CONSERVING ELECTRIC POWER

PART II

An engineer looks at ways to save dollars.

by William R. Jones*
Solar Atmospheres Inc.
Souderton, Pa.

Examining electric power consumption in a heat treatment facility can be a challenge, especially when it is undertaken in an effort to reduce operating costs. Any effort in this direction is definitely worthwhile when the magnitude of today's electric power pricing is taken into account. And, it can readily be done via measurements and calculations. Of course, it also helps to know what to look for and how to proceed. Toward that end, this article addresses the often overlooked power factor and what can be done to minimize power factor penalties, thereby minimizing electric power expenses for metal heat treating operations.

In Part I published in November 2002, operating costs for plant lighting, electric motors, electric furnace heaters, and high-vacuum diffusion pumps were reviewed for demand and load factor along with subsequent adverse effects on the electric utility bill.

Batch furnaces and load factor

Today, electric furnaces generally operate with programmable temperature controllers so that the heating rate ramps, usually in °C/min (°F/min) or °C/h (°F/h), can be preprogrammed. The advantage is to allow the furnace to be programmed to fit a specific metallurgical application. A typical example is heating from ambient temperature to a preheat temperature at a specific rate, soaking for preheat, and then ramping to the final high heat temperature and soak for a typical tool steel, annealing, or brazing application.

Unfortunately, the effect of electric power demand for a fixed rate temperature ramp is often overlooked. Fast heating rates in excess of 8°C/min (15°F/min) will decidedly peak electric power demand, which can be very costly, as noted in the previous article. Fortunately, there is a simple way to prevent electric power peaking with batch type furnaces: by presetting an output power limit into the temperature programmer.

In production, a single ramp program with an adverse peak power load of 375 kW (Fig. 1) can be costly. This can be avoided by simply using a 100 kW lower output limit setting. Here, the workload is raised to the same temperature, which entails an extended heating time of 10 min but, notably, electric power demand drops by an impressive 40% (Fig. 2). The reduced power demand and dollar savings in the electric power bill is significant, while the 10 min added to the overall process cycle is minimal.

Most electric furnaces have power supplies designed to heat the furnace to a maximum temperature with a

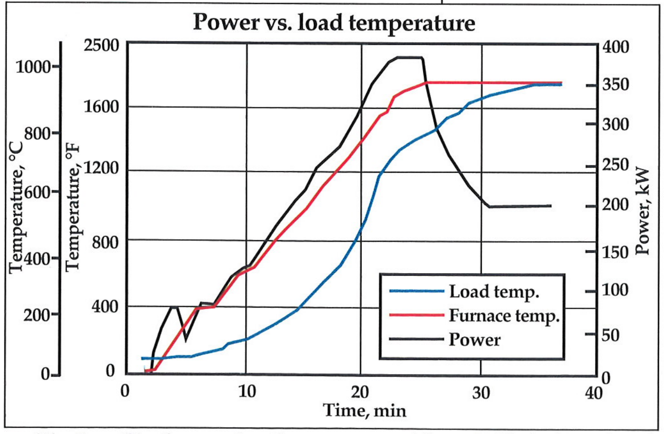

Fig. 1 — Single ramp heating program with an 8°C/min (15°F/min) ramp rate exhibits an adverse power peak at 375 kW. Data shown for AISI type 304 stainless steel can workload weighing 1360 kg (3000 lb).

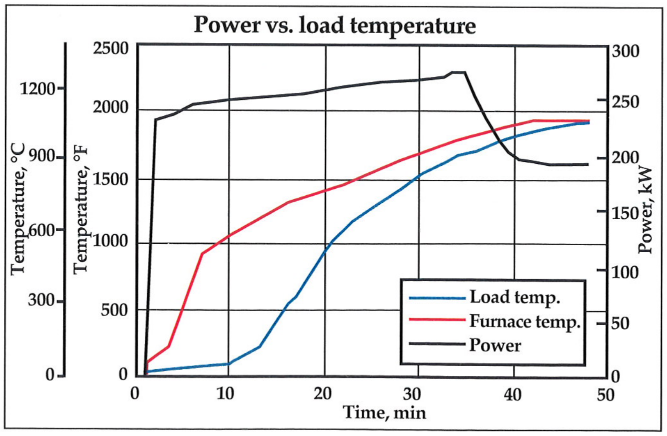

Fig. 2 — Limiting power output to 100 kW lower than Fig. 1 decreases electric power demand by 40%. Data shown for type 304 stainless steel can workload weighing 1360 kg (3000 lb).

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*Fellow of ASM International

Power factor penalty

Power factor can best be understood as consumed power that does no work. This is usually the result of electric motor loads or reactive magnetic loads like transformers. Phase angle fired SCRs also fall into this category.

It can be measured, or calculated as:

$$\text{Power factor} = \text{kW (real power)}/\text{kV} \times \text{amps (apparent power)}$$

Fig. 3

VARs: The out of phase component

The out of phase component is often referred to as VARs and can be measured with a meter, or calculated as:

$$\text{VARs} = \text{volts} \times \text{amps} \times \sin\phi,$$

where $\sin\phi$ is the phase angle between the current and voltage.

Billings in kW may or may not include paying a power factor penalty to the electric utility.

Billings in kVA probably include power factor penalties. An operating power factor of 0.5 (50%) can double an electric bill.

Fig. 4

Power factor penalties by state and utility

State	Utility or city	Billing, penalty
California	SoCal Edison	kVA means a penalty
Connecticut	United Illuminating	kW only, no penalty
Delaware		kW only, no penalty
Georgia	Georgia Power	Minimal penalty
Massachusetts	Mass. Electric	Greater kW or 90% kVA
Michigan	Detroit Edison	70–85% get a penalty; if <75% customer must fix it
New Jersey		kW only, no penalty
New York	Niagara Mohawk	kW + low power factor penalty
	Central Hudson	Primary power only for penalty
	Long Island Lighting	Minimal power factor penalty
Ohio	Ohio Edison	kVA means a penalty
	Cleveland, Toledo	Low power factor penalty
Pennsylvania	PECO	Power factor multiplier
	PP&L	kW only, no penalty
Virginia	Virginia Power	Minimal power factor penalty

maximum design load. In normal production when a furnace is operated at less than maximum temperature or with less than maximum design weight, the power required to provide the necessary heating rate can be greatly reduced. Imposing an output power limit via the temperature programmer/controller prevents an overpower condition, particularly with an unintentional or unnecessary heating rate ramp.

Power factor focus

A somewhat more difficult subject for those unfamiliar with electric power usage is power factor. Its effect on the electric power bill can be significant if your electric utility either charges a penalty for operating at a power factor less than unity or bills in kVA rather than kW. The relationship between kW and kVA is explained in Figures 3 and 4.

Electric furnaces that operate with resistance heating elements connected directly across the power line, or other electric power loads in the plant like incandescent lighting, operate at near unity power factor. However, electric furnaces that utilize saturable core reactors (Fig. 5) or phase angle fired silicon controlled rectifiers (SCRs) — interposed between the power line and the resistance heating elements for electric power control (temperature control) — typically operate at lower or considerably lower than unity power factor. This is due to the inherent operating principle of the control device. In practice, the difference between interposing variable reactors or phase angle fired SCRs for control purposes and newer technology power supplies is significant (Fig. 6).

Utilities penalize users in different ways for power factors (Fig. 7), with penalties varying according to loca-

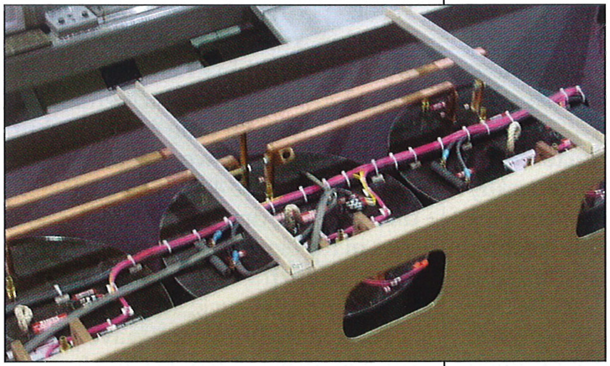

Fig. 5 — Typical saturable core reactor (magnetics) power supply operates at lower than unity power factor.

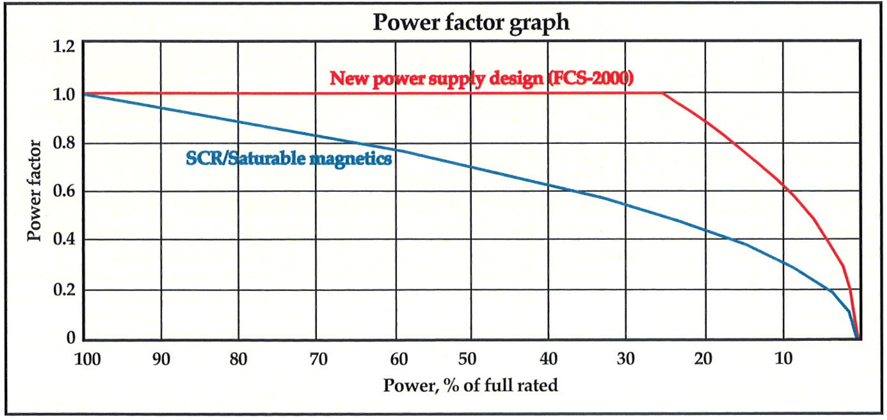

Fig. 6 — Newer technology power supply operates at optimal power factor as compared to variable reactors at less than unity power factor and a subsequent cost penalty.

Power factor penalties for different power utilities

- Some power companies that bill in kW only have no penalties.
- Some ratio up the billing demand for low power factor.
- Some bill in kVA, which means a low power factor penalty.
- Some power companies have low power factor penalties, which tend to be minimal.

Fig. 7

tion (see table). If not operating at maximum power condition, once many electric furnaces reach temperature and soak out the workload, they will operate between 40% and 50% of full power. For a typical furnace, running at such a reduced power factor will double the cost of electric power from \$0.10 to more than \$0.20/kVA. Operating at a reduced power factor is indeed costly, as indicated by the resulting penalty in ¢/kVA (Fig. 8).

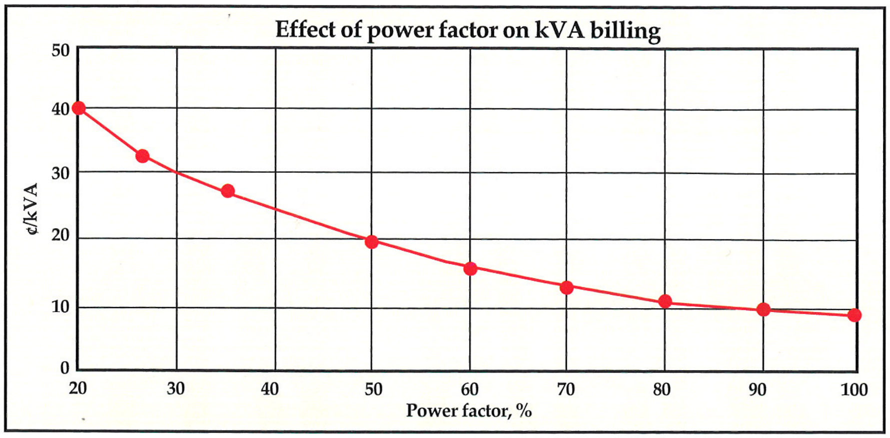

Fig. 8 — Cost penalties result from operation at reduced power factors.

Fig. 9 — Installed on a vacuum furnace with graphite heating elements, a 255 kW smart power supply (FCS-2000) combined with a tapped power transformer has operated for more than 10,000 hours.

Newer technology

In operating an SCR power supply connected directly to the heating elements, an engineering choice between a phase angle fired SCR or a zero crossover SCR can be made at purchase. Overall, the zero crossover SCR operates at near unity power factor and is a better choice over the older SCR phase angle fired device. However, a zero crossover SCR cannot be connected to the line side of a transformer. If this should be done, the transformer magnetics saturate, blowing the line fuses for the SCR and halting operation.

Over the last several years, a new type of power supply with newer technology microprocessors has been developed. Coupled with tapped power transformers, it allows a zero crossover SCR to properly drive a transformer without transformer saturation. Such a power supply installation is suitable for vacuum furnaces (Fig. 9). This power supply operates at near unity power factor and also compensates for the difference in resistivity (cold to hot) for either molybdenum or graphite heating elements. It can also operate special atmosphere furnaces that utilize silicon carbide or molybdenum disilicide heating elements that experience resistance changes over a ratio greater than 10 to 1 — an often difficult task for older SCR power controllers.

Not unexpectedly, technology and innovation comes at a price, with the newer power supply commanding a higher initial capital cost than older designs. Fortunately, the breakeven point is reasonable. In one plant operating multiple large vacuum furnaces that incorporate the newer power supplies, the higher initial capital cost was recovered in the first year of operation through reduced electric power utility bills, thanks to operation at near unity power factor.

With the utilization of a temperature/programmer controller and output limit settings, additional electric power savings can be realized with only a marginal increase in overall process cycle time. **HTP**

For more information: William R. Jones is CEO, Solar Atmospheres Inc., 1969 Clearview Road, P.O. Box 64476, Souderton, PA 18964-0476; tel: 215/721-1502; fax: 215/723-5039; e-mail: wrj@solaratm.com; Web: www.solaratm.com.

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Bruce A. Ruhf, Solar Atmospheres Mfg. Inc., Magnetic Specialties Div., 164 Keystone Drive, Telford, PA 18969.

James L. Watters, Delaware Valley Utility Advisors, 1939 Armstrong Drive, Lansdale, PA 19446.

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