INTEGRATION OF VACUUM PROCESSING INTO AN AUTOMATED VERTICAL QUENCHING FURNACE

Vertical vacuum integral-quenching furnaces give heat treaters a larger working zone for efficient and rapid quenching.

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Integral quenching (IQ) is a widely adopted heat treatment technique known for its efficient and rapid quenching capabilities. While applying vacuum processing in IQ is not a new concept, it has been limited in batch size capacity in vertical orientations. To address this limitation, a vertical vacuum IQ furnace has been developed. The principal reason for the vertical vacuum is to expand work zone size while leveraging the benefits of both vertical and vacuum treatment. Additionally, with current technology, there is the opportunity to expand on automation capabilities. In this article, the vertical vacuum IQ furnace line (Fig. 1) is introduced; it comprises a loading station, a vacuum furnace, a water wash tank, and tempering furnaces–all interconnected via a loading system. The operational workflow of the vertical vacuum furnace and integration of supervisory control and data acquisition (SCADA) systems allow for autonomous processing and are also discussed. The findings presented provide insights into the advancements and potential applications of vertical vacuum IQ furnaces in the heat treatment industry.

Fig. 1 — The vertical vacuum IQ furnace line.

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VERTICAL VACUUM IQ FURNACE LINE OVERVIEW

The vertical vacuum IQ furnace line is a novel configuration designed to overcome the limitations of traditional IQ vacuum furnaces. The line includes a loading station, a vacuum furnace, a water wash tank for post-oil quench treatment, tempering furnaces, and an automated loading system known as the loader.

The loading station serves as the initial point where hardware is staged prior to the heat treatment process. The loading system, or loader, is directed by the SCADA to automate transitions between furnaces and complementary equipment on the furnace line. Transitions such as a quench-to-water wash and subsequent transfer-to-temper cycle, and many more variations are directed by the SCADA and can be performed autonomously.

The vacuum furnace consists of a hot chamber and a cold chamber with an inner door separating the two, the former containing the work zone and the latter housing the gas quench chamber and an oil quench tank directly below.

Due to the multi-chamber nature of the vertical vacuum furnace, the inner door separating the hot and cold chambers prevents incorporating load thermocouples for temperature monitoring during production. A workaround to this limitation is to use a temperature-resistant recorder that can be loaded into the furnace with the hardware. The load thermocouples can then be connected to the recorder such that thermal data may be transmitted wirelessly or downloaded post processing.

OPERATIONAL WORKFLOW

Hardware is manually placed onto the loading station. The recipe is started, and the SCADA directs the loader to pick the hardware up and move it to the desired location. For the vacuum, the loader places the hardware into the vestibule and onto the internal elevator. The elevator takes the load upward into the hot chamber. After the hardware is in the hot chamber, carbon-fiber blades extend out into the work zone to secure the load. The door between the hot and cold chambers is sealed, and the chambers are pumped down using roughing pumps and a booster pump to the desired vacuum level via the SCADA.

When the desired vacuum level is attained, the temperature is raised per the recipe to the desired cycle temperature for the heat treatment process. The hot chamber has an operational temperature range of 1100°-2200°F allowing for most hardening and solution treatment cycles.

Upon completion of the heat treatment cycle, the cold chamber begins to partially pressurize and the inner door opens. The elevator then moves the hardware downward to the cold chamber, where it undergoes the quench of choice. Gas quenching is performed in the vestibule and oil quenching in the quench tank below.

The vertical vacuum IQ furnace line also includes a water washing station. Wash steps are added after oil quenches to ensure clean low-temperature cycles.

TABLE 1 – FURNACE LINE CAPABILITIES

Vacuum furnaces		Bell furnaces	
Temperature range	1100°-2200°F	**Temperature range**	300°-1200°F
Work zone	72-in. diameter x 174-in. length	**Work zone**	72-in. diameter x 174-in. length
Maximum loading	7000 lbs	**Maximum loading**	4500 lbs
Pyrometry	AMS 2750 Rev. G, Type D, Class 3	**Pyrometry**	AMS 2750 Rev. G, Types D and B, Class 2
Maximum vacuum	7×10^{-2} torr	**Atmosphere/pressure**	Air
Maximum quench pressure	1.5 barr		

Tempering and aging cycles are performed in tempering furnaces.

The loading system is a critical component of the vertical vacuum IQ furnace line. It is located parallel to the furnace line on a track system and can move hardware from one unit in the line to another. Table 1 shows typical furnace line capabilities at a glance.

AUTOMATION OF OPERATIONS

Users can create recipes specifying the heat treatment parameters for desired cycles. These recipes are then queued in the system, ensuring a seamless transition between different heat treatment cycles. Advanced controls over operational parameters allow for complex cycles to be performed autonomously.

PLC integration across the line allows for flexible operation modes. Processing can be anywhere on the spectrum between autonomous and manual. Some operations can run automatically, and some can be run manually at the same time without interference. The

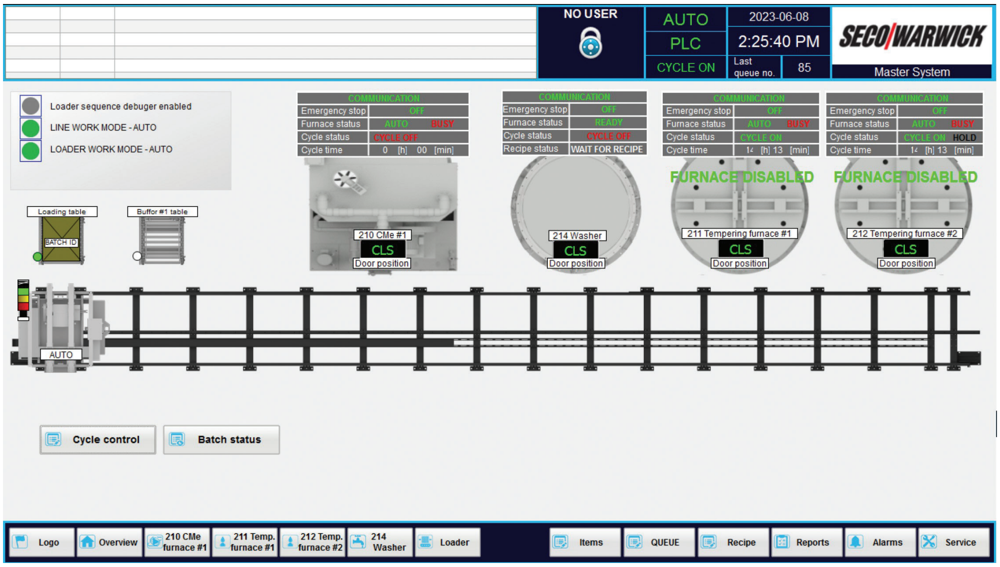

Fig. 2 — SCADA furnace line view.

system can be programmed to operate continuously by queuing recipes for uninterrupted furnace operation.

The furnace loading system, in coordination with the SCADA system, automates the movement of hardware between different units along the furnace line (Fig. 2). The automated loader picks up loads from the loading station and transports them to the desired locations within the line.

The control system of the vertical vacuum IQ furnace line incorporates internal communication and diagnostic capabilities. It can identify and diagnose disturbances or anomalies during operations, facilitating prompt troubleshooting and resolution.

The SCADA system provides hierarchical user access privileges, allowing controlled access to specific functionalities within the system. This ensures proper authorization and security in managing the furnace line operations.

The control system of the furnace line can integrate with a temperature data collection system, enabling seamless data acquisition and analysis. This integration contributes to process monitoring, quality control, and optimization of cycles. The SCADA allows operation at a remote desktop location. The "lights-out" automation promotes higher production with less human error.

CONCLUSION

The development of the vertical vacuum IQ furnace line has expanded the operational use of traditional IQ vacuum furnaces with a larger working zone. The integration of automation systems enables flexible operation modes and enhanced control over the heat treatment processes as well as a reduction in labor for processing hardware. Although not currently utilized by Rex Heat Treat, the furnace line has the capability for low-pressure carburization, offering the potential for future applications in low-pressure carburizing processes. **~HTPro**

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