Today's sophisticated control components, software, and automated materials handling systems help heat treaters improve product quality and reduce furnace operating costs.

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Optimizing process performance and increasing system throughput while reducing initial capital and operating costs are the drivers for recent improvements in furnace control systems and components. New technologies combine improved furnace components and control systems to reduce labor and manufacturing costs.

Control systems include carbon diffusion control, and batch furnace system automation control. Carbon diffusion control systems are capable of optimizing the process profile, operating the furnace, and making real time adjustments to the cycle to ensure parts' final quality. Batch furnace automation control systems allow for lights out unmanned operation. Automation controls track loads through the system, automatically control load transfers, and can be linked to carbon diffusion control systems to minimize furnace idle time.

In addition to the control systems, furnace features including recuperative radiant tube heating burners and in-situ created carburizing atmosphere (endothermic gas generator replacement) help reduce the initial capital cost as well as operating cost. The heating burner systems maximize efficiency while minimizing emissions.

Systems incorporating both a preheat and straight through integral quench furnaces (Figure 1) provide several unique benefits. The preheat furnace optimally heats loads through the forced convection more efficiently than that of the high temperature integral quench furnaces and reduces the number of integral quench furnaces. Thus, the preheat furnace maximizes energy efficiency and reduces initial and operating costs.

Straight through (Figure 2) and in-out integral quench furnaces, and the precision movements of loading and unloading cars, can be completely automated for carburizing, neutral hardening, and carbonitriding workloads. These furnace systems can include high efficient recuperative radiant tube burners, and in-situ atmosphere system. This article describes Ipsen’s Recon III recuperative radiant tube burner systems, Supercarb in-situ created carburizing atmosphere, ICTE batch furnace system automation, and Carb-o-Prof carbon diffusion control systems.

Recuperative Radiant Tube Burners
Our recuperative radiant tube...
burner systems include internal recuperators, are single ended, and each individually controlled by its own burner control unit. The burners fire into an inner silicon carbide tube and return in an outer alloy tube. The outer tube provides robustness for manual handling and thermal cracking, and simplifies assembly and disassembly. The inner silicon carbide tube provides extended tube life.

The burner combustion chamber includes separate air and combustion gas inlets. The combustion gas line is fitted appropriately to ensure that the pressure in the burner remains constant and the air supply is piped to provide the same flow to each burner. This arrangement ensures that optimal gas to air ratios are maintained, resulting in precise tuning and setup capability, high efficiency ratings (Figure 3) and low NOx emissions (Figure 4).

Each burner's control and atmosphere supply system configuration allows burners to be manually shut off independent of other burners in the furnace. It is not necessary to turn all the burners off in the event of a burner failure. Instead, the malfunctioning burner can be turned off, diagnosed, and brought back online without losing a valuable load. In the case of a more serious failure, the entire burner can be removed from the furnace and replaced without taking the furnace out of production.

**In-Situ Created Atmosphere**

The Supercarb in-situ processing atmosphere provides a stable and controllable reaction gas suitable for carburizing, neutral hardening and, in conjunction with ammonia, for carbonitriding. This atmosphere virtually eliminates the need for an endothermic gas generator or a nitrogen-methanol system as well as the operation and maintenance thereof. In this case, the atmosphere is created directly in the furnace. The heat treatment results of steel with this atmosphere are similar to the heat treatment of steel with endothermic and nitrogen-methanol atmospheres.

This atmosphere is based upon injecting a hydrocarbon gas (i.e. methane or propane) and air directly into the heating chamber. With the gas flow rate fixed, the desired carbon potential is controlled by varying the airflow rate. A furnace equipped for operation with this atmosphere includes a ceramic muffle. The gases are appropriately injected into the annulus created by the muffle and furnace wall (near the heating system), creating the reaction gas comprised mainly of CO, H2, and N2 with some residual CH4. Using air to control the carbon potential in the furnace results in constituent percentages not as constant as those resulting from an endothermic gas generator, which are only fairly constant. Thus, in addition to a heating chamber oxygen probe and temperature indicator, this atmosphere system also incorporates a reliable CO analyzer. From the measured furnace oxygen content, CO content, and temperature, a computer calculates the carbon potential of the reacted hydrocarbon gas-air mixture. The airflow rate is varied by a motor-operated valve in order to maintain the desired carbon potential.

Since this is an in-situ created atmosphere, it does have limitations regarding operating temperature, and carbon potential ranges. The operating temperature range is 800°C (1472°F) to 1000°C (1832°F) based on the type of hydrocarbon being used, as well as the processing requirements. The maximum admissible carbon potential is dependent upon soot formation at a specific tempera-
tured. Experience has shown that values for methane are slightly lower and for propane slightly higher.

**Automation Material Handling System**

Our ICTE automation material handling system enables a company’s internal procedures to be optimized, requiring minimum input from operations personnel. The benefits occur when the software brings together all the technological and commercial aspects of plant management. It incorporates three integrated or independent modules. Through the appropriate selection of specific modules required by the company and the flexibility of the system, it is possible to configure the system to be equally suited for both large and small companies. Although flexibility is particularly appropriate to the commercial heat treatment shop where diverse requirements of charge size, treatment targets, materials, and schedules are part of the daily business, it is also appropriate to the captive heat treating department. The following describes the three types of modules available.

The first module, the ICTE Com, handles sales order processing. It offers a means of estimating prices and generating formal quotations. It also tracks deadlines, generates invoices, enables price corrections, and determines job costs. This module is best suited for a commercial heat treating company.

The second module, the ICTE Tech, handles manufacturing planning. It includes furnace capacity optimization, manufacturing planning, load tracking, and enables storage, creation, and modification of programs. This module is appropriate for both the commercial heat treating company and a captive heat-treating department.

The third module, the ICTE AutoMag, is a software package designed to link atmosphere batch lines, vacuum furnace lines, and mixed atmosphere and vacuum furnace lines. Using this module enables reliable unmanned operation and more efficient use of high temperature furnaces with minimal delay in transporting loads. It is primarily designed to:

- Execute, control, monitor and log the individual steps of a load heat treatment process.
- Automatically link to all furnace and load handling PLC’s for easy system maintenance and troubleshooting.
- Monitor and log current furnace and load status within the complete system.
- Monitor and log the current status of all furnace and companion equipment.
- Provide an overview of the complete heat treatment system including all the units and loads present (Fig. 5).
- Provide complete textual and graphic processing documentation for the full heat treatment cycle including pre-heating, hardening, quenching, washing and tempering.
- Archive the complete heat treatment process and all relevant data including heat treatment programs, all relevant process histories, all user-defined charge- and customer-specific data, etc.

When logging a load into the computer, the operator can enter load specific information and parameters, or simply use the optional barcode reader for error free input. All data entered into the system are saved and archived for later retrieval, documentation, or back up. After completing the heat treatment process, an automatically generated load document can be printed. This document includes detailed information on each step the load has undergone.

The core of this module is the “Installation Visualization” screen (Figure 5). This is a graphic screen that is representative of the customer-specific installation layout. The screen provides a lot of information on the individually installed units, as well as the charges currently in the system. These can be called-up as required by the operator. The following information is available:

- All equipment set-points
- All equipment measured values
- Specific fault-condition status of each unit
- Carbon profile and temperature
- Load number and load specific data
- Remaining process time
- Digital status of individual equipment
- On-line / Off-line
- Position of doors
- Fault messages and location, etc.

The movement of all loads in the furnace system are monitored and tracked by the system. The loads are represented on the screen, each displaying a unique charge identifier, for example, heat number, charge number, order number, etc. The color of the charge is indicative of the destination planned for the next automatically controlled transport operation. Thus, at all times, it is possible to see where the charge is and where it is going next.

**Carbon Diffusion Control System**

Another example of current control capabilities is the Carb-o-Prof carbon diffusion control system, which provides real-time carbon diffusion modeling and control. An operator can generate time, temperature, and carbon potential recipes.
on-line by drawing from a comprehensive materials library. It is also capable of simulation; so the operator designing the recipe can simulate a carbon profile with altered recipe parameters and design a recipe that will hit the mark on the first try. This control system takes the guesswork out of carburizing, by using the diffusion model to precisely determine process duration and optimal switchover from the boost to diffuse. The diffusion model optimizes the cycle through an interactive iterative process-simulator to achieve the desired surface carbon content, and carbon depth (Figure 6).

This program was designed to produce the required case depth in the shortest time. It helps to optimize furnace operation by controlling the carbon level relative to the soot level at a given temperature. This way, furnace operation can be optimized without the worry of sooting problems. A recipe can be programmed to run at (for example) 10% to 15% below the soot level and it will control the furnace at that level relative to the temperature.

It continuously monitors real-time process parameters including furnace temperature, carbon potential, CO content (when using CO analyzer), and load status including the real time predicted part carbon profile. It also calculates, from actual temperature and atmosphere values, the estimated process duration and resultant carbon profile in the material (Figure 7). By monitoring these variables, it is capable of operating the furnace and of making real time adjustments to the cycle in order to ensure the desired carbon case depth, surface carbon content, and hardness.

The value of the live calculator should not be underestimated. Let’s say, for example, the furnace lost heat during processing. Maintenance is called in to diagnose and fix the problem. It won’t matter if it took a minute, an hour or a day, assuming the system has not been taken off line, it has monitored the atmosphere and temperature inside the furnace for the entire time the fault was being solved. Once the furnace is brought back on-line, the system will continue where it left off, recalculating to readjust the cycle based on what has happened and provide parts with the case depth originally requested. By initially entering into the system the part characteristics, including material to be processed and the desired case depth, it can create and control the recipe and ensure quality.

Upon completing the processing, all relevant data such as time at temperature and carbon potential can be printed out in a tabular and graphical report. All heat treatment data is archived and can be called up at a later date for inspection and reporting.

Finally, this control system directly interfaces with the automation control systems. For scheduling purposes it communicates to advise when load movements will be necessary based on how the loads are being processed. This way, the automation controls can anticipate upcoming movements, more efficiently route loads through the system, and minimize furnace idle time.

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