Energy savings through the application of High Emissivity Coatings

In cooperation with Cress B.V. and Steenfabriek Engels Oeffelt, TCKI conducted a study on the application of Emisshield supplied by Cress B.V. Cress B.V. is a service oriented, family owned company specializing in refractory materials for the (ceramic) industry and is the strategic partner and certified installer of Emisshield® coatings in Europe.

Ceramic manufacturers are facing increasing challenges to further reduce CO_2 emissions as part of the energy transition. In addition, the volatile energy market can lead to significant fluctuations in fuel costs. Reducing energy consumption can be achieved by optimizing the ceramic (kiln) process. Besides process measurements and operational adjustments, the application of new technologies and materials, such as Emisshield's high emissivity coatings, offers an additional opportunity to lower energy usage.

In this study, TCKI determined energy consumption and temperature profiles before and after the application of Emisshield in the tunnel kiln process at Steenfabriek Engels Oeffelt.

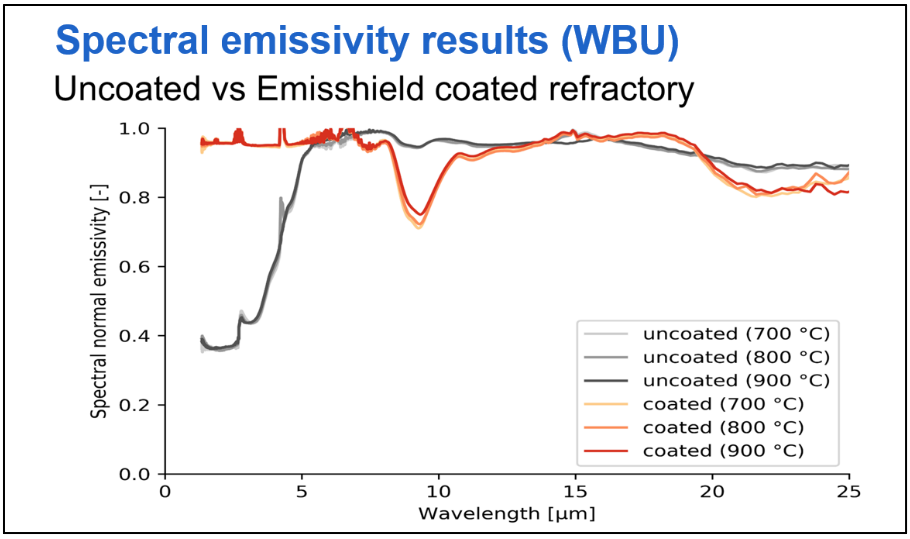
What is Emisshield?

Emisshield is a family of high-emissivity ceramic coatings produced by Emisshield Inc. based on patented technology licensed from NASA. This advanced emissivity technology was originally developed by NASA for the next generation of spacecraft. Emisshield Inc. combined its proprietary binder systems with NASA's technology to create high-emissivity coatings that strongly adhere to dense refractories, refractory bricks, ceramic fibers, and most metals. Applying Emisshield to refractory materials and ceramic fibers in tunnel kilns, batch kilns, roller kilns, etc., ensures more uniform heating, increased productivity, longer refractory lifespan, and fuel savings.

How does Emisshield work?

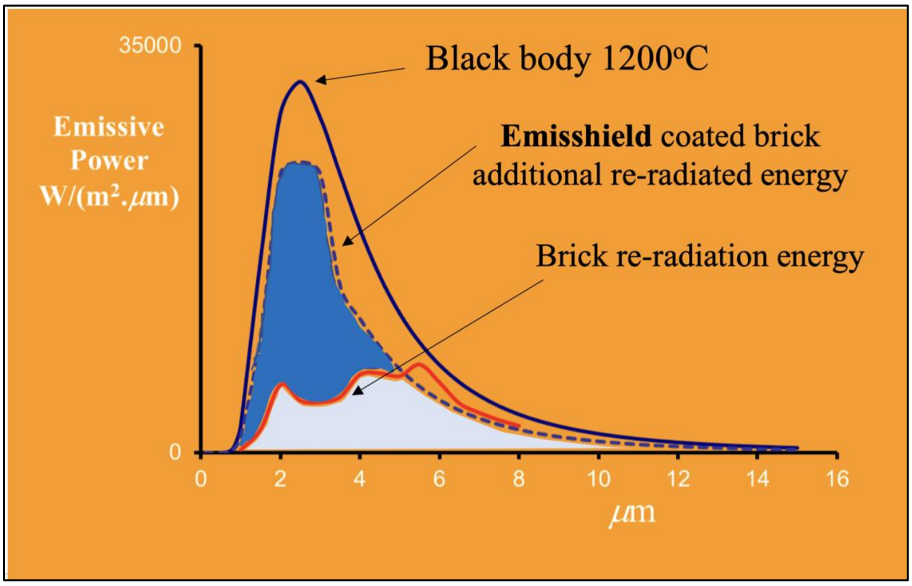
Emisshield is applied to the refractory wall linings and suspended roof linings of the kiln or furnace. Radiant and convective energy from the burners and hot furnace gases is absorbed at the surface of the coating and re radiated toward the cooler furnace load. A key factor in this process is the emissivity of the furnace wall and roof surfaces. Emissivity indicates how effectively a body absorbs and re emits energy compared to a black body at a given temperature and wavelength. A black body has a theoretical emissivity value of 100% and reflects no radiation.

The emissive power (W/m²) of a body depends on its physical properties, in other words, the emissivity of the material. Emissivity can be described, in simple terms, as a two step process involving the absorption and re emission of energy at longer wavelengths in the near infrared spectral range. It is incorrect to assume that a refractory or ceramic wall behaves as a gray body, meaning that absorption and re emission represent a constant fraction of a black body across all temperatures and wavelengths. For example, an alumina–silica refractory wall used in a kiln may have a total emissivity of approximately 0.8 at 260 °C, while at 1090 °C its emissivity may decrease to only 0.4.



Graph 1: Emissivity of insulating refractory bricks.

Graph 1 shows the emissivity (spectral emission measurements) as measured for insulating refractory bricks by the Western Bohemia University (WBU) at various temperatures versus infrared wavelengths in micrometers.
The primary peak infrared wavelengths for the emission of radiant energy in a kiln fall within the 2–7 micron range, with approximately 90% of the radiant energy generated below 6.4 microns in the near-infrared. These are the key wavelength bands—and also the wavelengths with the lowest emissivity for refractory materials.



Graph 2: Emissivity and the wavelength.

Graph 2 shows the curves of the black body, the emissivity coating, and the uncoated lining versus the wavelength. The area under each curve represents the amount of energy or emissive power (W/m²) that is radiated back from the surface of the body (lining, emissivity coating, or black body) to the kiln load and kiln car. This illustrates that Emisshield behaves as a grey body: across all wavelengths, it emits the same (high) fraction of radiative energy back into the process. This is not the case for uncoated products.

The thermal energy absorbed by the coating is re-emitted and absorbed by the cooler load. As a result, the refractory lining remains cooler, retains less heat energy, and transfers less heat to the materials behind it.
It is important to note that Emisshield is only effective when the surface temperature of the coating is higher than the temperature of the kiln load. Emisshield absorbs and re-emits energy most efficiently when the temperature difference between the coating and the load is greatest.
Uncoated refractory materials typically have an emissivity between 0.3 – 0.5 at tunnel kiln operating temperatures. Applying Emisshield increases the emissivity of these materials to approximately 0.9, meaning that 90% of the energy absorbed by the coating is re-radiated toward the cooler load.
As the load temperature approaches the coating temperature, heat transfer is significantly reduced. In a continuous kiln process, Emisshield is only applied in the preheating zone above 600 °C and the burner zone. In the burner zone, where the temperature difference between product and air is typically less than 50°C, the coating is usually not applied.
See Photo 1 for an example of coating application in a tunnel kiln.

Photo 1: Application of the emissivity coating in a tunnel kiln.

The Emisshield Results

In 2024, in collaboration with Steenfabriek Engels Oeffelt and TCKI, a tunnel kiln was coated with Emisshield by the company Cress B.V.
Cress B.V. applied the coating in consultation with Steenfabriek Engels Oeffelt in the preheating and firing zones of the kiln. In the final part of the firing zone, at peak temperature, no coating was applied due to the limited temperature difference between the products and the refractory lining.

TCKI conducted an energy balance for one week both before and after the coating application. This included measuring the main energy flows of the kiln, gas consumption, and the energy flows of the flue gases and dryer. Simultaneously, a Datapaq temperature measurement was carried out to assess the product temperatures in the kiln car load, and bricks were sampled to evaluate water absorption and product qualit The measurements were conducted on products sintered at temperatures between 1010 and 1040°C.

During the kiln shutdown, part of the sand channel was repaired and filled with new sand channel material. After restarting the kiln, flakes of the coating along with underlying refractory material were found on several kiln cars. At the next kiln shutdown, it should be determined from which zone the flakes originated. In a previous project in Germany, similar flaking was observed; during a subsequent shutdown, the affected area was recoated under warranty.

Datapaq – Kiln Curve Temperature Measurement

To examine the impact of the coating, thermocouples were distributed across both the outer and inner stacks of a kiln car load, see figure 1, to monitor the temperature profile. Within each stack, the thermocouples were further spread across the height and width of the load. Thermocouples 1 to 9 were positioned in the outer stack and thermocouples 11 to 19 in the inner stack. The reference measurement was conducted at 1010°C with a pushing rate of 10 kiln cars per day.

In the reference measurement, the temperature in the bottom layer of the outer stack reached a maximum of 985 °C (see Figure 2). The other product temperatures in the outer stack ranged between 1010 and 1020°C. In the inner stack, temperatures were higher, between 1030 and 1040°C. In general, the inner stack was about 20°C hotter, and the bottom layer of the outer stack deviated 30 °C from the average stack temperature.

After adjusting and monitoring the kiln's energy balance due to the coating application, a second Datapaq temperature measurement was performed one year later. Fine-tuning of the firing recipes took some time to ensure consistent product quality. The peak temperature and, in some cases, the preheating zone temperature were reduced depending on the recipe.
At peak temperature, the bottom layer of the outer stack reached 1055°C, and the other layers ranged from 1075 to 1090 °C. In the middle stack, temperatures were between 1070 and 1090°C. With a setpoint of 1040°C, the measured product temperatures were about 40°C higher. The temperature difference between the inner and outer stacks was smaller than before. However, the difference between the bottom layer and the rest of the outer stack remained around 27 °C, consistent with the reference measurement.

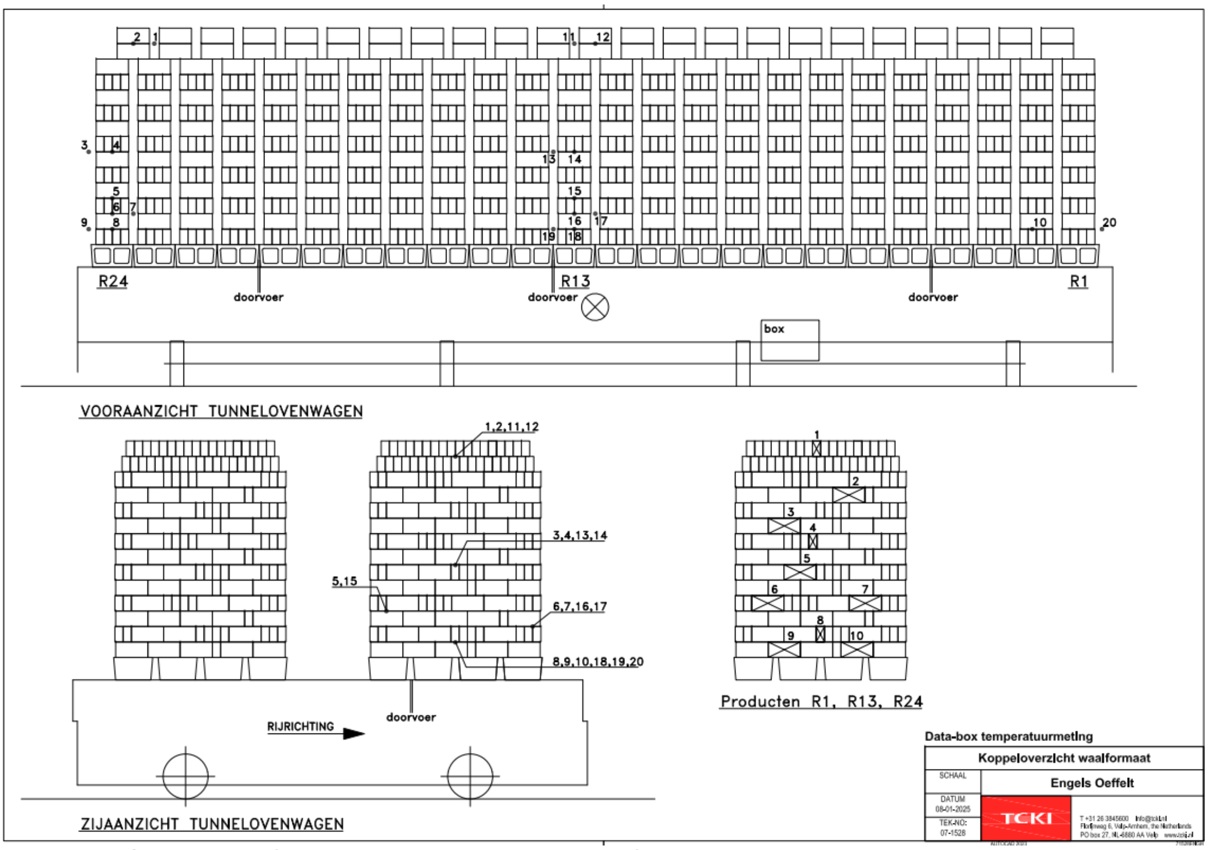


Figure 1: Overview of Thermocouple Placement for Datapaq Measurement and Product Sampling Overview.

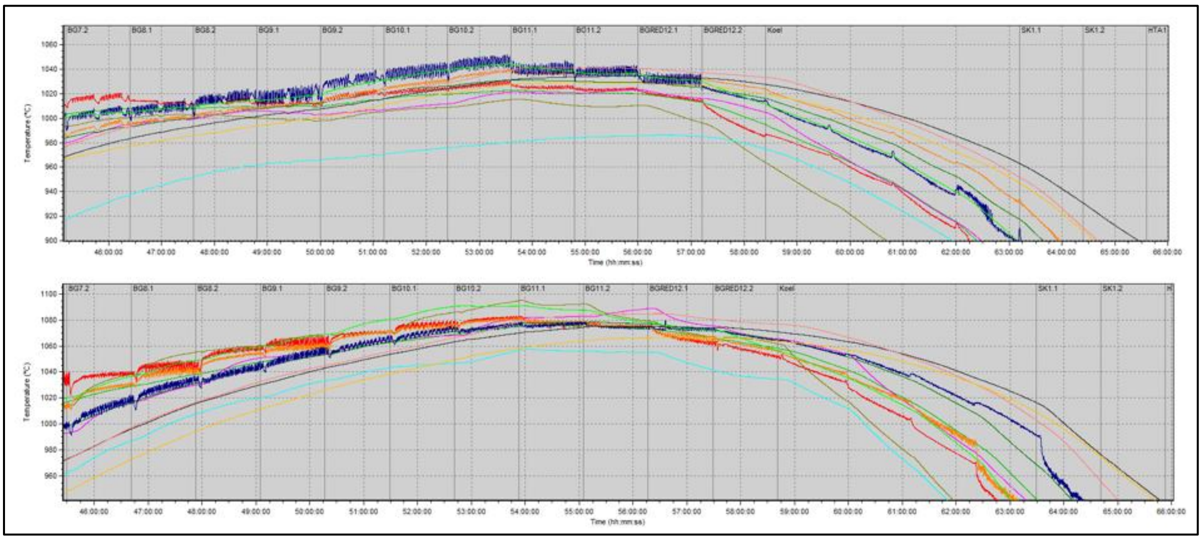


Figure 2: Datapaq Measurement Graphs – Lower Graph Shows Reference Measurement, Upper Graph Shows Post-Optimization Measurement.

Energy Balance

Simultaneously with the Datapaq temperature measurement, an energy balance of the kiln was carried out, focusing on the main energy flows during both the reference and the optimization measurement. The dryer was not considered in relation to water evaporation during either period.

During the time the Datapaq system was in the kiln, the gas consumption of the kiln and dryer was recorded, along with the flue gas (FG) and kiln/dryer air flow (KDAF). The FG and KDAF airflows were determined by measuring air velocity and temperature.

The specific energy flows, expressed in mn³/ton of fired product, are shown per measurement as percentages of the total specific gas consumption of the kiln and dryer combined. Due to the identical kiln throughput (10 TOW/day) and product arrangement on the kiln cars, the tonnage per hour was consistent across both measurements. During the reference measurement, the auxiliary firing of the dryer accounted for 14% of the total specific gas consumption. The gross gas consumption of the kiln was 86%, of which 62% was transferred to the dryer. This results in a net specific gas consumption of 24% for the kiln. In total, 23% of the gas usage was lost via the flue gases.In absolute terms, total gas and kiln gas consumption were approximately 10% higher than during the reference measurement. This is partly due to the higher firing temperature and environmental conditions, but may also be slightly offset by the application of Emisshield. During the optimization measurement in January 2025, the auxiliary firing remained at 14%, and the gross specific gas consumption of the kiln was 86%. Of this, 68% went to the dryer, resulting in a net specific gas consumption of 18% for the kiln. Flue gas loss during this period was 22%.

Product Analysis

After both firing tests, ten products were sampled per test from the outer and inner sections of the kiln car load. In Figure 1, the sampled products for water absorption and dimensional measurements are marked with a cross. Due to the higher peak temperature during the optimization measurement, the absolute product length was smaller, and the absolute water absorption was lower compared to the reference measurement. Based on the product lengths, it can be concluded that the spread between the minimum and maximum values increased during the optimization measurement. As a result, the standard deviation in the outer section rose from 0.5 to 1.6, and in the inner section from 0.9 to 1.4. For water absorption, the standard deviation in the outer section also increased—from 1.0 to 1.2—after optimization. The inner section remained stable.

Lengte afmetingen			**Lengte afmetingen**		
Positie wagen	**Referentie [mm]**	**Optimalisatie [mm]**	**Positie wagen**	**Referentie [mm]**	**Optimalisatie [mm]**
R24-1	215.0	209.5	R13-1	215.0	207.5
R24-2	214.0	210.5	R13-2	214.5	207.5
R24-3	214.0	208.5	R13-3	213.5	209.5
R24-4	215.0	209.0	R13-4	213.5	210.0
R24-5	215.0	209.0	R13-5	214.0	209.5
R24-6	214.0	210.5	R13-6	215.0	208.0
R24-7	214.0	209.5	R13-7	213.0	207.5
R24-8	214.5	210.0	R13-8	214.0	210.5
R24-9	214.0	212.5	R13-9	214.5	210.0
R24-10	215.0	213.5	R13-10	216.0	211.0
Gemiddelde	214.5	210.3	Gemiddelde	214.3	209.1
Min	214.0	208.5	Min	213.0	207.5
Max	215.0	213.5	Max	216.0	211.0
Stdev 10x	0.50	1.60	Stdev 10x	0.89	1.35
Stdev 8, 9 en 10	0.50	1.80	Stdev 8, 9 en 10	1.04	0.50
Vrijwillige wateropname			**Vrijwillige wateropname**		
Positie wagen	**Referentie [%]**	**Optimalisatie [%]**	**Positie wagen**	**Referentie [%]**	**Optimalisatie [%]**
R24-1	14	9	R13-1	14	9
R24-2	14	9	R13-2	13	8
R24-3	14	8	R13-3	14	8
R24-4	14	8	R13-4	13	8
R24-5	11	8	R13-5	14	8
R24-6	14	8	R13-6	15	7
R24-7	14	9	R13-7	13	8
R24-8	15	10	R13-8	14	9
R24-9	14	11	R13-9	14	8
R24-10	14	11	R13-10	14	9
Gemiddelde	13.8	9.1	Gemiddelde	13.8	8.2
Min	11.0	8.0	Min	13.0	7.0
Max	15.0	11.0	Max	15.0	9.0
Stdev 10x	1.03	1.20	Stdev 10x	0.63	0.63
Stdev 8, 9 en 10	0.58	0.58	Stdev 8, 9 en 10	0.00	0.58

Figure 3: Overview of Dimensions and Voluntary Water Absorption

Energy Monitoring
From 1990 to 2020, the ceramic industry participated in various Long-Term Agreements (LTAs) with the Dutch government. Within the framework of these LTAs, annual monitoring of production and energy consumption was conducted. After this period, the ceramic industry continued the inventory of this energy monitoring independently.
Over the past 20 years, the specific gas consumption and production of Steenfabriek Engels Oeffelt have been compared, as shown in Figure 4. The kiln operated for approximately 10 months in 2024 after the Emisshield coating was applied. The gas consumption for 2024 includes the startup phase and recipe adjustments. The specific gas consumption achieved in 2024 was approximately 3% lower than what the trendline, based on 20 years of data, would have predicted.

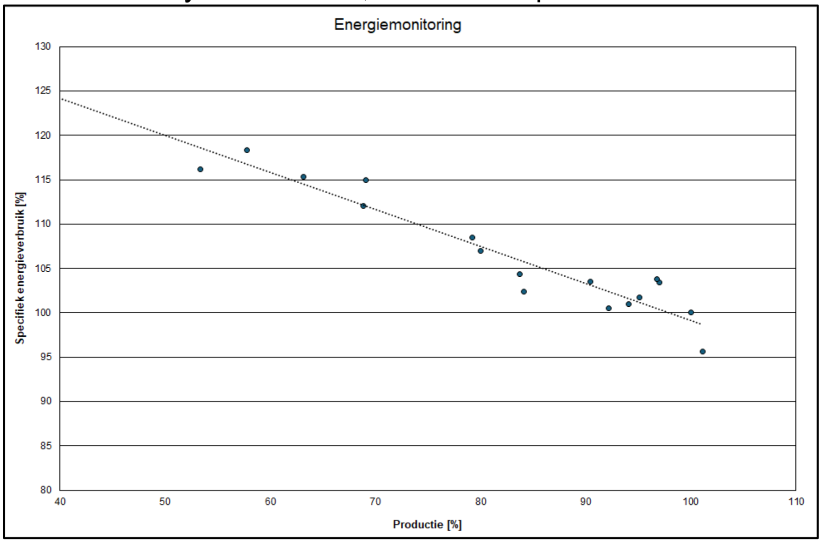


Figure 4: Correlation between Annual Production and Gas Consumption.

Conclusion
By applying Emisshield in the preheating and firing zones, the setpoint temperatures were adjusted downward to achieve the desired product quality. Due to radiation from the coating, not only the products but also the thermocouples are affected. Adjusting all product recipes took some time and is necessary to maintain product quality. During this adjustment phase, it is recommended to periodically monitor the energy balance and temperature curve, and to implement process adjustments based on these measurements.

To achieve the same product quality, Steenfabriek Engels Oeffelt reduced the firing temperature from 1080°C to 1040°C, a 40°C drop in peak temperature. After this reduction, both the color and dimensions matched the reference product prior to coating. During the optimization measurement, product temperatures measured with the Datapaq system ranged from 1070 to 1090°C.

Energy balance measurements show that the kiln's gross specific gas consumption remained around 86% of total gas consumption during both the reference and optimization measurements. However, total gas consumption was about 10% higher during the optimization phase. Based on both sets of measurements (before and after applying the coating), it can be concluded that the specific gas consumption to the dryer increased by approximately 10% in absolute terms, while the dryer's auxiliary firing remained constant. This increase is partly attributable to the higher setpoint temperatures during optimization. The specific flue gas losses remained nearly unchanged. Meanwhile, the net specific gas consumption of the kiln decreased by 15% after optimization. Although the dryer used more energy during optimization, the energy balance does not include the dryer's balance. If more water was evaporated during this period, the increased absolute energy use would be explainable, assuming the specific energy use for drying remained constant.

The product analysis still showed some variation in the quality (dimensions and water absorption) of the outer product stacks. It could be considered to apply the coating to the side walls and part of the roof deck near the side stacks throughout the peak temperature zone. Temperature measurements indicate that the temperature difference between air and product is greater in the outer stacks than in the inner stacks. Extending the heat transfer zone for the outer stacks could improve their quality.

After the kiln was recommissioned, an annual energy saving of approximately 3% was achieved, based on monitoring data from the past 20 years.