Automated Control of Vacuum Heat-Treat Equipment

Fig. 1. Design view

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Vacuum heat treatment's requirements are rapidly changing, with several accreditations influencing how heat treaters ensure product integrity. As requirements inevitably become more demanding, equipment must be evaluated for compliance. Heat treaters often find themselves questioning whether they should replace or retrofit equipment.

Vacuum heat treatment is evolving as quickly as any of the other subsets within the industry. Changes are ushered into the industry as customers, end users and governing bodies (AMS, Nadcap, etc.) press for increased visibility of both production and available historical data. Production and labor costs also significantly influence how equipment is evaluated as heat treaters look to increase utilization and reduce operational, rework and maintenance costs. As requirements become more demanding, many heat treaters are faced with a difficult question: Do we buy new equipment or upgrade what we have?

Considerations for Replacing the Entire Furnace

Once disassembled, a seemingly complex vacuum furnace consists of relatively few components: the shell, hot zone, VRT heating system, diffusion pump, vacuum pumping system and various plumbing/valves.

Once isolated, all of these components become much simpler to maintain. Cooling jackets can be cleaned, and specialized instrumentation determines weak points. Degrading hot zones and failing diffusion/vacuum pumps can be easily repaired, rebuilt and replaced. Working with one of the industry's many specialized contractors allows for equipment to be well maintained, serviced and repaired – greatly extending equipment life.

With routine maintenance, furnace replacement can be determined largely from production requirements. One example is a larger certified work zone, which can be difficult to increase even by a few inches. Production demands may exceed the throughput of a furnace, requiring a larger model. A new customer may require a positive-pressure quench process when the facility only offers atmosphere-rated equipment. Any of these scenarios may limit one's options, leaving a new purchase as the best choice.

Considerations for Upgrading Controls

If a new furnace is not inevitable, upgrading controls may provide all the needed functionality at a fraction of the cost. During *any* upgrade, it is important to review or work with your contractor to develop a modern and safe control package. "NFPA86 Chapter 14: Class D Furnaces" outlines what considerations need to be made when performing such work (Fig. 1).

New Panel vs. "Swapping" Out Hardware

The first question every heat treater considers: Do we replace the entire panel or just the outdated hardware? With a new panel significantly increasing the retrofit's price, the return on investment must justify the expense. New panels provide a clean, documented solution that certainly "shows better" to existing and potential customers. If space is of concern, the footprint can also be reduced with modern, smaller instrumentation allowing older two- to three-door enclosures being replaced with single-door equivalents (Fig. 2). In addition, new panels may significantly reduce unplanned downtime, offsetting the initial expense over the course of several years. Some considerations that may reduce downtime include:

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- What is the condition of the motor starters, relays, transformers and other components within the control panel? As these components fail, each failure will result in some type of downtime, perhaps impacting product – potentially resulting in liability or rework costs.
- What is the availability of a programmable logic controller (PLC), silicone-controlled rectifier (SCR), vacuum instrumentation and other complex components? Some of the components within a control panel may have become obsolete or have lead times exceeding four to six weeks. PLC failure from obsolete processors can be the single-most disruptive failure, resulting in extended downtimes. To help estimate the exposure to component failure, it is recommended that you routinely audit hardware, calling your local distributor to determine which are still offered. If offered, what is the lead time? This proactive approach can also help determine what needs to be stocked as spare parts.
- Are electrical schematics available for the control panel? If so, how accurate are they? Inaccurate schematics often extend unplanned downtime. Before beginning repairs, maintenance crews must trace and re-label wires to understand how a furnace is wired.

Uniformity Improvement via Heating-Circuit Redesign

Many furnaces struggle with passing both low- and high-temperature uniformity survey (TUS) ranges. Even with routine hot-zone maintenance, this may be inevitable. Minor modifications to the heating system can result in drastic improvements.

Traditionally, heat chambers have three to five distinct zones with the same number of variable reactance transformers (VRTs). Each VRT's output is proportional to a command signal and generates from a single silicone-controlled rectifier (SCR), split into three to five distinct signals. Each is manually trimmed via adjustable rheostats.

Unfortunately, ideal rheostat settings often vary between temperature ranges. Improvements are achieved by replacing the original SCR and rheostats with a dedicated SCR for each VRT.

The loop controller must also be evaluated because it will require the same number of isolated analog outputs as SCRs. Another desired feature is the ability to uniquely scale each output at various temperatures, improving uniformity and "centering" the load TC delta at setpoint.

Many controllers and PLCs can have expansion outputs added or replaced with an equivalent model supporting the appropriate number of outputs.

Recipe/Loop Controller Considerations

Controllers have seen significant advancements in recent years, gaining flexibility from historically basic ramp/soak profiles. Modern PLCs and controllers offer a wide range of custom features focused solely on vacuum heat treatment. When evaluating one's current controller, the following questions should be asked. Does my current controller:

- Provide all of the functionality required by my customers and accreditations?
- Allow for customization?
- Allow for a sufficient number of recipes?
- Provide complete visibility as to furnace operation, valve position and motor status?
- Allow for selectable load TC evaluations for guaranteed soaks?
- Generate and maintain an alarm history for all applicable alarms?
- Offer built-in PID tuning assistance?
- Load custom PIDs for various temperature ranges? Or by recipe?
- Automatically provide vacuum and outgas interlocks?
- Accommodate for expansion should additional analog outputs; load TCs; and diffusion pump, dew point or vacuum sensors be added?
- Communicate with a data-acquisition (SCADA)

Fig. 2. Vacuum control panel

system and any external instrumentation via industry-standard protocols (RS232, RS485, Modbus TCP)?
- Include a built-in maintenance program?
- Allow for remote access for support?

Is my current controller still offered by the manufacturer? Is it available "off the shelf," or is it an obsolete item?

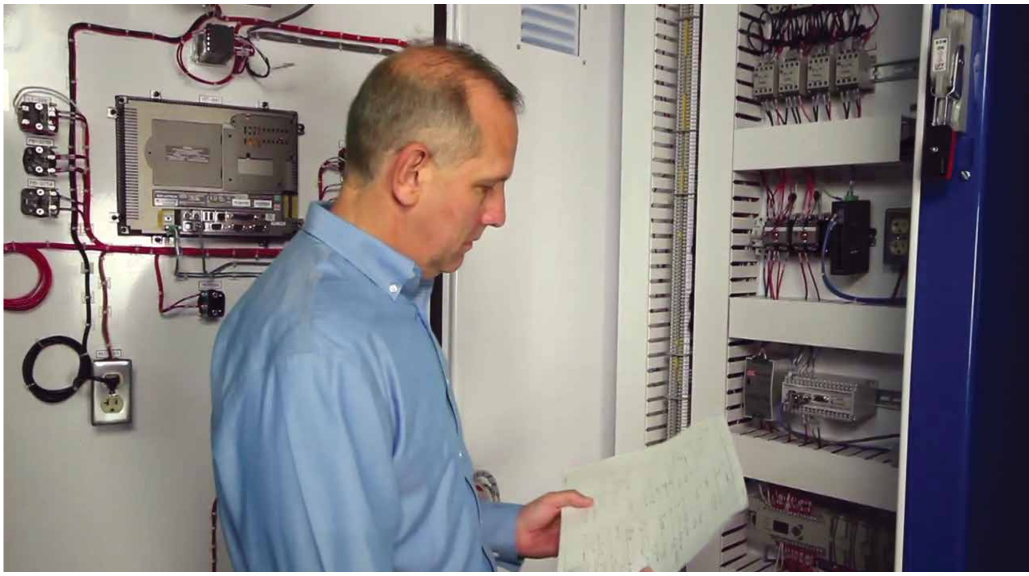
Fig. 3. Open control panel with prints

Built-In Maintenance Programs

Modern controllers also offer built-in maintenance programs. Simple maintenance programs record motor run times and valve and production cycles. Complex maintenance programs may utilize a database allowing specific users to track routine maintenance dates, downtime and costs.

Custom reports and searches then help shift from reactive to proactive maintenance schedules. Preventive maintenance reminders allow facilities to reduce unplanned downtime, which increases productivity. Plant-wide maintenance costs can further be reduced by performing maintenance on actual run times rather than estimated monthly intervals.

Vacuum Instrumentation Considerations

Several industry leaders have long provided extremely accurate, robust vacuum controllers to the heat-treating industry (Fig. 3). Recent developments in built-in communications may influence the decision to replace vacuum instrumentation. Does my instrument support communications? Communications are important because they eliminate the inherently greater error of analog signals. This not only increases data accuracy but reduces the need to calibrate chart recorder inputs.

Certain instruments allow communication modules to be added to the original design at a fraction of the cost of a new controller. Others have to be replaced with an equivalent model supporting communications.

High-Limit Controller Considerations

Several specifications now require that the high-limit controller's temperature be charted during production. Similar to that of vacuum instrumentation, the most accurate way to record data is to use a controller with communications.

Certain models allow communication modules to be added to the original design, while others have to be replaced with an equivalent model supporting communications.

Dew-Point Monitoring

Many heat treaters are required to record each furnace's inert gas dew point. Common practices require an operator to manually sample gas into a handheld analyzer. This requires the operator's time and necessitates a handwritten log. Combined with the trend chart, this creates two pieces of production documentation.

Modern controls integrate in-situ dew-point sensors that can be trended 24/7, eliminating the need for paper logs. SCADA and process controllers allow the operator or recipe to define alarm thresholds, alerting the operator should the dew point rise above a specified temperature.

Increased Visibility via Software

As electronic SCADA has become more common, the requirements have also become more stringent. Customers and governing bodies have organized to formalize what type of electronic data is acceptable. At minimum, a SCADA system must be of non-modifiable, read-only, write-once format. Storage in a non-encrypted database has the potential for post-process manipulation and is considered unacceptable.

When evaluating any SCADA system, it is important to understand today's requirements, as well as consider that new requirements may develop in the future. Leading software offers secure, web-based updates, allowing industry compliance for not only the year of purchase but the life of the software.

Historically, SCADA systems have recorded data in one- to two-minute intervals. As computer memory becomes less expensive, many now offer logging intervals as short as one second, sometimes mandated for shorter-cycle processing. SCADA systems should offer data in both graphical and tabular views, allowing heat treaters, customers and auditors to have valuable, irrefutable evidence of processing parameters such as load tracking, utilization and job status.

Load Tracking

Plant-wide software can effortlessly integrate production with a load-tracking database. Sophisticated databases allow management to:

- Restrict which recipes furnaces can process
- Maintain recipe revision history
- Access data from multiple computers
- Search production history via key information
- Produce trend charts and custom reports
- Reduce audit time

Utilization

Modern software also determines equipment utilization, calculating daily, weekly or monthly efficiencies. Shifts and departments can be compared to allow visibility during off hours. Utilities (gas and electricity) can be monitored to calculate per-lot and monthly costs.

E-mail and Phone-Based Alerts

Facilities requiring 24/7 visibility can utilize web-based alert software. Programming distinguishes which alarms warrant alerts, sending emails (or text messages) to mobile phones. Critical alarms can escalate so that an alert is immediately sent to a supervisor, followed by an email to engineering if the alarm is not resolved in a specified time.

Alerts can be used to notify production of job status, allowing them to reduce gap time. Example alerts include:

- Furnace alarms (high-limit condition, motor starter tripped, process deviation)
- Monitoring (poor inert-gas dew point, warming water temperatures)
- Maintenance alerts
- Production alerts (30 minutes remaining in cycle, end of cycle)

Summary

When considering major equipment changes, the ideas discussed within this article coupled with a practical, production-minded and financially sound approach allow one to answer the difficult question: Do we buy new equipment or upgrade what we have?

Today's technology can provide significant advantages for equipment automation – increasing productivity, reducing operating costs and maintaining compliance with the constantly evolving industry that is vacuum heat treatment.

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