



Application Bulletin

Tunnel Kilns

Introduction

Operators of all tunnel kilns are facing significant operating cost increases due to constantly increasing fuel costs. This is particularly true in the brick and ceramics 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 coatings¹ present an 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. This latest NASA emissivity technology was developed for the next generation of space vehicles intended to replace the existing shuttle fleet when retired in 2010 (Figure 1).



Figure 1 - X-33 Orbiter

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

Wessex 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 tunnel kiln 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.

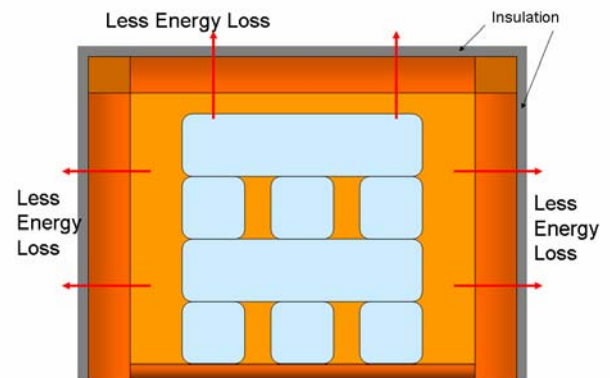


Figure 2 – Tunnel kiln cross-section with insulating refractory backing up dense refractory working lining.

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

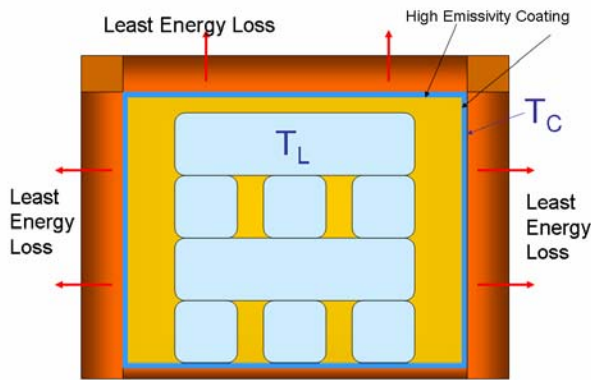


Figure 3 – Tunnel kiln cross-section with EMISSHIELD® high emissivity coating applied to the refractory hot face. The thermal energy absorbed by the coating, T_C , is re-radiated and absorbed by the colder load, T_L . The refractory lining is subsequently cooler and retains less heat energy.

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 kiln 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. Therefore, preheat and soak zones of tunnel kilns are coated with EMISSHIELD®. The cooling zone, where the fired ware is hotter than the refractory is never coated.

Application of EMISSHIELD® in Tunnel Kilns

Unlike the use of insulating materials that have predictable performance characteristics under steady state conditions, the benefits of using EMISSHIELD® depend greatly upon kiln design and operating parameters. Uncoated refractories have emissivities, E_w , in the range of 0.3-0.5 at tunnel kiln operating 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 kiln 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 kiln load, Q , will increase significantly. This may not be desirable where over-firing can change the properties or color of the ware being fired, 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 theory, the best way to adjust the burners to compensate for the increase in heat absorption by the kiln load is to locate the furnace control thermocouple adjacent to the load. In practice, tunnel kiln operation rarely allows this placement of the kiln control thermocouples. Control thermocouples usually measure the temperature of the kiln atmosphere and this approximates the temperature of the kiln load. When EMISSHIELD® is applied, the refractory emits absorbed heat which the load then absorbs and the refractory is cooler than the load. Traditional control thermocouple placement near the refractory will likely indicate a lower temperature than the actual ware temperature, resulting in the burners being turned up. This would cause the ware to be over-fired and fuel wasted. This condition is usually indicated by an increase in flue gas temperature.



It is possible to use a remotely-located control thermocouple in an EMISSHIELD®-coated tunnel kiln 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. Pyrometric cones or firing keys are also useful for insuring that the firing temperature of the load does not change after the EMISSHIELD® is applied.

Instead of turning down the burners to maintain a constant load temperature after the EMISSHIELD® is applied, the kiln car push rate can be increased to absorb the increased radiant heat without overheating the load. In some cases, this increase in productivity may be more economically attractive than the fuel savings.

Since EMISSHIELD® must be able to radiate absorbed heat to the furnace load, it is never applied on the refractory cold face, between the dense and insulating refractories, or on the furnace shell. The load must be “visible” to the coating for it to be effective. This means that some furnaces may not be ideal candidates for the application of EMISSHIELD®. Tunnel kilns, in which the refractory routinely becomes coated with condensed salts volatilized from the green brick body or combustion byproducts from alternate fuels, may not benefit from EMISSHIELD®. These deposits cover the coating, preventing the re-emission of absorbed energy.

The refractory to which EMISSHIELD® is applied can be dense brick, insulating firebrick, or ceramic fiber products. The substrate can have seen service and can be worn or corroded, but the surface must be free of dirt and oil and must not be friable or covered by any loosely-adhered mineral deposits or refractory wash coats. Figure 4 shows tunnel kiln refractory surfaces that have been successfully coated with EMISSHIELD®. These surfaces were spalled, corroded, and cracked, but still had solid

surfaces to which the EMISSHIELD® could adhere.



Figure 4 – Tunnel kiln refractories that have been coated with EMISSHIELD®.

All refractory repairs must be made prior to the installation of EMISSHIELD®. The coating should not be relied upon to fill cracks or joints.

EMISSHIELD® is sold on an installed basis and is sprayed by a Certified EMISSHIELD® Installer (Figure 5). Unless excessive surface preparation requiring sandblasting is necessary,



Figure 5 - EMISSHIELD® being sprayed in a tunnel kiln

the installation can usually be completed in one day. EMISSHIELD® will air dry in less than 24 hours and can be put into service the next day without any preheating.



Expected Results When Using EMISSHIELD®

When EMISSHIELD® is applied to refractory linings in tunnel kilns, 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. 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 made available to fire the furnace load; subsequently the flue gas temperature will decrease. The refractory materials stay cooler and are less subjected to thermal shock and thermally-induced stresses, lengthening their service lives.

More heat is available to fire green ware rather than heating the furnace lining or being lost out the flues. This allows the burners to be turned down to save fuel, the push rate to be increased

to improve productivity, or a combination of the two. 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.

When EMISSHIELD® is applied to furnace linings, the walls and crown become more efficient heat radiators. This improves the uniformity of radiant heating and has resulted in increased yield. More complete combustion can be expected and this, coupled with a lower fuel requirement, results in lower SO_x and NO_x emissions.

The most important benefit of using EMISSHIELD® in kilns is fuel savings. The Harbison-Walker EMISSHIELD® team will work with you to insure that you achieve the greatest benefit from your investment in this unique product.

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