When kiln car linings for high-temperature kilns are involved, most refractory producers primarily consider the aspects of cost and maintenance effort/lifespan. It is naturally very important that many of today's tunnel kilns which are in operation are already older models that use the same kiln car concepts that have been in existence for years now. The direct effect on the actual firing process is either not known or not considered. Naturally many different systems are used.

**Introduction**

In a great number of cases, the kiln car linings are made of large blocks of ramming mixture. These blocks are usually poured directly onto the car. The cost of these uniformed masses is much lower than for pre-formed bricks. And the great weight of the large individual blocks already ensures that the lining remains physically stable. However, a great amount of work is required since everything has to be done manually. This is the reason that this system is very frequently to be found in countries with low wage costs although refractory producers of industrial countries also use such systems frequently which, in actual practice, means that one group of workers is permanently occupied with repairing/relining the cars. This represents a significant cost factor in addition to the relatively short lifespan of the large blocks which frequently split due to their size.

When this method is used, the top-most layer or the two top-most layers are usually made of standard, dry-pressed bricks which are normally laid without mortar and, as the wearing layer, can be quickly replaced. Such a layer also absorbs the high specific pressure of the product setting. Cast or rammed mixtures are used for the layers underneath. These mixtures vary in quality depending on their location and the thermal stress whereas in the lower cold portion insulating mixtures can then also be used. Usually these blocks are shaped so that a physical fixation is created between them and the individual parts cannot slip. Fig. 1 shows a schematic view of such a typical set-up.

**Effects on the firing process**

In the preheating zone of a normal refractory tunnel kiln, the product is heated by exhaust gases coming out of the firing zone in the direction of the kiln entrance. Burners are only required for higher temperatures. If the kiln channel is constructed correctly and there is a flow-optimized product setting, hot exhaust gases surround the product and this then ensures that the material to be fired is heated up in a more or less uniform manner based on the flow pattern. However, the car lining can also only be heated convectively from above through the top-most layer which means that the upper layers of the kiln car lining heat up much more slowly than the product located above that. If a significant downward outflow of energy occurs due to the high heat conductivity of the lining layers located underneath, this causes distinct differences in the kiln between the temperatures in the product load above and below. Thus the temperature of the kiln car deck and the products directly above it have more than 200 °C difference in some cases. This can also almost never be corrected by optimization of the kiln settings. The temperature deficit of the lower layers in the kiln car product load usually continues up to the main firing zone and the temperatures of the product load are not equal again until the soak time area. This “running behind” of the temperatures in the bottom of the product load can only be attenuated by slowing down the firing speed although that reduces kiln performance and automatically increases specific power consumption. This has the reverse effect on the cooling. Here the kiln car is usually much warmer
than the product setting. Since the kiln car lining can only be cooled convectively from above via the top-most layer, the effectiveness of the cooling is limited and creates longer throughput times. Post heating after leaving the kiln is also typical for heavy linings. The already cooled down product is reheated again by the tremendously high temperatures of the heavy kiln car lining. This can slow down the unloading of the car significantly. With sensitive products this can also cause cracks in the product.

Although the layer of hollow blocks which is used occasionally under the product does somewhat improve the temperature compensation, it increases the mass to be heated and creates extra costs. Fig. 2 shows the great difference in temperature between the top and bottom product load in the preheating zone.

**Light kiln car design**

One solution to the described problem is to predominantly use insulating materials in the kiln car lining. This reduces the mass to be heated and prevents too much thermal energy from escaping. As a result, the top layers of the lining can warm up quicker and even the lower product layers reach the desired temperature faster. The differences between the top and bottom of the product setting are greatly reduced.

This has already been tried often in the past but specific properties of the insulating bricks used in the design have set certain limits. This is the reason why the predominant use of insulating bricks for a lining is still relatively rare even today.

One problem involved with this is the high physical load of the top layers caused by the product, which can be up to 2 t/m². As well known, insulating bricks consist almost exclusively of material containing high alumina which tends to deform under great physical loads and high temperatures which then reduces the lifespan drastically. In the past, this problem often caused designs with lightweight materials to fail. However, during the last 10 to 15 years, the selection and quality of available insulating bricks has improved significantly (e.g., several manufacturers offer insulating bricks of a certain temperature class with different degrees of density and strength). The significantly improved process control in modern tunnel kilns allows faster firing times than in the past so that the transient thermal stress of the bottom layers is reduced.

Even in a light-weight kiln car setting, at least the top layer of the kiln car lining must be made of dense bricks which offer sufficient resistance to pressure. In addition, a chemically resistant top layer is indispensable for basic products, for example.
and light kiln cars after having reached the temperature of 1750 °C after 30 h.

It is certainly sensible to give more attention to the kiln car of an existing kiln system particularly regarding acceleration of the firing process.

Summary
The use of light-weight kiln cars has a significant positive effect on the energy consumption of refractory kilns and should be considered in all cases. Results from recent kilns equipped with light-weight cars show high energy savings when compared to traditional massive kiln cars.