there's NO SUCH THING as a FREE LUNCH

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We at INEX are often asked if composite radiant tubes are more efficient or if they will make a heat-treat furnace more efficient. Those questions are spurred by confusion over the terms "efficiency" and "capability."

Thermal efficiency is quite simply the net heat transferred to the load divided by the gross input. This is a direct function of the type of burner, furnace design, refractory insulation (type and condition) and the proper adjustment of the combustion system. For example, deteriorated refractory brick or fiber can significantly increase wall and roof energy losses. Similarly, too much excess air can have a dramatic lowering of burner efficiency. This is precisely why frequent analysis of exhaust gas is recommended.

Capability, on the other hand, is simply an expression of how much work can be done in a given amount of time. This term is independent of efficiency but is interwoven into the same discussions. Users can elect to do more work, provided the system is "capable," but the effect on efficiency cannot be ignored. For example, heat treaters that want to shorten the cycle of a batch furnace or speed up the belt on a continuous furnace are really saying they want to do more work. Since, in these cases, work can be defined as the energy required to heat the load (net heat), the only way to do more work is to increase the gross input.

This is where the confusion begins when comparing composite (silicon/silicon carbide) tubes with metal-alloy tubes. This relationship requires a detailed explanation, so please read on. The equation below is used to calculate the heat transfer by radiation from a radiant tube.

$$Q = \sigma\, e\, (T^4_{Tube} - T^4_{Load}) \times A$$

Q = Heat Transfer (BTU/hour)
σ = Stefan-Boltzmann Constant
e = Emissivity of the tube
T_{Tube} = Temperature of tube °R
T_{Load} = Temperature of load (set point)
A = Surface area of the tube

The reader is advised not to give up on this discussion. If you want to transfer more heat (do more work), what are your options? You can't change the Stefan-Boltzmann number because it is a constant. The *"e"* term for emissivity is a material characteristic that is not a variable. In fact, at heat-treat temperatures, the emissivity of metal-alloy tubes and silicon-carbide fused materials are virtually identical. Assuming for a minute that tubes of equal size are used (composite vs. metal alloy), then the surface area is identical. The set point (T_{Load}) is determined by metallurgical considerations and is, therefore, not a variable.

What's left if you want to do more work (increase Q)? The only option available is to increase the tube temperature. Even a casual observer will note that the temperature in the equation is raised to the 4th power and that increasing the tube temperature even a little will provide the "capability" to do a lot more work. This is where the discussion gets interesting, so don't give up yet.

How do you raise the tube temperature? Here's where the no free lunch part comes in. If you want to do more work, you have to increase the energy input or, in simpler terms, fire harder. Users of metal-alloy tubes can and sometimes do increase the firing rate in order to raise the tube temperature.

The problem with this approach is that as the tube temperature goes up, so does the creep rate. Creep is the mechanism that leads to deformation of the tube over time and ultimately to failure or rupture. The rate of creep is dependent upon load and temperatures. The load in this case is the weight of the tube. Since the weight of the tube is fixed for purposes of this discussion, it can be considered a non-variable.

Temperature, however, is another matter. The rate of creep is accelerated by higher temperatures. The result is shorter time to failure. This is precisely why firing alloy radiant tubes harder leads to shorter tube life. Simply put, the capability of metallic radiant tubes is limited. Silicon/silicon carbide tubes also creep, but even at elevated temperatures (up to 2450°F) the creep rate is so low that the tube life is unaffected (see figure at left).

The conclusion is that composite tubes are capable of delivering more energy to the load (doing more work). How is that possible? The answer is raising the tube temperature (without worrying about shortening the life). How do you raise the tube temperature? The answer is by firing harder (putting in more energy). Why do this? To get more work through the furnace.

There is no free lunch, but there is definitely the opportunity to process more material in a shorter period of time. Some people call that productivity! That is why silicon-carbide tubes are gaining popularity worldwide.

By the way, if you call the author he will be glad to take you to lunch. Fair warning: The superior performance and long life of silicon/silicon carbide composite tubes will definitely be a "free" lunch topic of conversation.

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