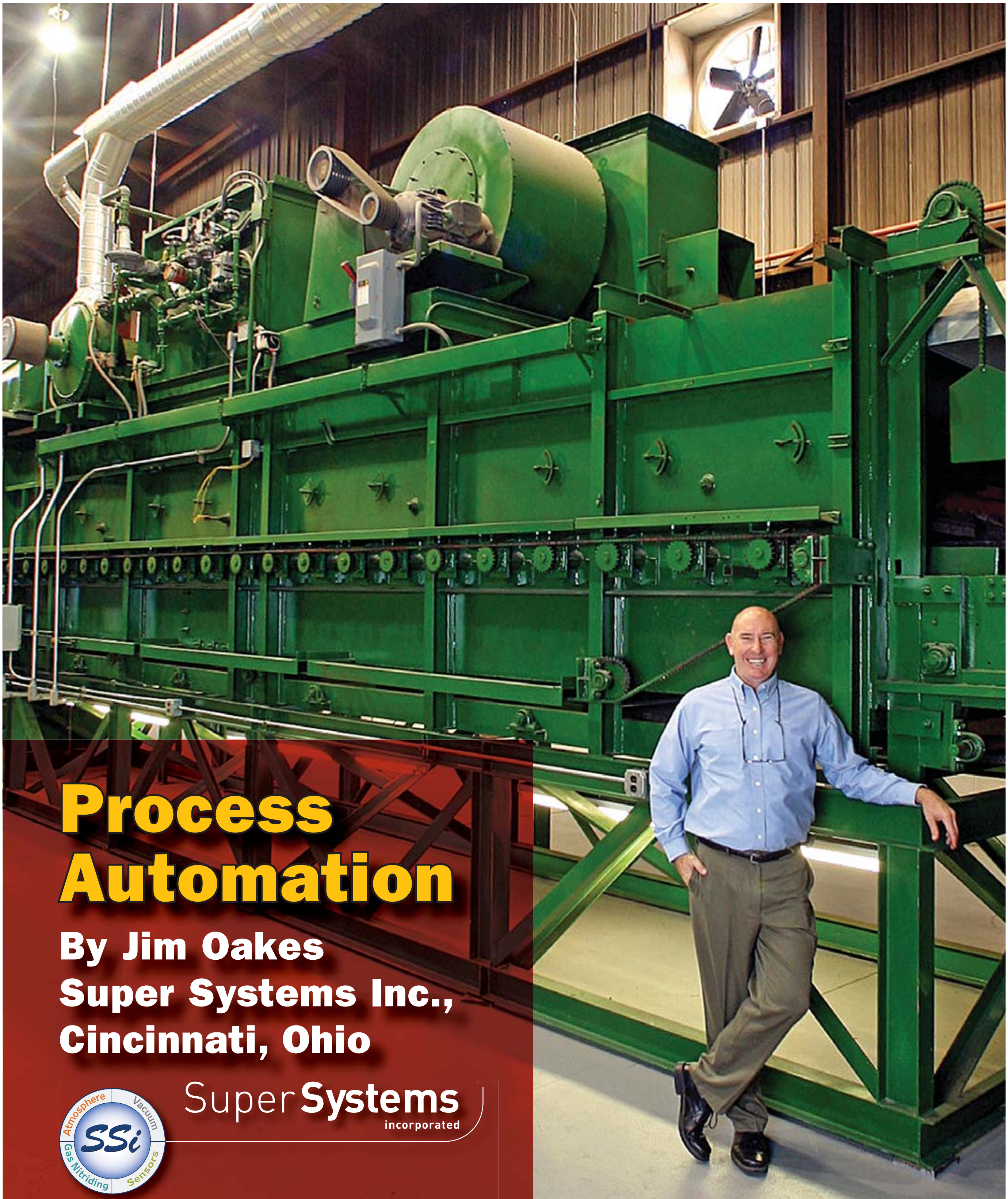
December 2007

Industrial Heating

THE INTERNATIONAL JOURNAL OF THERMAL TECHNOLOGY



Process Automation

By Jim Oakes
Super Systems Inc.,
Cincinnati, Ohio

Process Automation

Jim Oakes – Super Systems Inc., Cincinnati, Ohio

Process control deals with the algorithms for controlling a defined process. In heat treating, process control in its simplest form is controlling temperature to achieve a desired set point. In its most complex form, this may be a "lights out" operation where all mechanical, electrical and process control is being handled by instrumentation.

Many manufacturers are looking for ways to improve process control to provide more repeatability. The management of digital and analog inputs can be accomplished using many different types of instruments or manual processes. Automation minimizes human labor and error by utilizing mechanical and/or electronic equipment.

History

So why automation? Safety, quality, timeliness, cost, repeatability? Anyone interested in automating a process has one or all of these in mind.

There have been significant changes in the way manufacturing tasks are accomplished. With skilled-labor costs increasing and operating expenses on a sharp incline, efficiency drives process automation. As technology becomes more cost effective and applications become more numerous, the overall investment required is diminishing. The result is an attractive ROI.

There are many unique solutions that deliver automated process control. Programmable Logic Controllers (PLCs) and microprocessor-based stand-alone loop controllers are designed to synchronize the flow of inputs, sensors and contacts – from various field devices – to specific outputs, valves, motors, contacts, etc. The coordination of inputs and outputs leads to precisely controlled actions that permit tight control of almost any industrial process. With the proper safeties in place, risk is minimized.

As process understanding improves, the impact of a poorly controlled process on finished goods is easily quantified. This quantification has led to the creation of industry and customer standards requiring tighter and tighter process control and quality tolerances. Many of these standards require proof that the process has been performed properly and to the desired specification. In the heat-treatment industry, these quality standards include ISO, Nadcap, AMS and CQI-9.

As technology is integrated into manufacturing, many parameters that were difficult or expensive to quantify will be measured in a cost-effective manner. As technology provides more measurable parameters, industry specifications for heat treaters are detailing requirements

State-of-the-Art Automation

Phoenix Heat Treating (PHT) has been delivering quality to customers since the early 1900s. With state-of-the-art automation, computerized modeling and programmable control systems, as well as in-house metallurgical engineering and inspection labs, PHT is set up to manage the most difficult heat-treating requirements.

In early 2001, PHT set on a path to take advantage of the technology that was being made available to the heat-treating industry. PHT starts with documenting the job using Cornerstone's Visual Shop application. For carburizing parts, the process is verified using Super Systems CarbCALCII carburizing-simulation software. The simulation will determine if the programmed control recipes need adjusting. They can be updated from a computer workstation. The required steps are documented, and the necessary paperwork is produced with bar codes for the specific job. As the job makes it through the shop, each step is tracked. For processes performed in furnaces, PHT uses Super Systems' programmable controls to provide an automated process. As processes are completed, they are automatically time-stamped so an electronic record is stored along with all the process data.

PHT has a streamlined approach to produce an intelligent heat-treating environment. The use of computers, software and smart process controls has provided PHT with all the tools necessary to deliver quality parts efficiently.

related to automated controls. Reducing the risk of error through process automation enables suppliers to deliver higher-quality services.

Complex functions that were uncommon or unavailable in control schema are now available, practical and affordable. This functionality ranges from automatic PID tuning, cascade control, guaranteed soak time based upon multiple parameters, multivariable deviation alarms and redundant sensors. These functions are utilized in many control applications found in the metal-treating industry, and they are designed to automate a process anytime an operator must enter data or undertake a judgment decision. Automatic selection of a specific recipe based on part number and heat code is one example of automation adopted by companies in the heat-treatment industry.

Applications

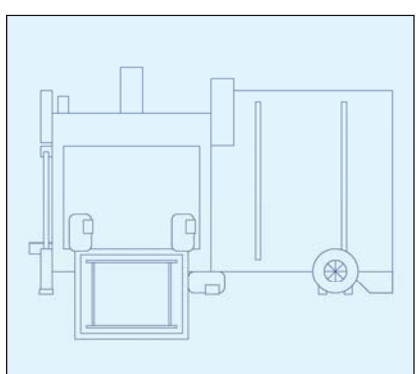
Generator Control

There are many different types of process control in heat treating. One of the simplest applications common in most heat-treating operations is the endothermic generator. The endothermic generator creates an atmosphere to provide a positive pressure in a heat-treating furnace and a platform on which a carburizing or decarburizing environment can be formulated – by adding enriching gas or dilution air. Generators provide 80% of the gas for atmosphere applications. The most common source of endothermic gas is the reaction product of air and natural gas in ratios between about 2.5/1 to 5.5/1. This ratio of air and natural gas is passed over a nickel-coated-ceramic catalyst at elevated temperatures. Since the reaction is not spontaneous below ratios of 6/1, it is necessary to supply heat to the generator.

Historically speaking, this process was managed manually by adjusting the mixer where the gases came together. The gases could be measured for an approximate dewpoint by taking a sample of the output gas. Today there are many automated control systems that maintain quality endothermic gas using microprocessor controls and sensors. These devices calculate and display dewpoint, control output for maintaining the dewpoint set point and control generator temperature. With these inputs, the controller regulates the addition of enriching gas or dilution air. If you choose a programmable controller, you can write a "watchdog" program that will sound an alarm if the control output is nearing its maximum.

Taking it one step further, automated control systems can be put in place to respond to the demand of endothermic gas and, when necessary, adjust the amount of endothermic gas produced. Generator controls utilizing fuel injection perform the mixing and control in one low-maintenance package. Automatic turndown provides gas flow on demand to all your furnaces without operator intervention or expensive venting of excess endothermic gas. Cost savings result when only the in-demand gas is produced.

There are many reasons people move to automated controls, but in the case of endothermic generators, your customers may require it. CQI-9 – the automotive-industry self-assessment – requires that generators be continuously monitored and automatically controlled.



Carburizing Control

Other forms of automation have also been implemented to improve the process. In the early '70s, the zirconia carbon sensor was introduced, which provided an in-process, continuous measurement of carbon potential in the furnace. These sensors, along with controls, could be used for control of carbon in these applications.

The "% carbon" algorithm – using sensor millivolts and furnace temperature – assumes a consistent gas composition of the natural gas coming into the building. The equation also assumes a known carbon monoxide (%CO) component. As pointed out earlier, this is why the endothermic gas produced by the generator is so important and is typically automatically controlled. If the composition of the natural gas changes, it not only influences the quality of the endothermic gas but also changes the additive or enriching gas. The calculation of "% carbon" from the mVs and temperature monitored by the probe could then be inaccurate. Shim stock – the only "true" test of carbon available in the furnace atmosphere – should always be used for verification. Control automation can be utilized to provide a real-time validation. To automate the correction in this process, three-gas infrared analyzers have been introduced. This measurement of the three-gas sample is independent of the probe and calculates the carbon potential from the temperature, CO, CO_2 and CH_4 in the furnace.

Periodic verification of the process is typically performed using dewpoint, shim stock or portable gas analyzers. Automation adjusts the calculation in the controller based on the three-gas calculation of carbon potential, thus providing a more accurate reading of carbon. This is commonly referred to as IR compensation.

When a process is in control, recipe management is another type of automation (Fig. 1). Many processes require precise management of variables to achieve the desired metallurgical results. With carburizing there is typically a heat-up time, carbon-boost phase, carbon-diffuse phase, cooldown and quench. Controlling

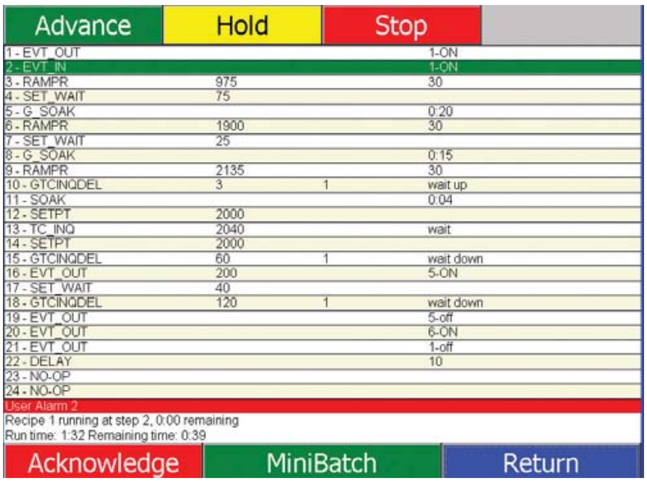


Fig. 1. Recipe management display with operation codes

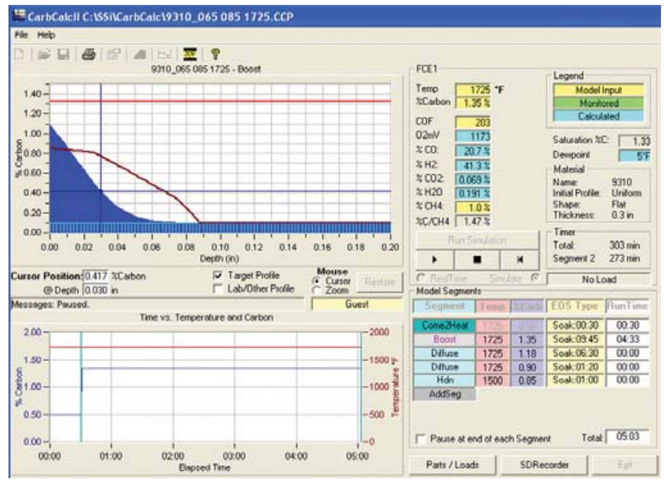
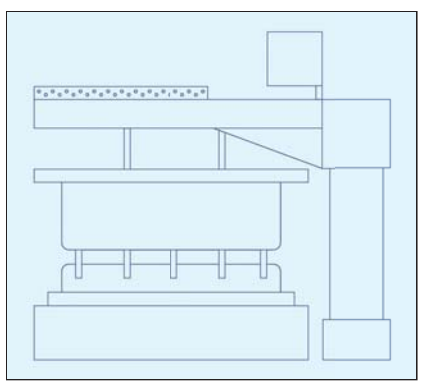


Fig. 2. CarbCALCII – Carbon simulation package

the variables such as time, temperature and atmosphere is crucial to producing quality work.

Automated control techniques allow temperatures and atmosphere to be guaranteed based on user-defined parameters, temperature ramp rates, atmosphere control and time for each step. Typically, time is a function referred to as a soak. Because computing power has allowed for complex applications to be more distributed, controls also exist that manage a process based on desired results such as case depth or surface carbon. Process modeling is now part of the control logic, creating a different approach to obtain the desired results. These controllers allow for target-value control instead of set parameters of atmosphere, time and temperature. Even though these applications are widely available, they have not been widely implemented for some heat-treating processes.

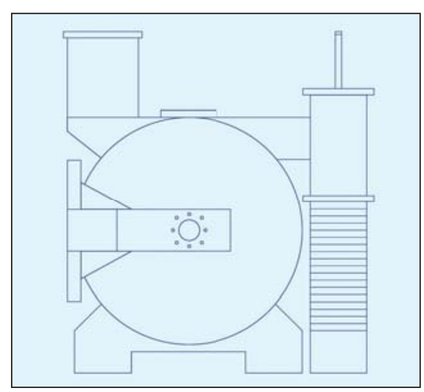
Carburizing, for example, has a number of modeling solutions that are used to simulate a process (Fig. 2). Some of these applications have a control component that manages the soak times on the boost and diffuse phase. This ensures that the proper carbon potential is available to the workpieces and that the diffusion meets the required case depth so as to achieve the desired metallurgical results.



Nitriding Control

Nitriding has followed a similar control-evolution path and is a little further behind in control acceptance. This is probably based on the amount of nitriding being performed as compared with other heat-treating applications like carburizing. With that said, there has been much recent interest in automating nitriding applications. Historically, gas nitriding used a periodic sampling method with manual inspection of an ammonia-dissociation burette. Operators would adjust flow rates based on this subjective measurement.

Sophisticated systems are available that continuously measure atmosphere along with all the safeties and multiphase processes. To achieve this, multivariable control systems monitor temperature, atmosphere, nitriding potential, flow rates, pressure, etc. to provide a safe environment with precise control of case and compound-layer variations.



Vacuum Control

Vacuum heat treating has certainly benefited from automation. Traditionally, vacuum applications have higher quality demands and require extensive traceability. As with all the other areas of heat treating, control-sensor technology and sophistication are providing the ability to control a process with more precision, resulting in higher-quality products. Vacuum control has traditionally used either hard-wired relay technology or programmable logic controllers for sequencing

Fig. 3. Control panel - large touch screen operator interface

and safeties. Vacuum heat treating has used process controllers, or PLCs, to run complete cycles using digital I/O, pressure sensors and thermocouples (Fig.3).

In vacuum heat treating, precision processing is always required. The phases of the process are typically the safety interlocks, pumping sequence, heating and cooling. From an automated-processing standpoint, the process controller is used to manage these steps. Either communication or discrete I/O is used to verify completion of the safety and pumping sequences. Once the heating circuit is enabled, algorithms are used to guarantee that temperatures are ramped appropriately to ensure the rate of heating doesn't produce a significant amount of stress on the load. The process controllers are also used to verify the temperature of the workpieces during the heating and cooling cycle. Load sensors used during vacuum heat treating verify a uniform part temperature, ensuring the desired metallurgical properties. More sophisticated controllers can manage load-sensor offsets, which provide a higher degree of accuracy when determining uniform part temperature. The ramping and cooling temperatures, when properly controlled, reduce the stress and distortion on the parts. Controllers can also manage out-of-tolerance issues or outgassing due to contaminated parts. With real-time visibility of vacuum levels, an automated programmable controller can be set up to guarantee correct vacuum levels.

Most vacuum furnaces are versatile when it comes to partial pressure and cooling. Gas-pressure quenches usually consist of nitrogen or argon and are used in conjunction with a cooling fan. Pressure gauges and contactors are monitored to ensure that these events are ready and have been turned on/off depending on the desired step in the process. With the sensors and verifications built into the processes, proper vacuum levels can be maintained, and the quality of the gas-quench media can be assured.

Electronic Data and Record Keeping

As a definition, automation replaces manual operations with mechanical or electronic equipment. As industry standards and customer requirements increase, the requirement of traceability and proof of processing is common. Companies are looking for an efficient method to generate the required paperwork. Computer systems are being installed to provide data and other load characteristics. SCADA systems (Supervisory Control and Data Acquisition) are known for providing quick access to information and a foundation for plant automation.

The goal of these systems is to provide a user-friendly environment to enter data associated with the load and to make the process of gathering this information quick and easy. With the use of scanning technology, computers and recipe programmers, the loading systems provide a method of automating this process. The

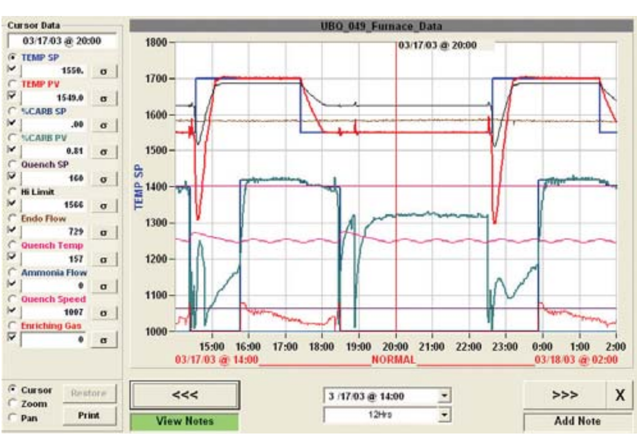


Fig. 4. Electronic data recorder - "Paperless" chart recording (real time and historical data)

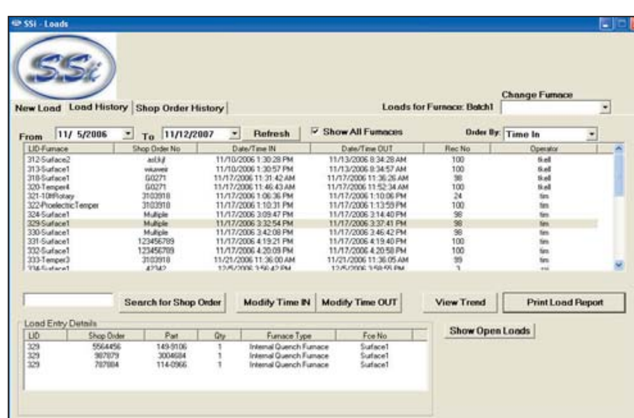


Fig. 5. Load tracking database

off-the-shelf relational database tools that run on standard personal computers enable end-user requirements specific to data capture and reporting to be incorporated into the load-tracking system. SCADA systems can be used to initiate programs running on each piece of equipment and then constantly monitor the equipment for an “end of cycle” notification. At the end of the cycle, the load is marked as complete, and a record of the process is stored electronically (Fig. 4).

The other benefit of load-tracking systems is the reduction of paper. With the acceptance of digital data, the trend is to move away from paper recorders. New electronic data-logging technology accomplishes the same thing, but paper can be produced when required. The logged data is easily retrieved and backed up. The direct benefit comes with reliability and integrity of the data as well as a reduction in maintenance labor to support the equipment. Information – both real-time and historical – is accessible at your fingertips, and there is no more changing paper stock on the recorders. These solutions are affordable and competitively priced with paper recording systems (Fig. 5).

Meeting industry standards with automated controls and data acquisition becomes easier. Process-control technology, with built-in alarms for deviation around set point, enables compliance for continuously monitoring temperature/atmosphere required by CQI-9. This takes the place of a manual verification and sign-off procedure. CQI-9 also calls out management review of the monitoring system in place. Plant-wide data acquisition provides a quick and easy way for management and quality assurance to review daily reports and ensure compliance.

Conclusions

Precise control of the measured process variables allows for the delivery of quality products. Automation and information increase the value of the heat-treat operation. Equipment will not be the only component providing value. Quality-driven heat-treat shops embrace technology to meet customer expectations the first time. Current tools provide the foundation for an error-free operating environment and a simple method for meeting industry requirements and customer demands. **IH**

For more information: Contact Jim Oakes, Sales & Software Development Engineer for Super Systems Inc., 7205 Edington Dr., Cincinnati, Ohio 45249; tel: 513-772-0060; fax: 513-772-9466; e-mail: joakes@supersystems.com

Additional related information may be found by searching for these (and other) key words/terms via BNP Media SEARCH at www.industrialheating.com: process automation, programmable logic controller, dewpoint, endothermic generator, carbon boost, carbon diffuse, gas pressure quench