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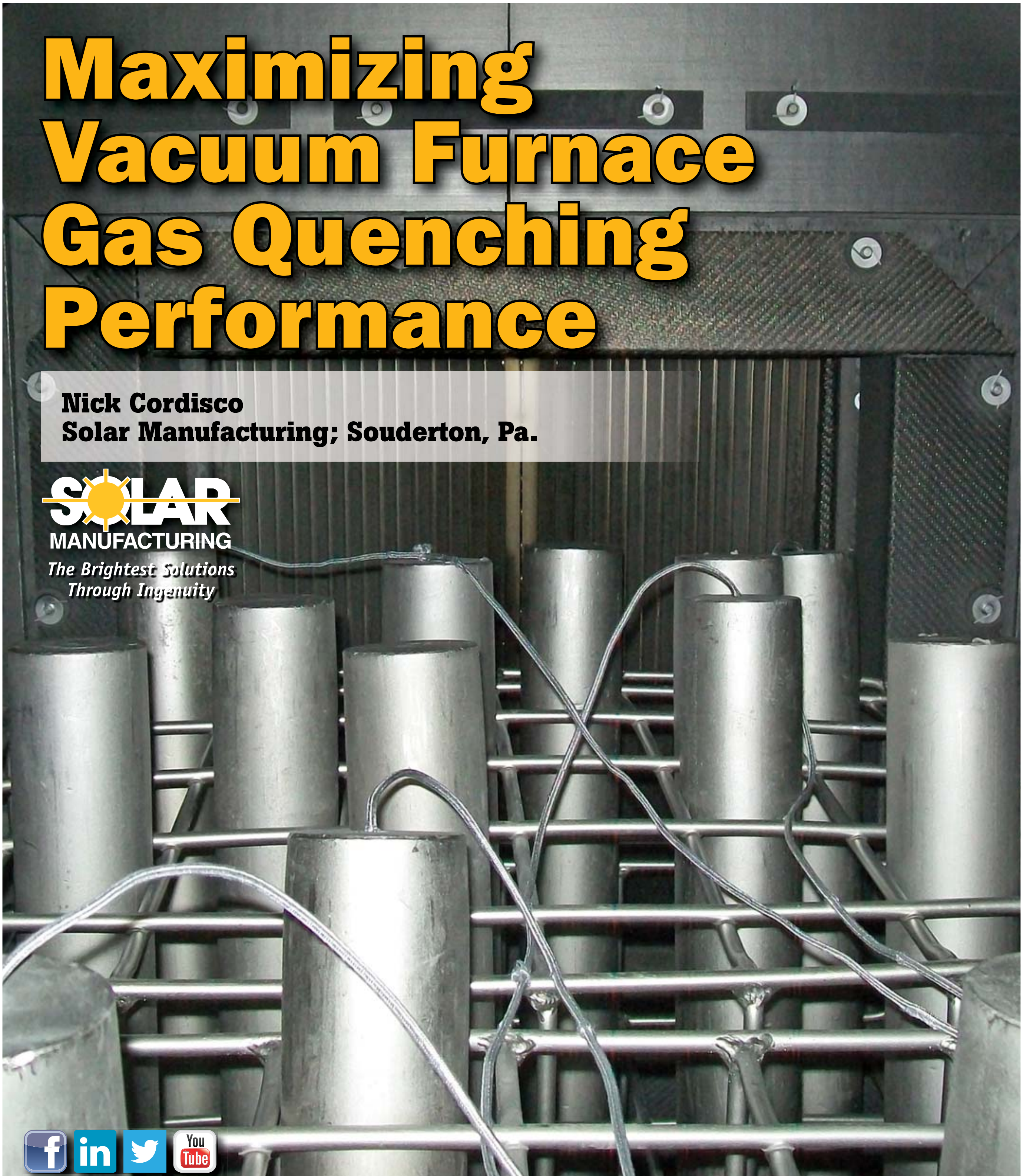

Maximizing Vacuum Furnace Gas Quenching Performance

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Maximizing Vacuum Furnace Gas Quenching Performance

Fig. 1. Test load used for data collection

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There are many critical factors that engineers must consider when designing a new, high-performance gas-quenching vacuum furnace, including:

- Proper fan design to achieve maximum gas flow
- Creating a minimal flow-resistance path for the recirculating gas
- Consideration of the types of cooling gases to be used
- A method to optimize the cooling system's available power

Most vacuum furnaces are designed to operate at maximum pressure for a specific gas type (nitrogen, argon, helium, hydrogen). This approach sacrifices system performance at pressures lower than the optimal pressure as specified by the design. It also lengthens cycle time and creates extreme performance limitations when implementing other gases. To compensate for the change in gas density, quench pressure and/or fan speed decreases. Since using argon as well as nitrogen is often a requirement in many heat-treating facilities, these issues are a cause for concern.

Synchronous Design Concept

In order to overcome many of the disadvantages that exist on current vacuum furnaces, Solar has implemented a synchronous design concept in its new high-pressure-quench furnace. Key components of this design include:

- Utilizing a variable-frequency drive (VFD) to "over-speed" the cooling-fan motor
- Selecting a specially designed motor that can withstand the "over-speed" conditions
- Designing an appropriately sized fan to operate across the entire pressure range

Comparing Synchronous to Conventional Design for Two Gases

As opposed to traditionally designed vacuum furnaces, the synchronous approach allows the cooling system of the furnace to operate at the high motor-speed range

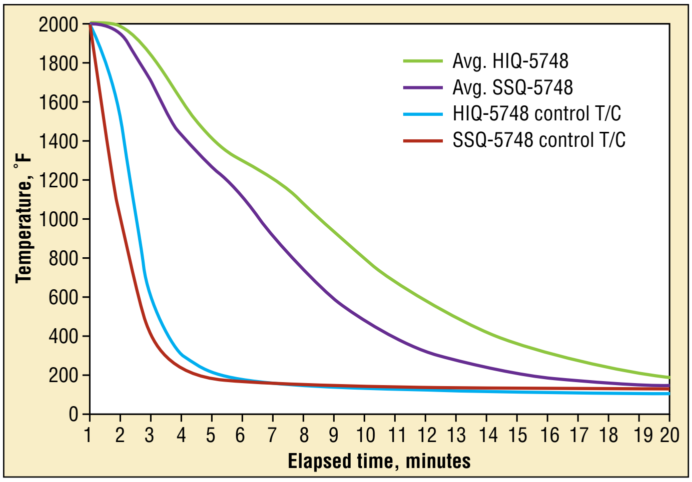

Fig. 2. 10-bar comparison (average work temperature) – SSQ-5748 vs. HIQ-5748

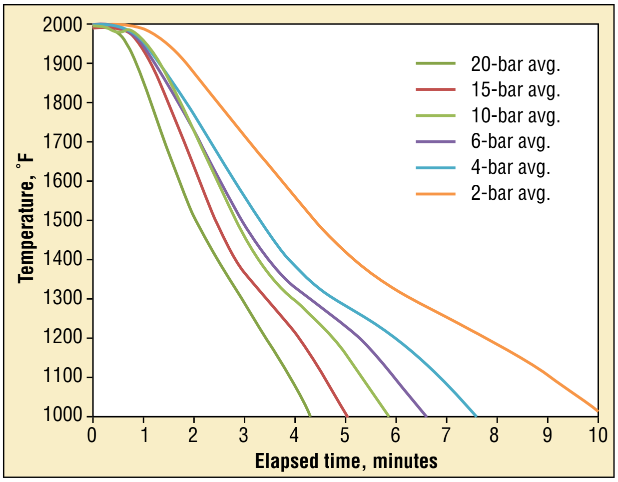

Fig. 3. SSQ-5748 average work temperature vs. time (varying pressure)

using nitrogen and at a slightly reduced speed with argon while maintaining the same pressure. Full horsepower can be utilized because the operating speed is still above the synchronous motor speed. Table 1 is normalized to compare the relative performance of each system when using nitrogen and argon gas.

Equating the relative performance of the two systems shows:

- Nitrogen: 7,200/7,200 = 1
  The two systems provide equal relative cooling for nitrogen at this pressure.
- Argon: 6,468/5,220 = 1.24
  This illustrates the improved relative cooling (24% better) when using argon in the synchronous system as compared to the conventional system.

Applying the Synchronous Design to New 20-Bar Vacuum Furnace

The synchronous design with its VFD was recently incorporated into Solar's newest 20-bar Super Quench vacuum furnace (SSQ). This recently manufactured and installed system has gone through an extensive testing program to fully compare its performance to prior conventional designs.

This furnace has a work zone that measures 36 inches wide x 36 inches high x 48 inches deep with a gas cooling system incorporating a 300-HP motor. The test load in Figure 1 was selected to represent a typical load for this size furnace and has been used on all tests and illustrations that follow. The test load incorporated:

- 20 steel bars, each measuring 3 inches O.D. x 28 inches long
- Six work baskets and one supporting grid
- Total load weight of approximately 1,300 pounds
- Seven T/Cs throughout the load to measure the core temperature

The cooling test procedure was as follows:

- The same load was used for all tests.
- Nitrogen was used as the cooling gas.
- The load would be quenched from 2000°F.
- The quench pressure was varied to obtain performance data.
- Quench pressures were 2, 4, 6, 10, 15 and 20 bar.

Comparison of Conventional 10-Bar Furnace and Synchronous Design Cooling at 10 Bar

In order to demonstrate the improved cooling of the newly designed 20-bar furnace, Solar proceeded with a test in a 10-bar furnace cooling at 10-bar pressure using the same load and compared that with a test from the 20-bar furnace cooling at 10 bar. The 10-bar conventional design is identified as the HIQ-5748 furnace, while the 20-bar furnace is identified as the SSQ-5748 furnace. Figure 2 illustrates the significant improvement of the synchronous design versus the conventional design.

The synchronous design cooling at 4-bar backfill pressure produced the same cooling performance as the conventional design cooling at 10-bar backfill pressure. That means the same results were achieved using 60% less gas.

Table 2 shows the unique varying components of the synchronous design as pressure increases.

Testing SSQ-5748 at Various Gas Pressures

The next series of tests involved processing the same test load across various gas pressures ranging from 2 to 20 bar (Figure 3). This illustrated the excellent cooling rates that can be achieved using the synchronous design.

These results also demonstrated cooling rates that could be applied to certain oil-quench-grade materials to achieve desired properties that were previously thought not possible with gas quenching. Further studies are now under way to establish which materials of a given cross-section could be processed in this style furnace.

Conclusions

Based on this comprehensive test data, the resulting conclusions are:

- Incorporating a VFD into a gas-quenching system allows for excellent versatility regarding gas cooling at different pressures and when using different gas types.
- Operating at or above synchronous motor speed maximizes system performance.
- The synchronous design concept allows using the largest possible fan to maximize efficiency across the entire pressure range.
- The SSQ furnace will allow gas quenching to replace oil quenching on certain materials, thus greatly improving part stability and any need for further post-process operations. **IH**

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Table 1. Relative performance comparison – argon vs. nitrogen

	Conventional design		Synchronous design	
	Nitrogen	Argon	Nitrogen	Argon
Pressure (P) - bar (a)	2	1.45	2	2
Density (r) - lb./cu.ft.	0.148	0.148	0.148	0.204
Speed (N) - RPM	3,600	3,600	3,600	3,234
Product of P x N	7,200	5,220	7,200	6,468
Relative HP used, %	100	100	100	100

Table 2. Effect of pressure increases

Gas backfill pressure	Frequency (Hz)	Motor speed (RPM)	Motor current (amps)
2 bar	113	3,291	325
4 bar	90	2,628	334
6 bar	77	2,261	327
10 bar	63	1,850	314

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