products Inc.
Cincinnati Gear Co.
Cincinnati Steel Treating
Engineered Heat Treat Inc.
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Franklin Steel Treating Co.
Gibson Heat Treat Inc.
The Gleason Works
Heat Treat Corp. of America
Impact Strategies Inc.
Industrial Steel Treating Inc.
Jasco Heat Treating Inc.
Kowalski Heat Treating Co.
Lindberg Heat Treating Co. —Racine
Lindberg Heat Treating Co. —St. Louis
Metallurgical Inc.
Metals Technology
Metlab Co.
Mountain Metallurgical
Ohio Metallurgical Service
Phoenix Heat Treating Inc.
Roboduction Thermal Processing
Specialty Steel Treating—Farmington Hills
Specialty Steel Treating—Fraser
Treat All Metals Inc.
Washington Metallurgical Services

SALT BATH NITRIDING

Abbott Furnace
Bomak Corp.
Cal-Doran Division
Cincinnati Gear Co.
Commercial Steel Treating
East-Lind Heat Treat
Engineered Heat Treat Inc.
Flame Metals Processing
Fox Steel Treating Co.
H & M Metal Processing
HI TecMetal Group—Cleveland
Illiana Heat Treating Inc.
Induction Metal Treating Co.
Jasco Heat Treating Inc.
Lake County Steel Treating
Lexington Heat Treat Inc.
Lindberg Heat Treating Co. —New Berlin
Lindberg Heat Treating Co —Racine
Metal Treaters Inc.
Metals Technology
National Broach
Nitro-Vac Heat Treating
O & W Heat Treat Inc.
Superior Metal Treating
Trutec Industries
Walker Heat Treating
Wear-Ever Surface Treating
Weiss Industries Inc.

SHOT PEENING

Metal Improvement Co.
Paulo Products Co. — Memphis

SINTERING

Abbott Furnace
Allread Products
American Brazing
Bennett Heat Treating & Brazing Co.
Certified Metal Craft
Cincinnati Gear Co.
Fluxtrol Manufacturing Inc.
Hinderliter Heat Treating Inc.—Tarzana
Hitech Metallurgical Co.
HTG Aerobraze
HTG-HiTech Aero
Hydro-Vac
Hy-Vac Technologies Inc.
Illiana Heat Treating Inc.
Induction Metal Treating Co.
Metal Improvement Co.—McLean/Wichita
Metals Technology
Modern Metal Processing
Pennsylvania Metallurgical
Progressive Steel Treating
Solar Atmospheres Inc.
Specialty Heat Treating Inc. —Athens
Specialty Heat Treating Inc. —Elkhart
Specialty Heat Treating Inc. —Grand Rapids
Specialty Heat Treating Inc. —Holland
Suncoast Heat Treating—Orlando
Suncoast Heat Treating—Pompano Beach
Syracuse Heat Treating
Walker Heat Treating

STEAM TREATING

Abbott Furnace
Advanced Heat Treating
Allread Products
Hi-Tech Steel Treating
Industrial Metal Treating
Solar Atmospheres Inc.
Sun Steel Treating
Syracuse Heat Treating

STRAIGHTENING

Century Sun Metal Treating
Cincinnati Steel Treating
Engineered Heat Treat
Midwest Flame Hardening
Treat All Metals
Westside Flame Hardening

STRESS RELIEVING

Abbott Furnace
ABS Metallurgical Processors Inc.
Accurate Steel Treating
Advanced Heat Treat Corp. —Monroe
Advanced Heat Treat Corp. —Waterloo
Advanced Metallurgical
Advanced Thermal Technologies, Inc.
Albany Metal Treating
Alco Heat Treating Corp.
Alliance Metal Treating
Alpha Heat Treaters
American Heat Treating
Am. Met. Treating Inc.
AMT Monroe Inc.
Atmosphere Annealing Inc.
Beehive Heat Treating Inc.
Benedict-Miller Inc.
Bennett Heat Treating & Brazing Co.
Bodycote/Hinderliter
Bomak Corp.
Bonal Technologies Inc.
The Bowdil Co.
Braddock Metallurgical
Braddock Metallurgical Alabama
Brazing & Metal Treating—Cleveland
Brazing & Metal Treating of KY
Brazing & Metal Treating of MN
Brite Brazing
Brite Metal Treating Inc.
Bucyrus International Inc.
Burbank Steel Treating Inc.
Cal-Doran Division
Carolina Commercial Heat Treating
Century Sun Metal Treating
Certified Heat Treating Inc.
Certified Metal Craft
Chicago Flame Hardening
Cincinnati Flame Hardening Co.
Cincinnati Gear Co.
Cincinnati Steel Treating
City Steel Treating Inc.
Cleveland Flame Hardening Co.
Coleman Commercial Heat Treating
Commercial Induction
Commercial Steel Treating
Cooperheat Inc.
Custom Heat Treating Co.
Delavan Steel Treating
Delphi Engineering
Detroit Flame Hardening
Detroit Steel Treating Co.
Diamond Heat Treating Co.
Disston Precision Inc.
Dixie Heat Treating Co., Inc.
Dixie Machine & Heat Treating Inc.
Drever Heat Treating
East Carolina Metal Treating Inc.
East-Lind Heat Treat
Eckel Heat Treat
Edwards Heat Treating
Elmira Heat Treating
Engineered Heat Treat Inc.
Erie Steel Treating Inc.
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Feinblanking Ltd.
Fenton Heat Treating
Flame Metals Processing
Fluxtrol Manufacturing Inc.
Fox Steel Treating Co.
FPM Heat Treating—Elk Grove
FPM Ipsen Heat Treating
FPM Milwaukee
Franklin Steel Treating Co.
General Heat Treating Corp.
General Metal Heat Treating Inc.
Geo. H. Porter Steel Treating Co.
Gibson Heat Treat Inc
Global Heat Inc.
Grand Rapids Heat Treating Co.
H & M Metal Processing
Hansen-Balk Steel Treating
Hauni Richmond Inc.
Heat Treat Corp. of America
Heat-Treating Inc.
Heat Treating Services
HI TecMetal Group—Cleveland
Hinderliter Heat Treating Inc.—Anaheim
Hinderliter Heat Treating Inc.—Dallas
Hinderliter Heat Treating Inc.—Tarzana
Hinderliter Heat Treating Inc.—Tulsa
Hitech Metallurgical Co.
Hi-Tech Steel Treating Inc.
Horizon Steel Treating Inc.
Horsburgh & Scott Co.
Houston Flame Hardening
HTG Aerobraze
HTG-HiTech Aero
Hudapack — Elkhorn
Huron Metallurgical Inc.
Hydro-Vac
Hy-Vac Technologies Inc.
Illiana Heat Treating Inc.
Induction Metal Treating Co.
Induction Services Inc.
Inductoheat Inc.
Industrial Metal Treating
Industrial Steel Treating Co.
Industrial Steel Treating Inc.
Ironbound Heat Treating
Irwin Automation Inc.
Jasco Heat Treating Inc.
JCS Engineering & Development
John V. Potero Co.
Kowalski Heat Treating Co.
Lake County Steel Treating
Lawrence Industries Inc.
Lexington Heat Treat Inc.
Lindberg Heat Treating Co. —Berlin
Lindberg Heat Treating Co. —Houston
Lindberg Heat Treating Co. —Melrose Park
Lindberg Heat Treating Co. —Racine
Lindberg Heat Treating Co. —Rochester
Lindberg Heat Treating Co. —St. Louis
M & M Heat Treat
Magnum Metal Treating Inc.
Mannings U.S.A.
Master Heat Treating Inc.
Merit Gear Corp.
Metal Improvement Co.—Columbus
Metal Improvement Co.—Lafayette
Metal Improvement Co.—McLean/Wichita
Metal Methods
Metal Treating & Research
Metallurgical Inc.
Metallurgical Processing Inc.
Metals Engineering Inc.
Metals Technology
Metlab Co.
Metro Steel Treating
Met-Tek Inc.—Clackamas
Met-Tek Inc.—Racine
Michigan Flame Hardening
Michigan Induction Inc.
Midland Metal Treating
Midwest Flame Hardening
Midwestern Machinery Co.
Modern Industries Inc.
Modern Metal Processing
Mountain Metallurgical
National Broach
National Induction Heating
National Metal Processing
Nettleson Steel Treating
Nitro-Vac Heat Treating
Oakland Metal Treating Co.
Ohio Metallurgical Service
Partek Laboratories Inc.
Paulo Products Co.—Bessemer
Paulo Products Co.—Kansas City
Paulo Products Co.—Memphis
Paulo Products Co.—Nashville
Paulo Products Co.—St. Louis
Penna Flame Industries
Pennsylvania Metallurgical
Peters Heat Treating Inc.
Pfauter-Maag Cutting Tools
Phoenix Heat Treating Inc.
Pitt-Tex Inc.
Precision Heat Treating
Progressive Steel Treating
Racine Heat Treating Co.
Roboduction Thermal Processing
Rochester Steel Treating
Rotation Products Corp.
S.K.S. Heat Treating Inc.
Scot Forge
Shanafelt Mfg. Co.
Shore Metal Technology
Solar Atmospheres Inc.
Sonee Heat Treating Corp.
Southeastern Heat Treating
Specialty Heat Treating Inc.—Athens
Specialty Heat Treating Inc.—Elkhart
Specialty Heat Treating Inc.—Grand Rapids
Specialty Heat Treating Inc. —Holland
Specialty Steel Treating—Farmington Hills
Specialty Steel Treating—Fraser
State Heat Treat Inc.
Steel Treaters, Inc.
Steel Treating
Sun Steel Treating
Suncoast Heat Treating—Orlando
Suncoast Heat Treating—Pompano Beach
Suncoast Heat Treating—Tampa
Superior Metal Treating
Syracuse Heat Treating
T. N. Woodworth Inc.
Therm Tech of Waukesha
Thermal Treatment Center
Thermet Inc.
Thermo Electron Metal Treating Div.
Thermo Treaters Ltd.
Tocco, Inc.
TracTech
Treat All Metals Inc.
Trojan Heat Treat Inc.

Trutec Industries
Universal Heat Treating
Vacu Braze
Walker Heat Treating
Wall Colmonoy Corp.
Washington Metallurgical Services
Weiss Industries Inc.
Western Stress Inc.
Westside Flame Hardening

TEMPERING

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Advanced Heat Treat Corp. —Monroe
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Cal-Doran Division
Calumet Surface Hardening
Carolina Commercial Heat Treating
Caterpillar Industrial Products Inc.
Century Sun Metal Treating
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Certified Metal Craft
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Chicago Induction
Cincinnati Flame Hardening
Cincinnati Gear
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National Broach
National Induction Heating
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Ohio Metallurgical Service
P & L Heat Treating & Grinding
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T. N. Woodworth Inc.
Therm Tech of Waukesha
Thermal Metal Treating
Thermal Treatment Center
Thermet Inc.
Thermo Electron Metal Treating Div.
Thermo Treaters Ltd.
Tocco, Inc.
TracTech
Treat All Metals Inc.
Trutec Industries
Universal Heat Treating
Vacu Braze
Walker Heat Treating
Washington Metallurgical Services
Weiss Industries Inc.
Westside Flame Hardening
Wohlert Corp.

VACUUM TREATING

Accurate Steel Treating
Advanced Metallurgical
Alliance Metal Treating
Allread Products
American Heat Treating
Am. Met. Treating Inc.
Beehive Heat Treating
Benedict-Miller
Bodycote-Hinderliter
Braddock Metallurgical Alabama
Burbank Steel Treating
Century Sun Metal Treating
Certified Metal Craft
Certified Heat Treating
Delavan Steel Treating
Drever Heat Treating
Dynamic Metal Treating
East-Lind Heat Treat
Elmira Heat Treating
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Erie Steel Treating Inc.
Euclid Heat Treating
Fenton Heat Treating
Flame Metals Processing
General Heat Treating
Hanson-Balk Steel Treating
Hauni Richmond Inc.
Hinderliter — Dallas
Hitech Metallurgical Co.
Hi-Tech Steel Treating
Horizon Steel Treating
HTG-HiTech Aero
Hudapack — Elkhorn
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Kowalski Heat Treating
Metal Treaters Inc.
Metal Treating & Research
Metallurgical Inc.
Metals Technology Corp.
Modern Metal Processing
National Metal Processing
Nitro-Vac Heat Treating
O & W Heat Treat Inc.
Paulo Products Co. — Bessemer
Paolo Products Co. — Kansas City
Paulo Products Co. — Memphis
Paulo Products Co. — Nashville
Phoenix Heat Treating
Precision Heat Treating
Progressive Steel Treating
Racine Heat Treating Co.
Richter Precision Inc.
Solar Atmospheres Inc.
Speciality Heat Treating –Grand Rapids
Specialty Steel Treating — Farmington Hills
Superior Metal Treating
Syracuse Heat Treating
Thermal Braze Inc.
Universal Heat Treating

OTHER

Beehive Heat Treating — *Neutral Salt Hardening*
Benedict-Miller — *Nitemper*
Cincinnati Gear Co. — *Electron Beam Hardening*
Cincinnati Steel Treating — *Sub-Zero*
Contour Hardening — *Metallurgical Services*
Delphi Engineering — *Portable h.t. on site*
East-Lind Heat Treat — *Air, Oil, Water Hardening*
Engineered Heat Treat — *Neutral Salt Hardening*
Erie Steel Treating Inc. — *Plug Quenching*
Flame Hardening of California — *On-Site Work*
Fox Steel Treating — *Select Hole Quenching*
Heat Treating Network — *Heat Treating Training*
Hinderliter-Anaheim — *Kool Kase "FNC"*
Hitech Metallurgical Co. — *Welding*
IHS — *Induction Heating*
Impact Strategies Inc. — *Consulting & Lab Work*
Induction Services — *Bonding Heat*
Inductoheat Inc. — *Induction Heating Equipment*
Industrial Steel Treating Inc. — *Magnetic Particle Inspection; Tensile Testing*
Ironbound Heat Treating — *Lab Work*
Irwin Automation Inc. — *Salt Quenching*
Kowalski Heat Treating — *High Pressure Vacuum, 20 Bar*
Metals Technology Corp. — *Hyperannealing, Bright Hardening*
Michigan Induction Inc. — *Consulting on Induction*
Paulo Products—Kansas City — *Inspection*
Progressive Steel Treating — *Water Quench/Polymer*
Rebco/Rolock/MTech— *Sales Engineer*
Sun Steel Treating — *Salt Bath Hardening*
Syracuse Heat Treating — *Ultrasonic Cleaning*
Thermal Braze Inc. — *Induction Brazing*
Westside Flame Hardening — *Vibra Hardening*

Programmable Separation of Runout From Profile and Lead Inspection Data for Gear Teeth With Arbitrary Modifications

Xiaogen Su & Donald R. Houser

Abstract

A programmable algorithm is developed to separate out the effect of eccentricity (radial runout) from elemental gear inspection data, namely, profile and lead data. This algorithm can be coded in gear inspection software to detect the existence, the magnitude and the orientation of the eccentricity without making a separate runout check. A real example shows this algorithm produces good results.

Introduction

The effect of radial runout (or eccentricity) on the profile and lead deviations has been noticed for a long time. Gear engineers know that radial runout changes the slopes of the traces of profiles and leads. A normal gear inspection usually measures profiles and leads from three or more teeth, and the average is often taken to compensate for this effect. In 1993, Laskin *et al.* (Ref. 1) found the analytical equations which describe the interaction between these element measurements and the radial runout. The equations show the profile and lead traces of all teeth are segments of a sine curve if no profile and lead modifications are introduced. More recently, Laskin and Lawson (Ref. 2) developed the method to separate out the effect of runout from these elemental inspection data. They used linear or cubic fitting to get the slope of every elemental inspection curve. From the information given by the slopes, a sine curve is fit, and the effect of the runout represented by the sine curve is removed. The method does not apply to the case where arbitrary modifications exist, either on the profile or on the lead. However, the method works for partly modified profiles and leads, but the validity of the results is compromised because the fitting processes use only that portion of the profile (or the lead) that is free of modifications. If considerable roughness exists on the tooth surfaces, the curve fitting of these short trace segments is not very reliable.

This article presents a method that applies to any kind of modification of either profiles or leads. More importantly, only one fitting process that takes into consideration all the inspection data is used. The process is non-iterative, and a good result can be expected. This method only applies to gears with eccentricity (radial runout). It does not apply to egg-shaped gears or gears with considerable wobble (axial runout).

Extraction of Profile Modification from the Inspection Data

We start our discussion with profile inspection data. The same procedure applies to the lead inspection data. Referring to Fig. 1, the teeth and the base circles are plotted. Eq. 1 in Laskin *et al.* is cited here, and their symbols are used as well. The equation says:

$$M_{\phi L} = M_t M = e\sin(\angle EO_m N) = e\sin[(\theta_{e1M} - \alpha_{pBt}) + (k-1)\tau + \varepsilon_M] \quad (1)$$

where $\theta_{e1M}(\angle EO_m H)$ is the angle from the eccentricity direction to the center of Tooth 1. $\alpha_{pBt}(\angle B_o O_m H)$ is the angle extended by the half base tooth thickness. $\tau(2\pi/\text{teeth number})$ is the tooth pitch angle. $\varepsilon_M(\angle BO_m N)$ is the roll angle at the measurement point. e is the eccentricity.

If no profile modification exists, using Eq. 1 and Fig. 2, the profile trace f_p on each tooth is a segment of a sine curve having amplitude e. If an arbitrary profile modification $m_p(\varepsilon_M)$ is applied, the measured profile trace $(f_p + m_p)$ is the sinusoidal segment superimposed by the profile modification.

In real measurements, the inspection data may be presented separately or may be overlaid together and supplemented with a K chart. The final inspection data v_{pi} is $(f_p + m_p)$ shifted by D (referring to Fig. 2b, c).

$$v_{pi} = f_{pi} + m_p(\varepsilon_M) - D_i \quad i = 1, 2, \ldots, n. \quad (2)$$

n is the total number of measured teeth. $D_i(1,2, \ldots,n)$ are constants representing the shifts of profile traces, and they are unknown. Usually, three or four teeth are inspected, and n is either 3 or 4. From Eq. 1, the sinusoidal segment for the i^{th} measured profile trace is:

$$f_{pi} = e\sin[(\theta_{e1M} - \alpha_{pBt}) + (k_i - 1)\tau + \varepsilon_M] \quad i = 1,2,\ldots,n. \quad (3)$$

$k_i(i = 1,2,\ldots,n)$ are the tooth numbers. If we set:

$$\phi_i = (k_i - 1)\tau \quad i = 1,2,\ldots,n. \quad (4)$$

$$\varepsilon = (\theta_{e1M} - \alpha_{pBt}) + \varepsilon_M \quad (5)$$

These substitutions simplify Eq. 3 to:

$$f_{pi} = e \sin(\varepsilon + \phi_i) \quad i = 1,2,\ldots,n. \tag{6}$$

Substituting Eq. 6 into Eq. 2 gives a new equation for the shifted profile traces.

$$v_{pi} = e \sin(\varepsilon + \phi_i) + m_p(\varepsilon_M) - D_i \quad i = 1,2,\ldots,n. \tag{7}$$

Expanding and rewriting Eq. 7, we get:

$$e \sin(\varepsilon)\cos(\phi_i) + e \cos(\varepsilon)\sin(\phi_i) + m_p(\varepsilon_M) = v_{pi} + D_i \quad i = 1,2,\ldots,n. \tag{8}$$

The profile modification m_p can be solved through any combination of three out of these n equations. If i_1^{th}, i_2^{th}, i_3^{th} equations are used, we have:

$$\left.\begin{array}{l} e \sin(\varepsilon)\cos(\phi_{i1}) + e \cos(\varepsilon)\sin(\phi_{i1}) + m_p(\varepsilon_M) = v_{pi1} + D_{i1} \\ e \sin(\varepsilon)\cos(\phi_{i2}) + e \cos(\varepsilon)\sin(\phi_{i2}) + m_p(\varepsilon_M) = v_{pi2} + D_{i2} \\ e \sin(\varepsilon)\cos(\phi_{i3}) + e \cos(\varepsilon)\sin(\phi_{i3}) + m_p(\varepsilon_M) = v_{pi3} + D_{i3} \end{array}\right\} \tag{9}$$

Taking $e \sin(\varepsilon)$, $e \cos(\varepsilon)$ and $m_p(\varepsilon_M)$ as three unknowns, the mean profile modification, $m_p(\varepsilon_M)$, can be solved.

$$m_p = \frac{\begin{vmatrix} \cos(\phi_{i1}) & \sin(\phi_{i1}) & v_{pi1} \\ \cos(\phi_{i2}) & \sin(\phi_{i2}) & v_{pi2} \\ \cos(\phi_{i3}) & \sin(\phi_{i3}) & v_{pi3} \end{vmatrix} + \begin{vmatrix} \cos(\phi_{i1}) & \sin(\phi_{i1}) & D_{i1} \\ \cos(\phi_{i2}) & \sin(\phi_{i2}) & D_{i2} \\ \cos(\phi_{i3}) & \sin(\phi_{i3}) & D_{i3} \end{vmatrix}}{\begin{vmatrix} \cos(\phi_{i1}) & \sin(\phi_{i1}) & 1 \\ \cos(\phi_{i2}) & \sin(\phi_{i2}) & 1 \\ \cos(\phi_{i3}) & \sin(\phi_{i3}) & 1 \end{vmatrix}} \tag{10}$$

This solution depends on the reference of each profile which dictates the applied shifts, $D_i(i = 1,2,\ldots,n)$. These shifts are unknown at this stage. But Eq. 10 reveals that the D_is only shift m_p upwards or downwards and do not change m_p's shape. Setting D_i to zero gives rise to:

$$m_p = \frac{\begin{vmatrix} \cos(\phi_{i1}) & \sin(\phi_{i1}) & v_{pi1} \\ \cos(\phi_{i2}) & \sin(\phi_{i2}) & v_{pi2} \\ \cos(\phi_{i3}) & \sin(\phi_{i3}) & v_{pi3} \end{vmatrix}}{\begin{vmatrix} \cos(\phi_{i1}) & \sin(\phi_{i1}) & 1 \\ \cos(\phi_{i2}) & \sin(\phi_{i2}) & 1 \\ \cos(\phi_{i3}) & \sin(\phi_{i3}) & 1 \end{vmatrix}} \tag{11}$$

Normalize m_p by making its maximum zero if necessary:

$$m_p - max(m_p) \Rightarrow m_p$$

If we want to make use of all of the inspection data to get a better result, all different combinations (i_1, i_2, i_3) out of (i_1, i_2,...,i_n) can be used separately and the m_ps found can be averaged. In other words, if four profile traces are available, there are four combinations of these traces that could be used to get four mean profile traces that can be further averaged to give a global average.

The extracted profile modification m_p not only includes intended profile modifications, such as tip and root relief, but also includes some systematic profile error which shows the same tendency on each gear tooth. An example of a systematic profile error could be a pressure angle error (Ref. 4).

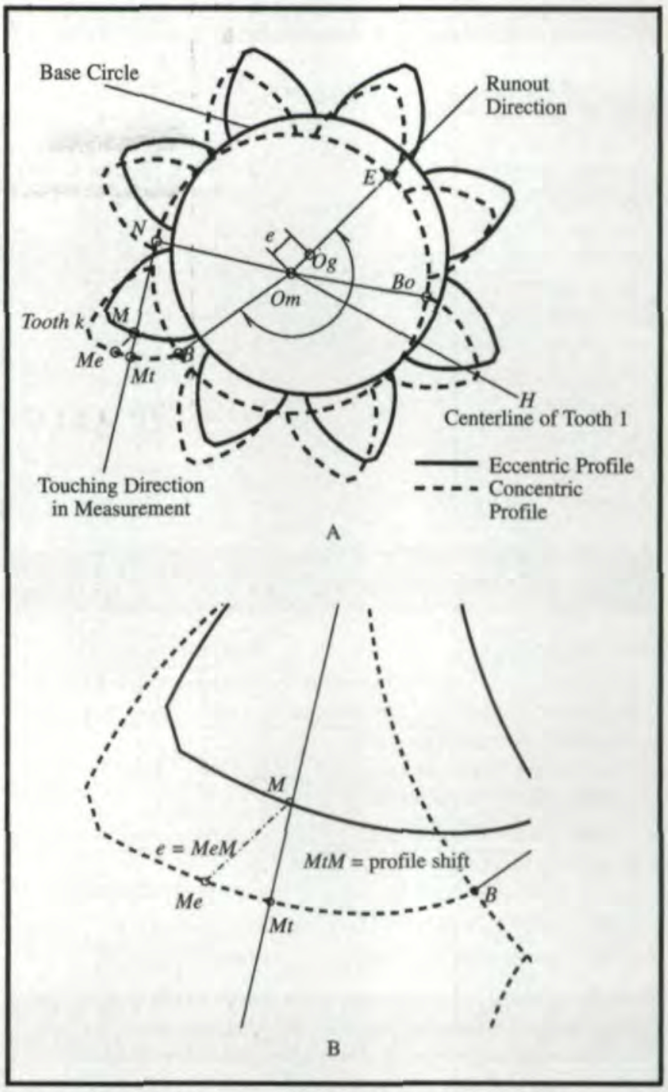

Fig. 1 – Profile Measurement on Eccentric Gear (left flank).

If the inspected teeth are exactly (in most cases, approximately) evenly spaced around the gear, the profile modification can be calculated simply by averaging the profile deviations measured on all inspected teeth. This practice is well known, and the proof is given here. Summarize Eq. 7 over $i = 1,2,\ldots,n$.

$$\sum_{i=1}^{n} v_{pi} = e \sum_{i=1}^{n} \sin(\varepsilon + \phi_i) + n\, m_p(\varepsilon_M) - \sum_{i=1}^{n} Di$$

When the measured teeth are evenly distributed, $\Sigma_{i=1}^{n} \sin(\varepsilon + \phi_i)$ tends to disappear. Setting D_i to be zero shows that the average profile trace $m_p(\varepsilon_M)$ is a simple average of the individual profile traces.

$$m_p(\varepsilon_M) = \frac{\Sigma_{i=1}^{n} v_{pi}}{n} \tag{12}$$

Separation of Runout from Profile Inspection Data

After the modification is found, it can be removed from the individual profile traces, $v_{pi}(i = 1,2,\ldots,n)$. The residuals, $v_{pi} - m_p(i = 1,2,\ldots,n)$, caused by a pure eccentricity are the segments of a sine curve. A best fit is made to find the sine curve (both amplitude and phase) as shown in Eqs. 13–24.

Introducing new variable ε_1:

$$\varepsilon_1 = (\theta_{e1M} - \alpha_{pBt}) \tag{13}$$

TABLE 1 — GEAR GEOMETRY

Parameter	Value	Unit
No. of Teeth	25	
Face Width	31.75	mm
Normal Pressure Angle	23.4541	degree
Helix Angle	21.5	degree
Normal Module	2.9541	mm
Normal Tooth Thickness	4.53	mm
Pitch Diameter	79.37	mm
Base Diameter	71.94	mm
Transverse Pressure Angle ϕ_{Mt}	25	degree
Transverse Tooth Thickness	4.87	mm
Helix Lead	633.05	mm
Helix Angle at Base Dia.	19.65	degree
Angle α_{pBt} in Eq. 1	5.23	degree
Angle α_{pMt} in Eq. 27	3.52	degree

TABLE 2 — BEST FIT RESULTS FROM PROFILE TRACES WITH ARTIFICIAL ECCENTRICITY

Parameter	Value	Unit
Introduced Eccentricity Magnitude	0.0718	mm
Introduced Eccentricity Orientation	–118.77	degree
Magnitude e Found Out From Traces of Left Flanks	0.0693	mm
Orientation θ_{e1M} Found Out From Traces of Left Flanks	–120.31	degree
Magnitude e Found Out From Traces of Right Flanks	0.0746	mm
Orientation θ_{e1M} Found Out From Traces of Right Flanks	–122.48	degree

TABLE 3 – BEST FIT RESULTS FROM LEAD TRACES WITH ARTIFICIAL ECCENTRICITY

Parameter	Value	Unit
Introduced Eccentricity Magnitude	0.0718	mm
Introduced Eccentricity Orientation	–127.8	degree
Magnitude e Found Out From Traces of Left Flanks	0.0588	mm
Orientation θ_{e1} Found Out From Traces of Left Flanks	128.66	degree
Magnitude e Found Out From Traces of Right Flanks	0.0462	mm
Orientation θ_{e1} Found Out From Traces of Right Flanks	128.24	degree

TABLE 4 – BEST FIT RESULTS FROM PROFILE TRACES WITHOUT ARTIFICIAL ECCENTRICITY

Parameter	Value	Unit
Eccentricity Magnitude Detected by Runout Check	0.0105	mm
Eccentricity Orientation Detected by Runout Check	–164.2	degree
Magnitude e Found Out From Traces of Left Flanks	0.0101	mm
Orientation θ_{e1M} Found Out From Traces of Left Flanks	–174.34	degree
Magnitude e Found Out From Traces of Right Flanks	0.01014	mm
Orientation θ_{e1M} Found Out From Traces of Right Flanks	–146.5	degree

$$\varepsilon = \varepsilon_1 + \varepsilon_M \tag{14}$$

Eq. 7 becomes:

$$v_{pi} = e\sin(\varepsilon_1 + \varepsilon_M + \phi_i) + m_p(\varepsilon_M) - D_i \quad i = 1,2,\dots,n. \tag{15}$$

We have $(n + 2)$ unknowns, $D_i(i = 1,2,\dots,n)$, e and ε_1. Eqs. 15 are linearized by introducing:

$$D_{n+1} = e\sin(\varepsilon_1) \tag{16}$$

$$D_{n+2} = e\cos(\varepsilon_1) \tag{17}$$

Then,

$$f_i(\varepsilon_M) = -D_i + D_{n+1}\cos(\varepsilon_M + \phi_i) + D_{n+2}\sin(\varepsilon_M + \phi_i) + m_p(\varepsilon_M) - v_{pi} = 0 \quad i = 1,2,\dots,n. \tag{18}$$

If p points are measured on each flank, then totally p x n equations exist. We will solve all p x n equations by minimizing F, where

$$F = \sum_{j=1}^{p}\left(\sum_{i=1}^{n} f_i^2(\varepsilon_{Mj})\right) \tag{19}$$

$\varepsilon_{Mj}(j = 1,2,\dots,p)$ are the roll angles corresponding to the measured points. Setting $\frac{\partial F}{\partial D_k}$ $(k = 1,\dots,n + 2)$ to zero gives $(n + 2)$ linear equations:

$$[A]_{(n+2)x(n+2)}[D]_{(n+2)x1} = [B]_{(n+2)x1} \tag{20}$$

where,

$$a_{ij} = \begin{cases} p & i = j \\ 0 & i \neq j \end{cases} \qquad i, j = 1,2,\dots,n.$$

$$a_{n+1,i} = a_{i,n+1} = -\sum_{j=1}^{p}\cos(\varepsilon_{Mj} + \phi_i) \quad i = 1,2,\dots,n$$

$$a_{n+2,i} = a_{i,n+2} = -\sum_{j=1}^{p}\sin(\varepsilon_{Mj} + \phi_i) \quad i = 1,2,\dots,n$$

$$a_{n+1,n+1} = \sum_{j=1}^{p}\sum_{i=1}^{n}\cos^2(\varepsilon_{Mj} + \phi_i)$$

$$a_{n+1,n+2} = a_{n+2,n+1} = \sum_{j=1}^{p}\sum_{i=1}^{n}\sin(\varepsilon_{Mj} + \phi_i)\cos(\varepsilon_{Mj} + \phi_i)$$

$$a_{n+2,n+2} = \sum_{j=1}^{p}\sum_{i=1}^{n}\sin^2(\varepsilon_{Mj} + \phi_i)$$

$$b_i = -\sum_{j=1}^{p}[v_{pi}(j) - m(\varepsilon_{Mj})] \quad i = 1,2,\dots,n$$

$$b_{n+1} = \sum_{j=1}^{p}\sum_{i=1}^{n}[v_{pi}(j) - m(\varepsilon_{Mj})]\cos(\varepsilon_{Mj} + \phi_i)$$

$$b_{n+2} = \sum_{j=1}^{p}\sum_{i=1}^{n}[v_{pi}(j) - m(\varepsilon_{Mj})]\sin(\varepsilon_{Mj} + \phi_i)$$

The solution is:

$$[D] = [A]^{-1}[B] \tag{21}$$

$$\text{eccentricity magnitude } e = \sqrt{D_{n+1}^2 + D_{n+2}^2} \tag{22}$$

$$\varepsilon_1 = \arctan\left(\frac{D_{n+1}}{D_{n+2}}\right) \tag{23}$$

$$\text{eccentricity location} \quad \theta_{e1M} = \varepsilon_1 + \alpha_{pBt} \tag{24}$$

The system of Eq. 20 can be very efficiently solved using the Gaussian Elimination Method (Ref. 3). It is not necessary to invert the coefficient matrix A. The profile deviations after the removal of the effect of runout are:

$$\overline{v_{pi}} = v_{pi} + D_i - e\sin(\varepsilon_1 + \varepsilon_M + \phi_i) \quad i = 1,2,...,n. \tag{25}$$

For the right flank, Eq. 4 in Laskin *et al.* (Ref.1) says:

$$M_{\phi R} = e\sin[-(\theta_{e1M} + \alpha_{pBt}) - (k-1)\tau + \varepsilon_M] \tag{26}$$

Similar steps can be followed to obtain the magnitude and orientation of the eccentricity from the profile traces of the right flanks.

Separation of Runout from Lead Inspection Data

For spur gears, runout does not affect the lead inspection data. The separation is applicable only for helical gears. Referring to Fig. 6 in Laskin *et al.* (Ref. 1), Eq. (13) of the sinusoidal curve of lead traces says:

$$M\psi_L = e\cos(\psi_b)\sin[\theta_{e1} + (\phi_{Mt} - \alpha_{pMt}) + (k-1)\tau + x_M \frac{2\pi}{L}] \tag{27}$$

where ψ_b is the base helix angle. θ_{e1} is the angle from the eccentricity direction to the center of tooth 1 at the top face. ϕ_{Mt} is the transverse pressure angle at the measurement diameter. α_{pMt} is the angle extended by the half tooth thickness at the measurement diameter. L is the helix lead (negative for left handed gears). x_M is the axial distance from the top face to the measurement point.

Eq. 27 has the same format as Eq. 1. We first define:

$$e_l = e\cos(\psi_b) \tag{28}$$

$$\varepsilon_1 = \theta_{e1} + (\phi_{Mt} - \alpha_{pMt}) \tag{29}$$

$$\varepsilon_M = x_M \frac{2\pi}{L} \tag{30}$$

$$\varepsilon = \varepsilon_1 + \varepsilon_M \tag{31}$$

From Eqs. 27–31, the lead trace f_l due to the eccentricity can be expressed as:

$$f_{li} = e_l\sin(\varepsilon + \phi_i) \quad i = 1,2,...,n. \tag{32}$$

If an arbitrary lead modification m_l is applied, the measured lead deviations can be written as:

$$v_{li} = e_l\sin(\varepsilon + \phi_i) + m_l(\varepsilon_M) - D_i \quad i = 1,2,...,n. \tag{33}$$

The mean lead modification m_l can be expressed by the ratio of two determinants.

$$m_l = \frac{\begin{vmatrix} \cos(\phi_{i1}) & \sin(\phi_{i1}) & v_{li1} \\ \cos(\phi_{i2}) & \sin(\phi_{i2}) & v_{li2} \\ \cos(\phi_{i3}) & \sin(\phi_{i3}) & v_{li3} \end{vmatrix}}{\begin{vmatrix} \cos(\phi_{i1}) & \sin(\phi_{i1}) & 1 \\ \cos(\phi_{i2}) & \sin(\phi_{i2}) & 1 \\ \cos(\phi_{i3}) & \sin(\phi_{i3}) & 1 \end{vmatrix}} \tag{34}$$

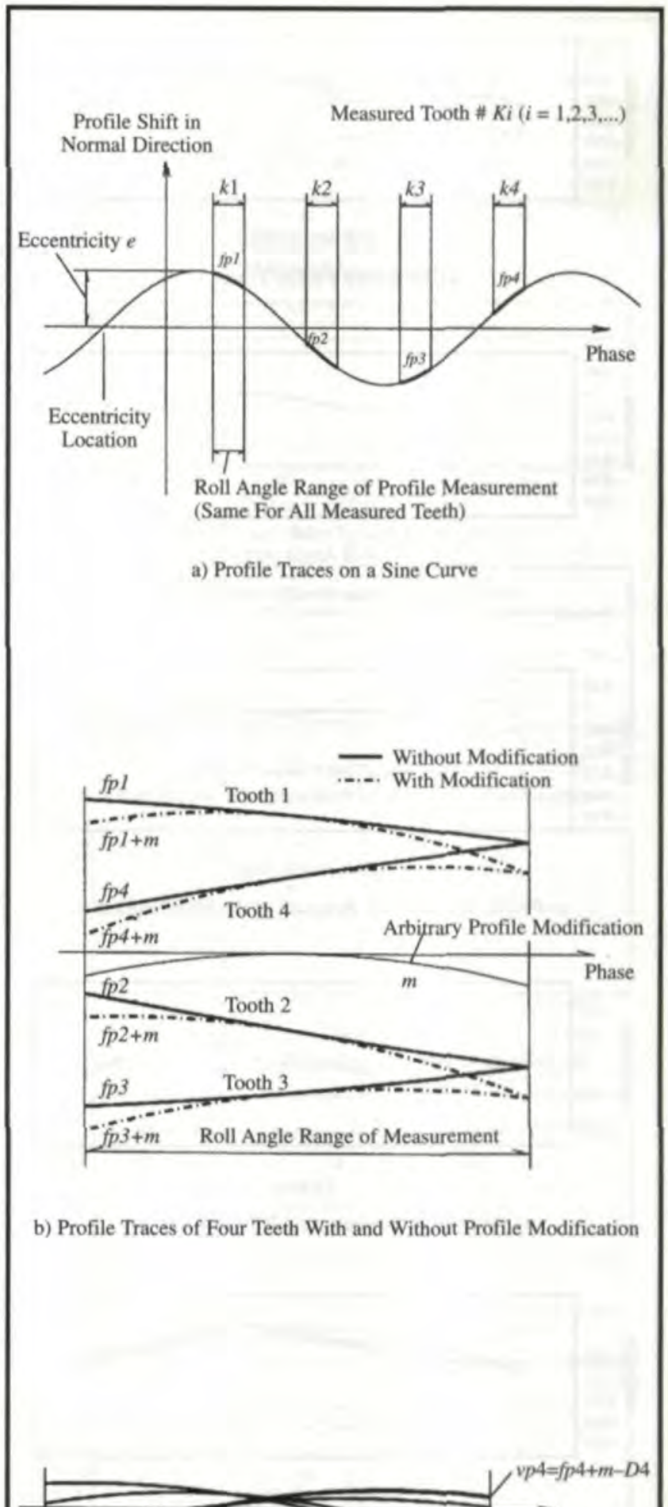

Fig. 2 – Profile Measurements with Arbitrary Modification.

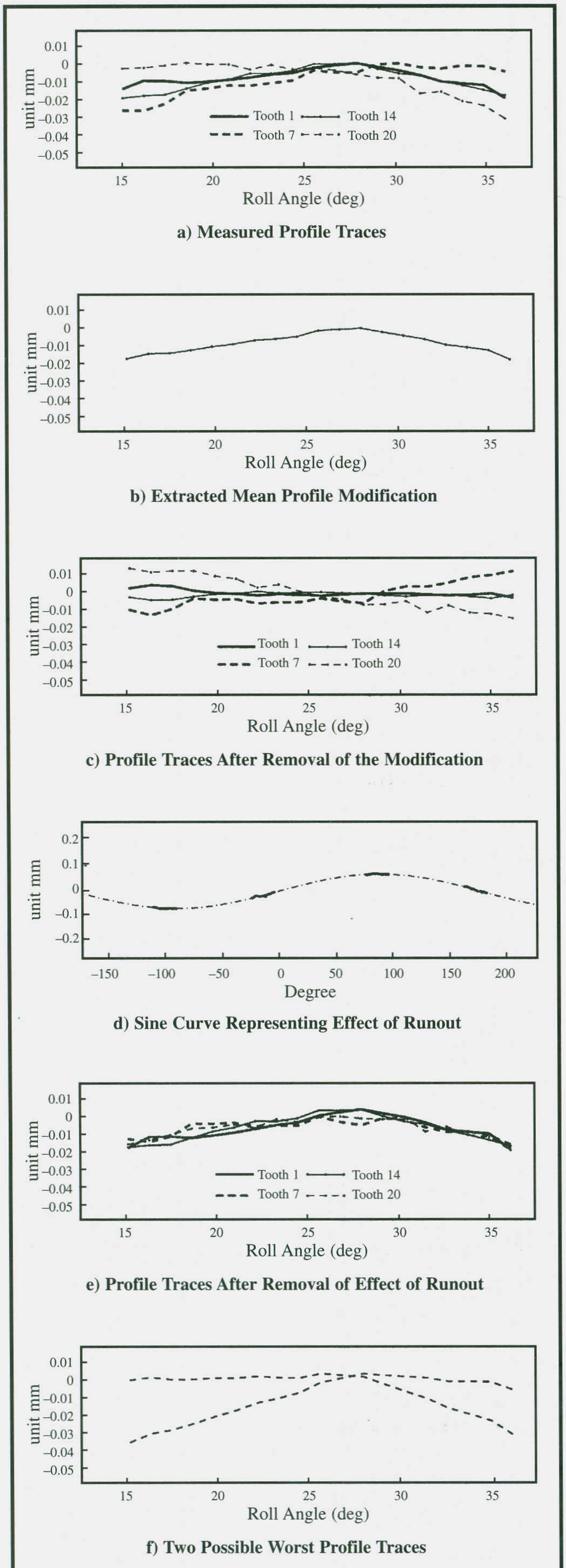

Fig. 3 – Example Gear Inspection: 4 teeth inspected; left flank; profile trace.

where ϕ_i, $D_i(i = 1,2,...,n)$ have the same meanings as in Eq. 10.

The extracted mean lead modification, m_l, not only includes the intended lead modification, such as crowning, but also includes the systematic lead error which shows the same tendency on each gear tooth. An example of such a systematic lead error could be the alignment error (Ref. 4).

Similarly, if the inspected teeth are exactly (in most cases, approximately) evenly spaced around the gear, the mean lead modification can be calculated simply by averaging the individual lead traces measured on all inspected teeth.

Using Eqs. 31 and 33:

$$v_{li} = e_l \sin(\varepsilon_l + \varepsilon_M + \phi_i) + m_l(\varepsilon_M) - D_i \quad i = 1,2,...n. \qquad (35)$$

Eq. 35 has the same format as Eq. 15. Solution of Eqs. 19–21 could be used, but $v_{li}(i = 1,2,...,n)$ should be used instead of $v_{pi}(i = 1,2,...,n)$, while $b_k(k = 1,2,...,n + 2)$ in Eq. 20 are calculated. e_l and ε_1 are obtained,

$$e_l = \sqrt{D_{n+1}^2 + D_{n+2}^2} \qquad (36)$$

$$\varepsilon_1 = \arctan(\frac{D_{n+1}}{D_{n+2}}) \qquad (37)$$

The amplitude and the phase of the sine curve from the eccentricity are:

eccentricity magnitude $e = e_l/\cos(\psi_b)$ (38)

eccentricity location $\theta_{e1} = \varepsilon_1 - (\phi_{Mt} - \alpha_{pMt})$ (39)

Example Inspection of A Real Helical Gear

A Boeing NASA helical gear was inspected to verify the developed algorithm. The geometry of the gear is listed in Table 1. Originally the gear had very little eccentricity, so an artificial eccentricity of 0.0718 mm was created on the CMM (Coordinate Measurement Machine). Four teeth were inspected by a universal CMM. The CMM has a resolution of one micron, and an accuracy of about three microns. According to the specification, a circular profile modification was applied from the form diameter to the outside diameter. No lead modification was required. The profile inspection was performed at the middle of the face width, and the lead inspection was performed at the pitch diameter.

Fig. 3 shows the profile inspection data. Only the traces of the left flanks are given here. The original deviation curves are drawn in Fig. 3a. The extracted mean profile modification is presented in Fig. 3b. The profile traces after the removal of the modification are shown in Fig. 3c. The fitted sine curve is shown in Fig. 3d. The profile traces after the removal of the effect of runout are shown in Fig. 3e. The maximum and minimum slopes of the fitted sine curve is its amplitude e and – e respectively. If these slopes are added to the mean profile trace m_p, we can get the two possible worst profile traces that could be obtained in profile inspection. These two possible worst profile traces are shown in Fig. 3f. The results of the best fit are listed in Table 2.

Fig. 4 shows the lead inspection data. No lead modification appears to exist on the gear. The results are presented in Fig. 4a–4f and Table 3 respectively. Note that the orientation angles of the introduced eccentricity are different in Table 2 and Table 3 because the first one is relative to the centerline of Tooth 1 at the middle of the face width where profile measurements were performed, and the second one is relative to the centerline of Tooth 1 at the top face as stated in Eq. 27.

Conclusions and Comments

A new programmable algorithm is developed to separate out the effect of runout from the profile and lead inspection data. The method presented here is more convenient, more reliable and easier to program than that proposed by Laskin and Lawson (Ref. 2). Because the pure radial runout does not contribute to the noise and vibration of transmissions as much as the real profile and lead deviations (Ref. 2), the separation of the effect of runout from profile and lead inspection data is significant.

In the Gear Dynamics and Gear Noise Research Laboratory at The Ohio State University, a CMM is often used to inspect gears. The effect of runout was removed using a two-step inspection, where runout inspection was performed, a new center was determined; profile and lead inspections were performed based on the new center. This approach takes more time. The approach presented in this paper gives us an alternative way to save inspection time.

In our example, the fitting process from the profile inspection data produces a better result than the fitting process from the lead inspection data. It is expected because a regular gear with non-negligible wobble (axial runout) is used instead of a test gear of very good accuracy as in Laskin and Lawson (Ref.2). In most cases, the profile traces are preferred in the separation of the effect of runout, particularly when the face width of a gear is relatively small compared with its helix lead. In this case, the lead traces are tiny segments (Fig. 4d) of the sine curve, and this makes the fitting process less reliable. Compared with Fig. 3d, the profile traces are longer than the lead traces for our test gear (1.5:1). The use of lead inspection data to separate out the effect of runout should be avoided unless the helix angle and/or the face width are really large.

The same gear was inspected once more. This time no artificial eccentricity was introduced. Its actual eccentricity was detected through a separate runout check. The eccentricity was also calculated from the profile traces. The results were listed in Table 4.

The separation of eccentricity based on the profile traces was very successful, but the separation of eccentricity based on the lead traces failed in this case. The reason is the gear has wobble (axial runout) comparable with the eccentricity (radial runout) that violates the wobble-free assumption from which Eq. 27 was derived.

A more ambitious approach would be to use all the inspection data from both flanks to make one sine curve fitting. Take the profile inspection data as example. The sine curves represented by Eq. 26 (for right flank) and Eq. 1 (for left flank) can be viewed as the same sine curve (the phase difference can be calculated). We could then fit the profile traces of both left and right flanks to one single sine curve. This approach has not been tried yet by the authors. ✪

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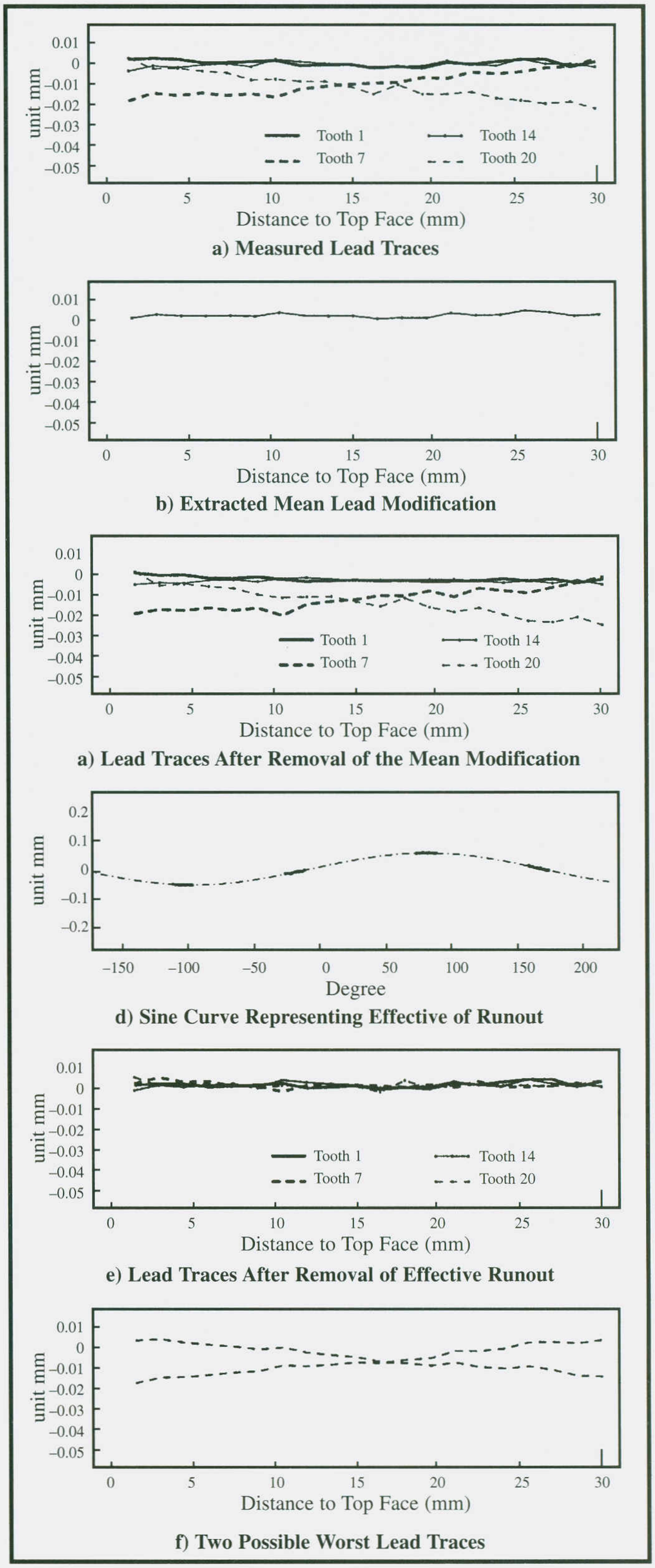

Fig. 4 – Example Gear Inspection: 4 teeth inspected; left flank; lead trace.

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Fahrenheit 451: Gear Up For Induction Hardening

Daniel J. Williams & Ellen F. Kominars

So, you've been assigned the task to buy an induction heating system for heat treating: It's an intimidating, but by no means impossible, assignment. With the help of the information in this article, you should be able to develop common ground with your supplier and have the tools to work with him or her to get the right machine for your jobs.

Begin your task by asking questions, lots of them. Your induction heating equipment manufacturer possesses a wealth of information and experience that he or she is only too willing to share.

What Is Induction Heating?

Induction is a noncontact electromagnetic process where metal pieces to be heat treated are passed through a magnetic field that emanates about a copper induction coil. The coil is fed current at a specified frequency and power level to cause the heating. Most of the heating is due to currents induced into the part. Some heating is due to hysteresis. The induction method requires no warm-up, is fast, predictable, clean and like resistance heating, is an in-line process, eliminating the need to store inventory between operations. Likewise, the induction method is a noncontact process and can be readily used with atmospheres to eliminate or reduce scale.

When Should a Gear Manufacturer Consider Induction?

Most gears must be heat treated to maximize strength and minimize wear. Inexpensive, medium carbon steels are easily machined and hardened and are compatible with induction heat treat processes.

Warning: all cutting, forming and hobbing should be done prior to induction hardening. Whenever possible, heat treating should be the final step.

The two methods used to heat treat gears are in furnaces or by induction. Induction heating is often the method of choice for a number of reasons.

1. Because of their size and heat output, furnaces are often located in remote dedicated areas of the plant away from the production line. Induction lends itself to synchronous, in-line, cell-type manufacturing. The inductor can be mounted on the line, in several places if necessary, for uninterrupted flow.

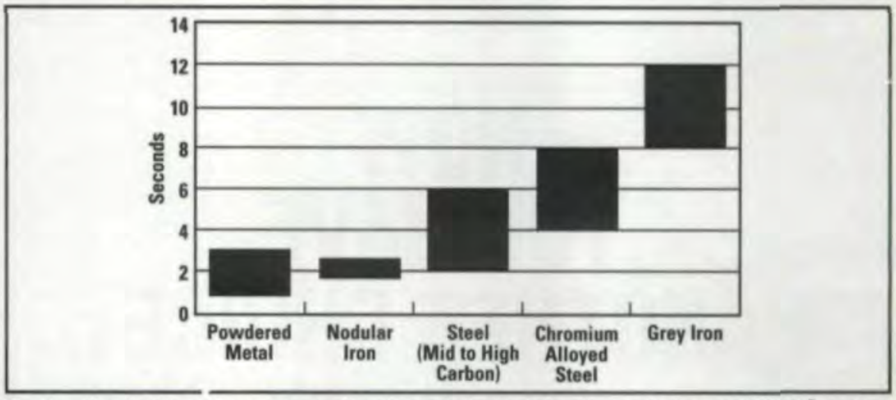

Fig. 1 — Nominal heat times to get carbon into solution for induction hardening at 10 kW/in² nominal power density.

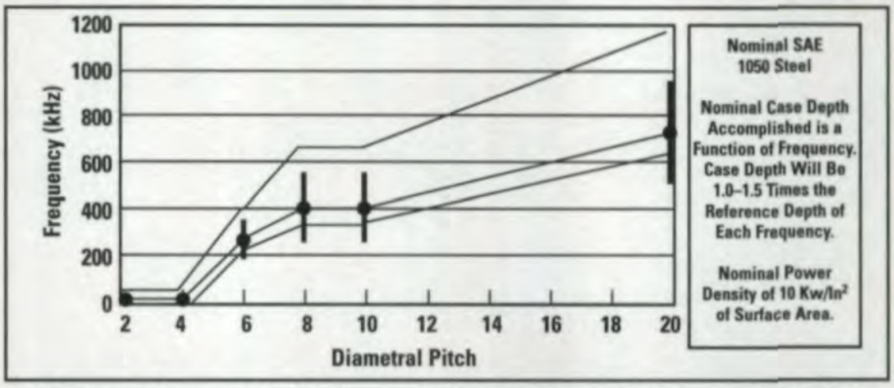

Fig. 2 — Proper frequency selection is needed to accomplish even heating across the tooth face. Selecting a frequency that is too low will only heat the tooth root as a result of field cancellation at the tips. Too high a frequency will overheat the gear tooth tips and not heat into the roots sufficiently.

Table 1 — XYZ Gear Part #945	
Variables	**Specifications**
Part Measurements	4" x 1/2" face width, 6 D.P.
Production Rate	45,000 pieces/mo.
Part Material	SAE-5135
Case Depth	0.15–0.30 mm below root
Hardness Required After Heating	Rc 55 at 1/2 depth

Table 2 — Estimated Cycle Time (in seconds) = 20.0 180 parts/hr.	
Unload/Load Machine	7.0
Initiate Cycle	1.0
Towers Raise	2.0
Heat On	3.0
Quench Gear	5.0
Lower Tower	2.0
Total Cycle Time	**20.0**
Parts Per Hour	**180.0**

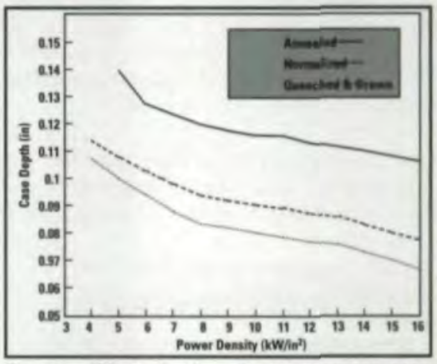

Fig. 3 — Effect of prior microstructure on case depth.

2. Fewer processes are needed with induction. Stop-off paints and copper plating operations are entirely eliminated as selective areas of the gear can be hardened.

3. While furnaces require batches of product to heat, one gear at a time can be processed with induction. Individual parts are accepted or rejected based on the correct process parameters being applied.

4. Induction equipment does not produce emissions.

5. Induction equipment is more efficient than furnaces, as only the area of the part to be hardened is heated (opposed to the entire part). Ambient air is not heated. As the induction unit is idle about 75% of the time, much less energy is consumed.

6. Gas furnaces need to be preheated; induction machinery does not.

7. Induction heating causes minimal distortion of gears.

What Does Your Induction Heating Machinery Supplier Need To Know?

Your potential short-, medium- and long-term applications. Mention all of these to your supplier even if they are not confirmed. Induction equipment can process different types of gears (with retooling); however, the supplier must know your needs beforehand.

Measurements of the gear(s) to be heat treated. Drawings and process sheets are very helpful. Your induction equipment supplier will study your gear prints and use your specifications to determine process parameters for the application.

Production rates. Determine how many parts need to be produced (by day, week or month). Specify the number of shifts the plant runs per day. From this data, your induction heat supplier can determine how many pieces need to be processed per machine cycle and calculate the power supply needed to meet this rate. The best information to have for your supplier is the total gross hourly production rate required of the equipment.

Part material. Carbon content, alloying elements and prior microstructure will affect the amount of power and time required to heat the gear. Gears with lower carbon content (below 0.2%) can undergo carburization prior to induction heating to speed up the heating rate in applications involving hardening.

Fig. 1 shows approximate heat times for various types of metals. Of course, actual times will vary based on the diameter, thickness and area of the part to be heated.

Case depth (depth of heating). Frequency selection is very important to obtain specified results. Too low a frequency will leave the tooth tips unheated. On the other hand, heating with too high a frequency will not heat the root area, but it will overheat the tips. There is a direct correlation between diametral pitch and frequency.

Frequency determination starts with carefully evaluating the desired or specified pattern. Take special note of these details: Is through-hardening of the tooth tip desired, or is the pattern profiled along the face of the gear? Is hardness required in the root? If so, to what depth?

Hardness required after heating. Hardness is dependent on material and is generally specified by the buyer. Carbon content, alloying elements and prior microstructure all affect hardness.

Application needed. A variety of applications can be handled by induction. Your equipment supplier will need to know which ones you will be using. Among those possible with induction heating are

- Surface hardening. Heating the surface of a component above transformation temperature, then rapidly quenching to create a hardened case on the surface.
- Through-hardening. Heating the entire workpiece above transformation temperature, then rapidly quenching to harden the part from surface to core.
- Tempering or stress relieving. Heating to a low temperature (120°–600°C) and allowing the heat to soak into the piece to relieve residual stress and reduce surface hardness to prevent cracking.
- Normalizing. Heating above transformation temperature and allowing piece to air cool.
- Annealing. Heating above transformation temperature and using controlled cooling.

What Will Your Induction Heat Machinery Supplier Determine?

A typical induction heat treat application is governed by the following equipment process parameters: Heat time, power level, power frequency, quench flow part position/rotation, and quench concentration. Your equipment supplier will need the range of these settings used in your applications–specifically:

1. Cycle Time. The induction heat treat process comprises the following primary elements:

Load/unload	6–10	seconds
Index in/out of coil	2–4	seconds
Heat	1–10	seconds
	(material dependent)	
Delay to quench	0–2	seconds
Quench	2–10	seconds
TOTAL	11–36	seconds*

*If tempering is needed, add six to eight seconds.

Actual time will be based on production rates, part material, power supply, etc. (See Fig. 2.)

2. Power level. Power level is a function of surface area:

Surface area = πdh x 2 (for gears)

For example, if a gear measures 4" wide by 1/2" high,

Surface area =

3.14 x 4 x 1/2 x 2 =

12.5" x 10 = 125 kW.

(The actual formula for determining definitive gear surface is more complex than this, but for the purposes of this article, we are using a simplified version.)

In some cases, the specific heat of the material, along with the weight of material to be processed and temperature to be reached, is used to determine the power supply size. (See Fig. 3.)

3. Power frequency. Based on case depth, the required level of hardening depth is calculated. Frequency is a function of case depth. The higher the frequency, the shallower the case depth. If

the frequency is too low, the piece does not get heated properly (Fig. 2).

4. Part position/rotation. Based on production volume and mix, budget requirements, plant standards and other information, the supplier will suggest ways to best meet production with manual or automated loading. Among other factors to consider are these: Manual loading is less expensive, but automation is more dependable.

5. Quench flow. This is critical only to hardening applications. Heat must be extracted very rapidly and precisely from the steel. The rate of heat extraction is largely a function of quench flow.

6. Quench concentration and filtration method. Quenchants are application specific. Water, polymer-water, soluble oil, salt water oil and even lead can be selected as quench alternatives. A few applications, such as low-hardenability materials, are best suited for a straight water quench. Polymer quenchant manufacturers should be consulted for each application to assure compatibility with other fluids that may be introduced.

Filtration of quench is necessary to assure process consistency and extend the useful life of the quenchant. Particles in the quenchant can block the small holes on quench barrel assemblies. Quench hole size is considered with selecting strainers and/or filters on quench water systems. Strainer hole size must be smaller than the quench hole size to prevent blockages.

Other less critical factors to be considered include quench temperature and quench time.

Additional Information

The cost of induction heat treating equipment can vary from $100,000 to $500,000, depending on production rate. The average price is $250,000. If XYZ Gear were to manufacture 200,000 gears a year over five years (or 1,000,000 gears), the cost per gear would be 25 cents.

When purchasing induction heat treating equipment, it is helpful to note additional budget items: Electricity, cooling tower or chiller water, quenchant, disposal of quenchant, inductor coils and part touch tooling, floor space, cost of preventative maintenance, operator/attendant costs, maintenance and daily destructive evaluation of production samples.

A Case Study

XYZ Gear needs to induction heat treat gear #945, which is 4" wide and 1/2" high (See Table 1).

ABC Induction Supplier determines the needed machine using the following calculations.

1. Power supply. The general rule is 10 to 15 kW per square inch. (Metric measurements need to be converted into the English system.)

4" x 1/2" x 3.14 x 2 = 12.56 in^2 x 10 = 125.60 kW.

Based on standard tables, a 150kW/30 kHz power supply is selected.

2. Production rate. XYZ Gear operates two 6.5 hour shifts, five days per week and is open 4.3 weeks per month.

45,000 pieces/mo = 162 pieces/hr at 279 hrs/mo.

A piece must be processed every 22.2 seconds.

Given the production rate, the power supply and company experience in this type of job, the applications engineer calculates the cycle time as shown in Table 2.

What Do You Need To Know About Commercial Heat Treaters?

Perhaps your production is low enough to consider outsourcing heat treating. Commerical heat treaters charge somewhere between 50 cents and $3.00 per gear. Companies can work out the economic feasibility based on an approximate cost of $2.50 per gear versus an investment in the capital equipment of $250,000 (the average price of induction heat treating equipment), plus ancillary costs.

Other factors should be considered before outsourcing. Are you willing to give up control of this process? Can you trust an outside heat treater to process gears that meet your standards?

A good place to begin is by consulting the directory included in this issue of *Gear Technology* or the *Directory of Commercial Heat Treaters*. Keep the following in mind:

- Make sure your commercial heat-treater has the proper equipment and experience.
- Make sure the skill set and equipment needed reside within the commercial heat treater now. Don't let anyone experiment with your project or use your job as a "learning experience."
- Make sure quality systems are in place. ⭘

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Welcome to our Product News page. Here we feature new products of interest to the gear and gear products markets. To get more information on these items, please circle the Reader Service Number shown.

Meteor Temperature Compensation System

Albion Devices has announced the availability of its Meteor temperature compensation system for column and bench-top gages. The company says that the system can improve shop floor gage performance and dimensional control and reduce cost of scrap, rework and warranty while helping users meet quality control specifications and ANSI and ISO standards. Meteor can correct column and other bench top gages for the effects of temperature automatically and in real time; interfaces electronically with gages via analog or RS232 ports; can display results as if workpiece, master and gage were constantly at the International Reference Temperature; can run via PC or laptop and includes setup software and a complete temperature compensation instruction guide.

Circle 216

8x Magnifiers for Hand or Desktop Use

GEI announces the availability of two magnifiers, models ONS-0080 and ONS-0082. These inexpensive, high quality magnifiers feature eight-power magnification with a double acrylic lens system. The magnifiers are 2" high , 1" in diameter and have a 1" diameter lens. The company says these magnifiers are ideal for inspection applications where it is not possible to justify the cost of expensive magnifiers.

Circle 217

Dimensioning Standards Guide

Effective Training Inc. has announced the availability of a new publication, *Quick Comparison of Dimensioning Standards.* This manual explains the differences between the American ASME Y14.5 standard and the European ISO standards. Over 75 differences between the ASME and ISO standards are explained in a series of charts and diagrams. Each point has been indexed and arranged for quick on-the-job consultation. Volume discounts are available.

Circle 218

Induction Heat Treater

POWERMATE II from the Welduction Corporation is a fully automatic induction heat treat machine able to process up to 900 parts per hour. It comes equipped with integral electromechanical load/unload and reject capabilities. All motions and functions, including process parameters, are automatically monitored and controlled by the integral machine controls. Optional handling devices include pick-and-place, clamp transfer and rotary dial. Its high-wall design with viewing windows and electrically interlocked doors keep hands away from moving hot parts.

Circle 219

"Virtual" Heat Treating

DEFORM™-HT simulation software from Scientific Forming Technologies minimizes trial-and-error in process development by predicting a wide range of part-specific metallurgical and physical properties, including residual stress, distortion and hardness before manufacture. Using advanced finite element methods, DEFORM™-HT can model most aspects of the heat treating process, including normalizing, annealing, quenching, tempering, aging and carburizing. It can predict the distribution of hardness, volume fraction of metallic structure, distortion, stress/strain and distribution of carbon in the carburizing process.

Circle 220

Brinell Tester

Micro-Cal, Inc. offers the Chicago Brinell Tester. The tester's cylinder ram extends to meet samples on a 24" x 24" testing table with dual foot pedal operation. Four loads—3000, 1500, 1000 and 500 kgf—are included and can be changed with a push of a button. This is a production-quality instrument with automatic dwell time and hydraulic retraction, 18" vertical capacity with a 13" throat depth, and a 10 mm ball and retainer. Complies with ASTM E10-96.

Circle 221

Send your new product releases to:
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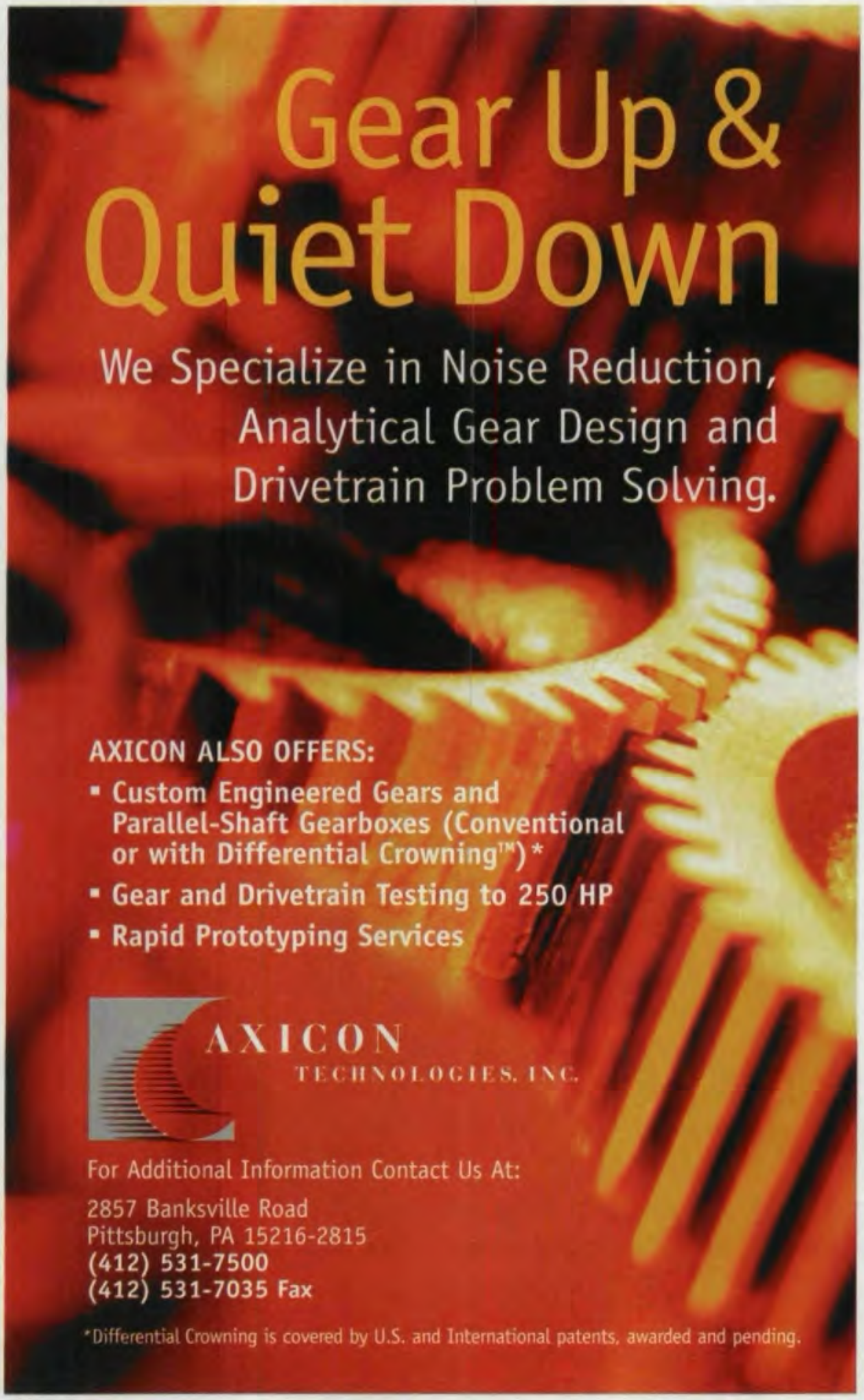

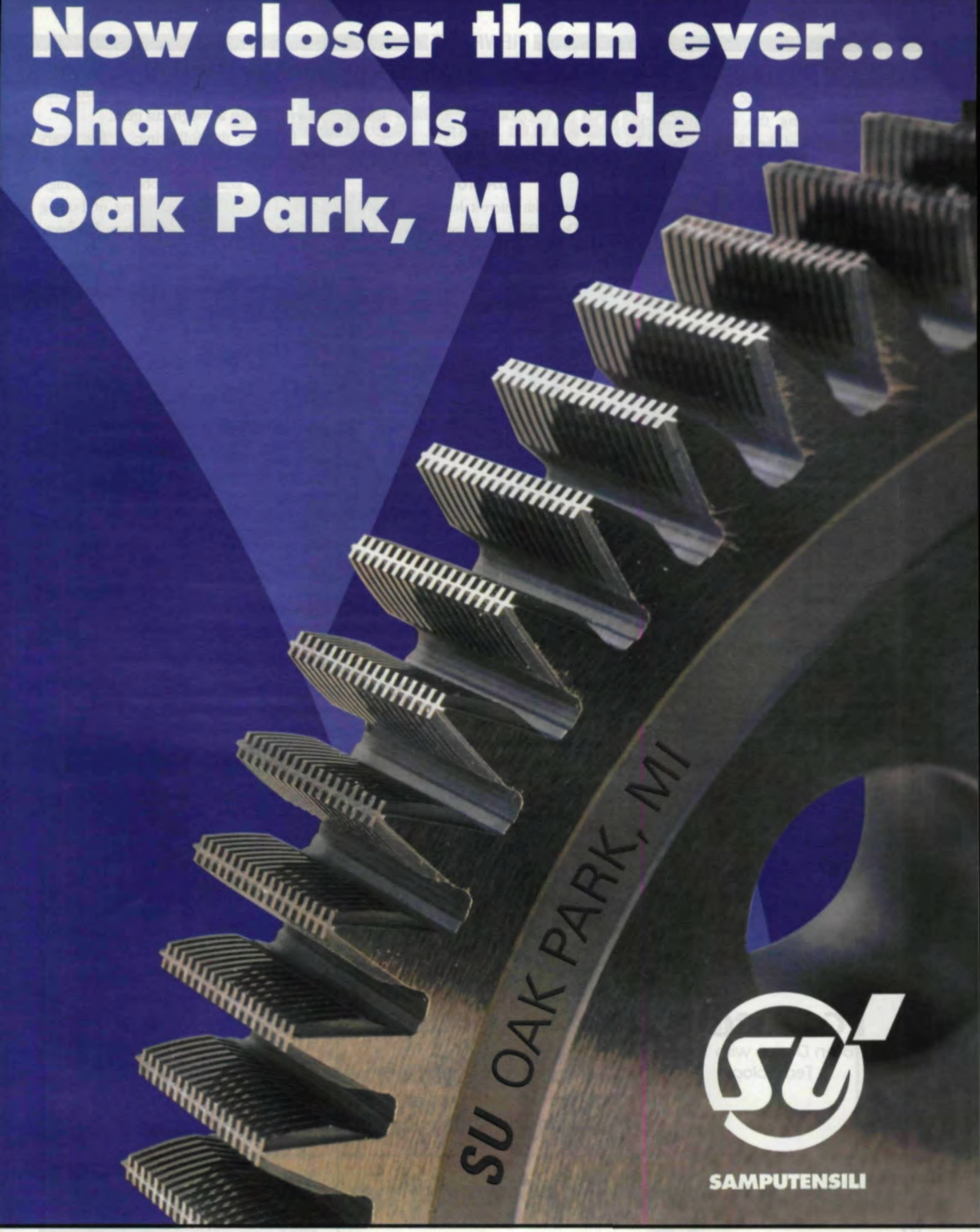
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THE KISH HUNTING METHOD

I read with surprise the letter from Mr. Mosier concerning the ancient Greek Euclidean origin of the "Kish method." I would like to assure your readers that I never met Mr. Euclid. The only thing I know about him is that he had something to do with geometry. The situation sort of reminds me of a patent application I once submitted that was rejected because an identical device was patented for an elevator in 1870. There really is nothing new in the world of gearing, is there?

Jules Kish, Sikorsky Aircraft

MORE ON GEAR SHAVING BASICS

I read with interest John Dugas' article (Nov/Dec, 1997) about gear shaving basics in your last issue. I would have expected a more convincing presentation in favor of the shaving process, even though it has been in vogue for over 60 years. **Shaving is still the most effective and economical way to finish a rough-cut gear.**

Consider the following: A few years ago, Ford's German operations tried to resolve the gear noise problem with a high tech solution—finish grinding or honing all gears in the manual gear box. It's interesting to note that Ford's newly built Brazilian transmission plant does not use the honing/finish grind operation to the large extent they did in Germany. Perhaps Ford realized that the reduction in gear noise obtained by hard finishing the gears was not significant enough to justify the additional cost incurred by this very expensive operation. (As the Italian proverb has it, the play was not worth the candle.)

Lately, some leading Japanese and German companies, lured by lower production costs, have set up manufacturing facilities in the U.S. Very often gear prints provided by German companies do specify the production gear process. Nevertheless, with the new generation of CNC shaving cutter resharpening machines and CNC shaving machines, the quality of shaved gears has definitely increased one or two class points, enlarging the shaving operation field. Perhaps an adequate hobbing/shaping operation, followed by a good shaving operation with proper workholding fixtures would be enough to produce those gears that, if made in Germany, probably would have been ground.

In the last analysis, the grinding/honing process should not be regarded as a panacea for all gear problems. Correcting heat treat distortions by finish grinding is very costly.

To conclude, I would urge gear manufacturers to fully evaluate the process they will use when producing gears in a global market economy. The bottom line is being able to evaluate the manufacturing cost for the quality required. This is the determining factor in which manufacturer ultimately gets the order.

It will be interesting to see in ten years whether the majority of gears will be finished by shaving or by hard finishing.

Dr. Sante Basili, Global Carbide Tools, Inc.

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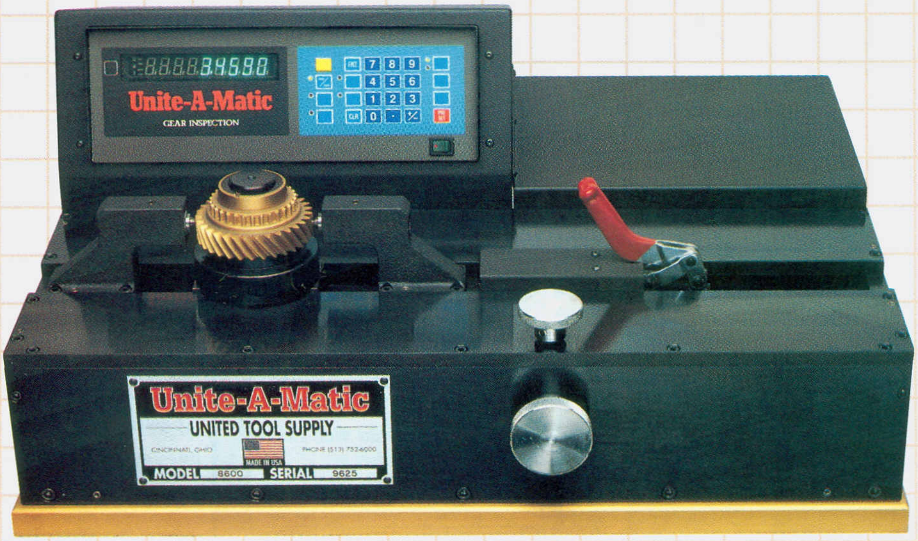

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Mr. Jackson's Amazing, Mysterious Machine

Gear Technology's bimonthly aberration — gear trivia, humor, weirdness and oddments for the edification and amusement of our readers. Contributions are welcome.

In our never-ending quest to bring our readers information about the unusual, the unique and—dare we say it?—the bizarre, the Addendum Staff has traveled for this issue to the wilds of Darkest Tennessee and the Museum of Appalachia. This museum of Appalachian folk art, crafts and history is located in Norris, TN, about 16 miles north of Knoxville. Among the 250,000 items collected by the museum's founder, John Rice Irwin, is a "thing," a "contraption," an "*objet trouvé*"; to wit, Asa Jackson's mysterious machine.

Jackson family history and popular folk wisdom in Appalachia say that it's a perpetual motion machine and that it worked at one time, running longer than a month without stop. And perhaps it did. But you couldn't prove it by anyone now alive.

This problem is this: Its builder, Asa Jackson (1792–1870), a local farmer, was a very secretive man. He didn't write down any of his plans or instructions for the assembly of the device. Jackson family members say he hid the machine in a cave outside Murphreesboro during the Civil War to keep it out of the hands of both the Union Army and any poachers who might be casting lustful eyes on his invention. When no one was in attendance on the machine, he took it apart so no one could figure out how the thing worked. Irwin suggests that he may have even built extra, dummy parts just to confuse the inappropriately curious. When Jackson died, the machine, but none of the instructions or plans for it, passed to his descendants.

Asa Jackson's perpetual motion machine.

And what was Farmer Jackson's motive for building such a machine? Family history suggests that he built it in response to a competition of some sort, perhaps sponsored by the federal government, that offered a million dollars—a powerful incentive even in 1998 dollars—to the person who could design a perpetual motion machine. Whatever the motive, it was enough to make the construction of the machine something of an obsession with Jackson. Apparently he neglected his farm and went into debt to work on it.

Irwin acquired Asa Jackson's machine from his great-great grandsons in 1994 and brought it to the musuem. Engineers from up the road at the government Y-12 plant in Oak Ridge have devoted some of their spare time to studying Jackson's machine, videotaping it and its extra parts and experimenting with various ways to put it together. So far, they haven't even agreed on exactly how it's supposed to be assembled. And none of them has displayed the daring of Asa Jackson in suggesting that they've repealed the laws of physics or outguessed the likes of Galileo and Sir Isaac Newton and found a perpetual motion machine. Still, they'd like to know exactly how it works.

One likely scenario is that weights powered the large wooden wheel (about 5 feet in diameter) much like a clockworks. As the wheel turned, it compressed springs, which when released, returned the weights to their original position, allowing the cycle to start all over again.

> It went "zip" when it moved,
> And "pop" when it stopped,
> And "whirrr" when it stood still.
> I never knew just what it was,
> And I guess I never will.
>
> Tom Paxton, "The Marvelous Toy"
> Cherry Lane Music, Inc., ASCAP

Whatever its original purpose or practicality, Jackson's machine is an amazing piece of construction. It is built entirely of wood, and all the connections and fasteners are also of wood, pegged into place in much the same manner as furniture of the period was made. All the parts, including the large toothed wheel, were hand-carved. Originally, the machine is believed to have hung in a frame some 25 feet square, but the frame has long since disappeared. Now it is on display in the Museum of Applachia in one possible configuration.

Okay, all you reverse engineering fans, here's your challenge should you choose to accept it: Take the trip to Norris. Study the machine. See if you can figure out how it works. John Rice Irwin, Asa Jackson's family and a lot of curious engineers would be be delighted if you could. ⭘

For more information about The Museum of Applachia, call 423-494-7680 or 423-494-0514.

The Addendometer: If you've read this far on the page and enjoyed it, please **circle 225.**