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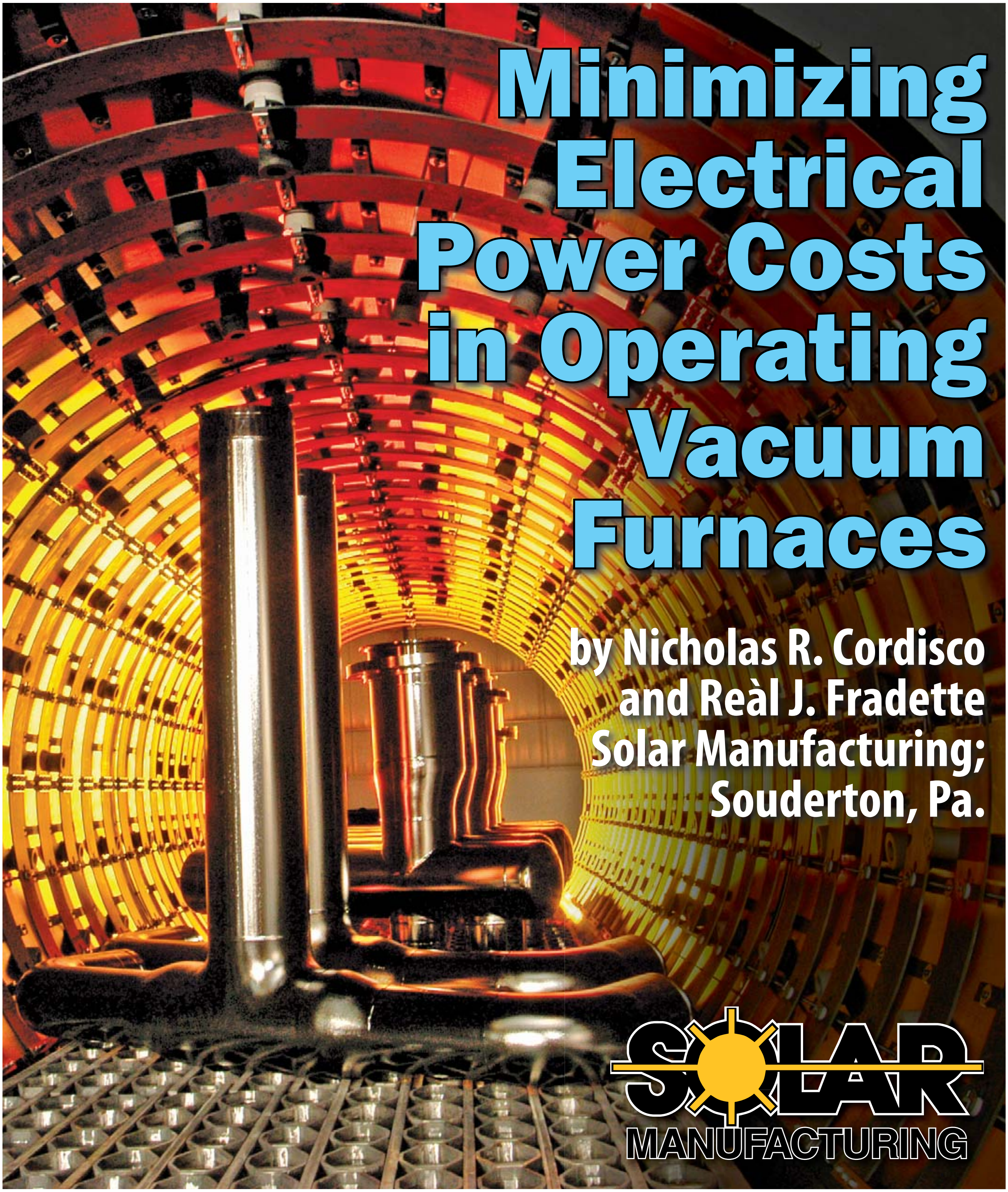

Minimizing Electrical Power Costs in Operating Vacuum Furnaces

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Minimizing Electrical Power Costs in Operating Vacuum Furnaces

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With the increasing concern relating to electrical power costs for operating vacuum furnaces, it has become essential that all aspects of furnace cycle parameters and hot-zone efficiencies be thoroughly considered. Solar Atmospheres and Solar Manufacturing have concluded an extensive study on various power considerations as they relate to optimizing production while minimizing operating costs.

Utilizing one of our medium-sized horizontal furnaces, a Solar Manufacturing Model HFL–5748 with workload dimensions that measure 36-inch wide x 36-inch high x 48-inch long, several cycles were run to establish baselines for different heating and load conditions.

An initial cycle was completed heating an empty furnace and stabilizing at different temperatures to establish furnace power "losses" at these temperatures. Power measurements were recorded using a Fluke Model 1735 Power Logger, which provides true RMS power data. Thermocouples were also placed in several areas of the hot zone to create a temperature profile across the hot-zone insulation to determine different temperature gradients and furnace insulation efficiencies.

From this initial test, a "Power Loss versus Temperature Curve" for this particular hot zone was plotted. This chart allows the user to predict furnace losses at any specific temperature. The losses for this hot-zone construction were then plotted against other hot-zone designs to compare efficiencies of each type (Fig. 1). As is illustrated, a significant difference exists between the designs, demonstrating the need for the end-user to evaluate which design becomes most cost effective over the life of a given hot zone.

Electrical Power Cost

In reviewing a typical monthly power bill as provided by our local electrical provider, P.P.L. of Allentown, Pa., most electrical suppliers break their charges into two major categories. These are:

1. The total energy consumed (kWh) for the month.
2. A supplemental charge based on peak power demand (kW). The peak power demand is the highest single power reading for the month over a 15-minute period.

As one can see from these charges, reducing total energy consumption or minimizing peak power demand can significantly affect final cost. It should be noted that each power company uses different billing rate structures for energy usage and for peak demand. We know that one power company charges as little as $2.30/kW for peak demand, while several East Coast companies average $11.00/kW for this charge. We also know that one supplier charges $29.00/kW for peak demand.

Our study was to try to determine the impact of furnace heating rates to total energy usage and peak demand, with the objective of reaching conclusions as to the best recommended heating rate for given billing structures.

The furnace tests were performed first using an empty furnace (Fig. 2) and then heating a 1,000-pound load, ramping at different heating rates. The load consisted of three Inconel baskets filled with various sizes of stainless steel pipes that established the total weight. All tests went from room temperature to 2000°F with three different heating rates: 10°F/minute, 15°F/minute and 20°F/minute. Tests recorded both peak power demand and energy usage versus time. The two graphs

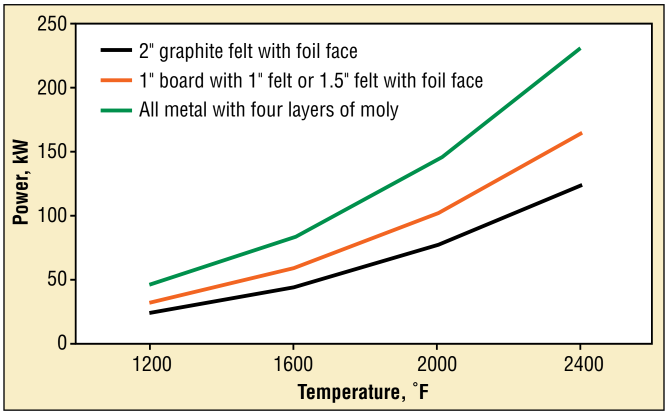

Fig. 1. Furnace power losses for different hot-zone types


Fig. 2. Empty furnace used for testing

show the furnace heating characteristics superimposed for the three heating rates (Figs. 3 & 4).

Based on our charts, Table 1 could be created for heating the 1,000-pound load. Using Table 1, we can now calculate cost for geographical areas based on several different electrical-service billing rate structures. Where the peak demand is $2.30/kW, energy is $.08/kWh. Where the peak demand averages $11.00/kW, the rate averages $.10/kWh. Where peak demand is $29.00/kW, the rate is $.11/kWh. Using the electrical data obtained from the three heating tests, we can calculate and compare the total cost per cycle for the different billing rate structures. Please note that our calculations are based on processing 50 production cycles per month.

As the comparisons in Table 2 demonstrate, the first example reflects very little variations in cycle cost. This means that the user should run his work as fast as the load can be processed to optimize throughput. The second example begins to reflect the impact of peak demand cost to total cycle cost (between 50% and 65%) and the overall cycle cost based on the different heating rates. The third example illustrates how critical peak demand now impacts total cycle cost and must be seriously considered when trying to establish the best heating rate for optimizing furnace production.

Using the 15°F/minute heating rate as an average, we can now look at the impact of peak demand pricing on total cycle cost. One could use Table 3 to estimate the approximate percent of any peak demand cost as it relates to total cycle cost for different electrical rates within a given electrical provider's area. Also, as stated previously, our calculations were based on a conservative utilization of 50 production cycles per month. The influence of peak demand cost on total cycle cost will obviously be affected based on the number of cycles processed in a given month, which is a very important point.

Hot-Zone Efficiencies

As one can also see from Figure 1, the power "losses" for a given type of hot zone will have a significant impact on the final operating costs. Our tests were performed with a furnace that had a hot zone incorporating four layers (1/2 inch each) of graphite felt with a graphite foil hot face. From Figure 1, we know that at 2000°F, the peak loss is approximately 78 kW, resulting in a watt density value for this hot zone equating to 7.1 watts/inch^2 at 2000°F.

If a facility has a furnace with a hot zone using three layers of graphite felt or 1-inch graphite board backed by two layers of graphite felt, Figure 1 shows that this hot zone would have a peak loss at 2000°F of approximately 103 kW. We can also see in Figure 1 that the all-metal hot zone has losses at 2000°F that peak at 145

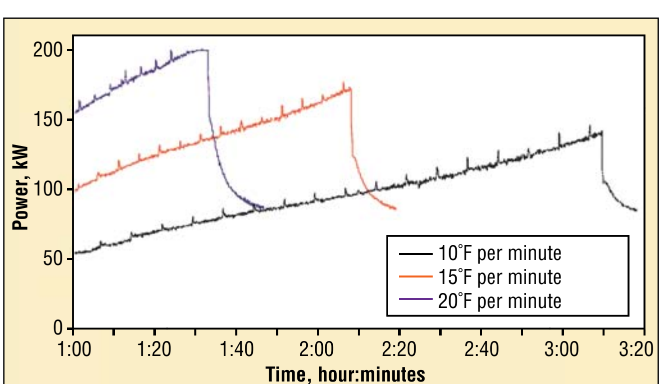

Fig. 3. Furnace hot-zone power demand

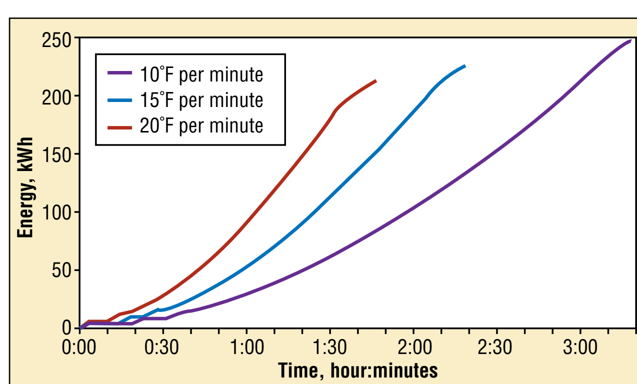

Fig. 4. Furnace hot-zone energy usage

kW. It should be noted that the all-metal hot zone is necessary in certain applications, but it must also be stated that this all-metal design is very inefficient and costly to operate. However, the hot zone used in this test and the second insulated hot zone described above certainly can be compared.

Table 1. Energy information for heating of the 1,000-pound load

Heating rate	Heating energy (kWh)	Pumping system energy (kWh)*	Total energy (kWh)	Peak power demand (kW)	High 15 minute average (kW)
10ºF/minute	247	33	280	140	135
15ºF/minute	225	23	248	174	168
20ºF/minute	212	18	230	200	194

*This value represents how much energy was consumed by the pumping system operating in a conservation mode. It would be higher without this feature.

Table 2. Compares the total cost per cycle for the different billing rate structures

Heating rates	Total energy cost	Peak demand cost	Total cycle cost
Cost for $.08/kWh and $2.30/kW			
10˚F/minute	$22.40	$6.21	$28.61
15˚F/minute	$19.84	$7.73	$27.57
20˚F/minute	$18.40	$8.92	$27.32
Cost for $.10/kWh and $11.00/kW			
10˚F/minute	$28.00	$29.70	$57.70
15˚F/minute	$24.80	$36.96	$61.76
20˚F/minute	$23.00	$42.68	$65.68
Cost for $.11/kWh and $29.00/kW			
10˚F/minute	$30.80	$78.30	$109.10
15˚F/minute	$27.28	$97.44	$124.72
20˚F/minute	$25.30	$112.52	$137.82

Table 3. Shows the impact of peak-demand pricing on total cycle cost

Peak demand rate	Peak demand cost	Total cycle cost	% of total cycle cost
$2.30/kW	$7.73	$27.57	28%
$11.00/kW	$36.96	$61.76	60%
$29.00/kW	$97.44	$124.72	78%

Table 4. Monthly and yearly hot-zone cost comparison based on peak demand costs

Peak demand and energy cost	Hot zone 1	Hot zone 2	Added cost per period
Monthly @ $2.30/kW & $.08/kWh	$1,171	$1,337	$166
Monthly @ $11.00/kW & $.10/kWh	$2,098	$2,508	$410
Monthly @ $29.00/kW & $.11/kWh	$3,626	$4,499	$873
Yearly @ $2.30/kW & $.08/kWh	$14,052	$16,044	$1,992
Yearly @ $11.00/kW & $.10/kWh	$25,176	$30,096	$4,920
Yearly @ $29.00/kW & $.11/kWh	$43,512	$53,988	$10,476

Evaluating the two insulated hot zones, we can illustrate the added annual cost of one over the other when considering hot-zone power losses as related to added energy consumed and higher peak demand required. This comparison is based on 50 production cycles per month and a 15°F/minute heating rate. As one can see, the results in table 4 demonstrate the advantage of having a more efficient hot zone when selecting a new furnace or replacing an existing hot zone for an older furnace.

Conclusions

- When focusing on optimizing production in vacuum-furnace operations while trying to minimize electrical power costs, it is essential to review and understand your present electrical-power billing structure.
- Peak power-demand costs represent a substantial part of electrical billing.
- Hot-zone losses can be minimized by using more efficient designs. Initial capital investment will be quickly recovered based on the resulting electrical cost savings.
- Peak power-demand costs are largely dictated by furnace heating rates.
- When peak demand costs are a minimal concern, heating rate should be established based on load composition and desired throughput. **IH**

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