Application Bulletin

Heat Treating Furnaces

Introduction

Operators of all intermittent furnaces are facing significant operating cost increases due to constantly increasing fuel costs. This is particularly true in the heat treating industries where fuel is one of the largest cost components of operations. Increasing world demand for energy and political instability in energy-producing countries has caused commodities analysts to forecast that energy costs will continue to increase throughout this decade. High temperature processing efficiencies can be gained by employing the latest burner or controller technologies or by using insulation to its fullest advantage. EMISSHIELD® high emissivity coatings[1] present a further opportunity to gain additional savings.

What is EMISSHIELD®?

EMISSHIELD® is a family of high emissivity ceramic coatings manufactured by Wessex, Inc. based on patented technology licensed from NASA. The NASA emissivity technology is the latest available that was developed for the next generation of space vehicles that is intended to replace the existing shuttle fleet when it is retired in 2010 (Figure 1).

Figure 1 - X-33 Orbiter

[1] US Patent 6,921,431, Other Patents Pending

Wessex has combined their own patented binder systems with the NASA technology to produce high emissivity coatings that will strongly adhere to dense refractories, insulating fire brick, refractory ceramic fiber, and most metals. Coating heat treating furnace refractories with EMISSHIELD® will provide more even heating, increased productivity, longer refractory life, and fuel savings.

How Does EMISSHIELD® Work?

EMISSHIELD® is not an insulator. It is not a barrier to the conduction of thermal energy through a furnace wall. Insulating refractories are generally placed behind dense refractories at the cold face of refractory linings. While this reduces heat loss from a furnace, the amount of heat stored in the refractory is increased and the refractory materials must withstand higher mean temperatures. Because the working lining acts as a heat sink, valuable process energy (Figure 2) is repeatedly lost during cyclical operation.

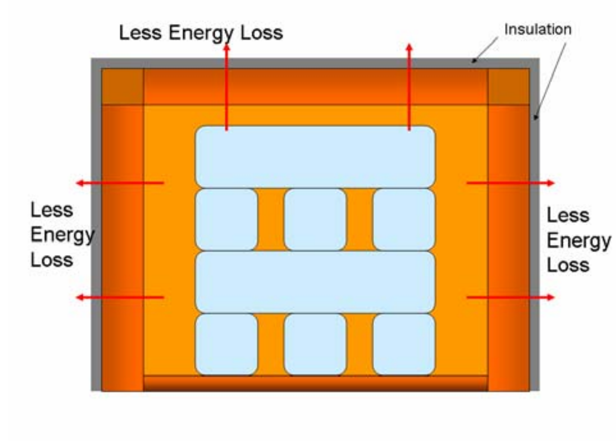

Figure 2 - Reheat furnace with insulating refractory backing up dense refractory working lining.

When EMISSHIELD® is used, it is applied to the hot face of the furnace (Figure. 3). Radiant and convective energy from the burners and hot furnace gases are absorbed at the surface of the coating and re-radiated to the cooler furnace

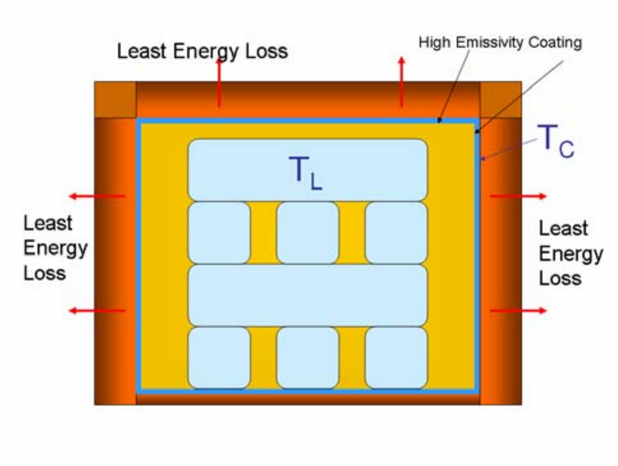

Figure 3 - Reheat furnace with EMISSHIELD® high emissivity coating applied to the refractory hot face. The thermal energy absorbed by the coating, T_C, is re-radiated and absorbed by the colder load, T_L. The refractory lining is subsequently cooler and retains less heat energy.

load. It is important to remember that for EMISSHIELD® to be effective, the temperature of the coating surface must be greater than the temperature of the furnace load. The amount of heat re-radiated from EMISSHIELD® is predicted by the following equation:

$$Q = E_w \cdot \sigma \cdot (T_C^4 - T_L^4)$$

Where: Q = re-radiated energy absorbed by the furnace load
E_w = emissivity of the coating
σ = Stefan-Boltzmann constant
T_C = coating temperature
T_L = load temperature

Since the temperature of the coating and the temperature of the furnace load are raised to the fourth power, it is apparent that EMISSHIELD® absorbs and re-radiates the most energy when the temperature difference between the coating and the load is the greatest.

Application of EMISSHIELD® in Heat Treating Furnaces

Unlike the use of insulating materials that have predictable performance characteristics under steady state conditions, the benefits of using EMISSHIELD® depend greatly upon furnace design and operating parameters. Uncoated refractories have emissivities, E_w, in the range of 0.3-0.5 at heat treating temperatures. The application of EMISSHIELD® to the refractory increases the emissivity of the refractory to about 0.9. This means that about 90% of the energy absorbed by the coating is re-radiated to the cooler furnace load. *The emissivity of the load dictates how much radiant heat will be absorbed.*

Referring to the equation in the previous column, it is easy to see that by increasing the E_w of the refractory, the heat absorbed by the furnace load, Q, will increase significantly. This is not desirable where carefully-controlled heat treatments must be maintained, so something else in the equation must be reduced to compensate for the increase of E_w, while maintaining a constant Q. The factor that must be reduced to maintain a constant Q is the temperature, and this is accomplished by turning down the burners. Of course, when the burners are turned down, fuel savings are gained.

In practice, the best way to adjust the burners to compensate for the increase in heat absorption by the parts being treated is to locate the furnace control thermocouple adjacent to the parts. Figure 4 shows the ideal thermocouple location for a casting being annealed. This thermocouple placement will automatically maintain the desired temperature of the furnace load by adjusting the burners to achieve the set

Figure 4 – Location of furnace control thermocouple adjacent to a cast pipe in an annealing furnace

point temperature. If the control thermocouple were located much further from the load, it may read a lower temperature from the coated refractories and call for more heat, potentially overheating the parts being heat treated. It is possible to use a remotely-located control thermocouple in an EMISSHIELD®-coated heat treating furnace when necessary; however, a means must be devised to correlate the load temperature before the EMISSHIELD® was applied to the temperature of the load after the installation of the coating. An optical pyrometer or other remote temperature measurement instrument could be used to insure that the temperature of the materials being treated remain at the desired temperature while new, lower burner settings are being established.

The greatest energy savings will be realized in furnaces that are heavily loaded. Ideally, the surface area of the EMISSHIELD®-coated refractory should approximate the surface area of the furnace load. Large furnaces containing small loads are not good candidates for coating with EMISSHIELD®. Small furnaces do not realize significant benefits when coated, regardless of the load. Furnaces that remain empty for long periods of time between loads should not be coated with EMISSHIELD®. If an empty coated furnace is held at temperature long enough, an *increase* in fuel usage may result. The EMISSHIELD® will still absorb more energy, but without a load to re-radiate to, this additional energy will be lost by increased conductance through the refractory. Generally speaking, the greater the thermal work being done in a heat treating furnace, the greater the potential fuel savings. This result is assured by applying EMISSHIELD® to large, fully-loaded furnaces.

Expected Results From Using EMISSHIELD®

When EMISSHIELD® is applied to refractory linings in heat treating furnaces, the coating absorbs up to three times more radiant and convective heat from the burner flames and hot furnace gases than uncoated refractory. Heat absorbed by the coating is immediately re-radiated to the cooler furnace load. More heat is made available; subsequently the flue gas temperature will decrease. Because less of the available heat is absorbed and stored in the furnace lining, the refractory materials stay cooler and are less subjected to thermal shock and thermally-induced stresses. Longer refractory life, especially in furnace doors, will result. Lower substrate temperature reduces devitrification and associated shrinkage of refractory ceramic-fiber modules, boards, and blankets. Consequently, the maintenance costs of fiber-lined furnaces coated with EMISSHIELD® are significantly lower.

Since EMISSHIELD® reduces the amount of heat being absorbed by the refractory, coated IFB linings and dense refractory linings behave more like low thermal mass linings. More heat is available to heat treat parts rather than heating the furnace lining or being lost out the flues. In addition to the obvious energy saving, the reduction of absorbed energy by the furnace lining allows faster heat-ups and quicker temperature recovery when cold loads are inserted into hot furnaces. This will shorten cycle time, increase furnace capacity and improve productivity.

When EMISSHIELD® is applied to furnace linings, the walls and crown become more efficient heat radiators. This improves the uniformity of radiant heating and the quality of the treated parts.

The most important benefit of using EMISSHIELD® in heat treating furnaces is fuel savings. EMISSHIELD® users routinely report fuel savings from 6% to over 20%, depending upon how their furnaces are designed and operated. The harder a furnace is pushed, the greater the fuel savings and the faster the payback will be. The Harbison-Walker EMISSHIELD® team will work with you to insure that you achieve the greatest benefit from your investment in this unique product.
