



**48<sup>+</sup> Years**  
*Of experience*

**ROTARY DRUMS FOR  
EFFICIENT DRYING & COOLING**



In Association with SVCH-Technologii, Moscow (Russia)

ISO 9001:2015 | ISO 14001:2015 | ISO 45001:2018

# ABOUT US

KERONE is now renowned for serving the specialized needs of customers with the best quality and economical process of application engineering solutions and industrial heating products manufactured in a high-quality environment by a trained and qualified workforce (special purpose machinery)



KERONE is a pioneer in application and implementation engineering with its vast experience and team of professionals.



KERONE is devoted to serve the industry to optimize its operations both economically and environmentally with its specialized process engineering solutions.



KERONE is having immense expertise in manufacturing and implementing various types of engineering solutions.



KERONE is possessing employee strength of more than 280+ experts continuously putting efforts for happy industrial engineering solutions



48+ Years Manufacturing Excellence



Great Sale Support



Highly Customized Product



Adherence to Standards



Sound Infrastructure



Team of experts Delivering Quality



Timely Delivery



Cost Effective Solutions

# WHY CHOOSE US

"Choose Kerone for innovative solutions tailored to your unique product needs, ensuring efficiency, reliability, and unmatched quality."

With decades of expertise, cutting-edge technology, and a customer-centric approach, Kerone Engineering offers tailor-made Applications Engineering solutions that prioritize quality, flexibility, and cost-effectiveness. Benefit from our commitment to excellence, post-sales support, and innovative solutions for your unique Applications Engineering needs. Choose Kerone Engineering for reliability, performance, and unmatched value.

## MISSION



To enhance the value of customer operation through our customer need centric engineering solution.



We are committed to providing our customers with unique and best-in-class products in the industrial thermal processing segments. Through strategic tie-ups for technical know-how with renowned leaders in industry-specific segments, we ensure that our offerings meet the highest standards of quality and innovation.

## VISION



Turn into a world leader in providing specialized, top-notch quality and ecological industrial heating, cooling, and drying solutions across the globe.



To attain global recognition as the best of quality and environment-friendly engineering solution company.



Enhance the value of customer operation through our customer need centric engineering solution.



# TRUSTED PARTNERS





## ABSTRACT

Rotary drum dryers have been used for decades for drying many different types of goods and are widely used in the building, minerals, and raw material industry, as well in the chemical industry, fertilizer industry and other branches.

At the same time, further, drum dryers have been improved for energy-efficient applications, particularly in the mineral industry, for very robust and hard-wearing solutions. Significant progress has been achieved for special applications, such as drums for combined drying and subsequent cooling in one unit, dryers with heat recovery by gas circulation or the use of evaporating cooling, rotary drums for granulation and coating procedures, indirect cooling drums for hot products by air or water with heat recovery, etc.

### Drum dryers

#### **energy-efficient and particularly robust and reliable**

Rotary drum dryers are present in industry for many decades. They are used for drying and cooling, calcining, granulation, and coating. While historical drum dryers are mainly inclined to realize solids transport in combination with the rotation, modern drum dryers are more often installed horizontally. Lifting blades pick up the moist solid from the bottom of the drum letting it fall again, allowing contact between the hot drying air and the moist solid. An essential factor for the efficient utilization of the heating energy is the optimal design of the dryer's internal fittings, as these have to guarantee optimal and intensive contact between solids and the drying gas.

The design of the arrangement, shape, and the number of fittings require a combination of extensive experience, trials, and calculation for proper design. In most of the drying applications, the solid material is conveyed in a co-current flow (i.e. in direction of the gas flow). A combination of parallel flow and cross flow between the drying gas and the material is produced in the dryer, while cooling in most cases is done in countercurrent mode. Countercurrent applications for drying or heating are found mainly in the asphalt industry as well as in high-temperature applications and calcining.

Various methods for heat recovery by exhaust air circulation or evaporative cooling are available and have been developed to the latest state of art during the last decades.

Modern double-shell drums are horizontally designed, allowing the material in the outer shell to be conveyed in the opposite direction to the material in the inner shell. This allows a combination of drying and cooling in one unit. Drum dryers are suitable for fine materials such as silica sand, but especially for rather coarse bulk solids. They are built for solid mass flow rates between 5 and 350 tph (Figure 1). Particular advantages of drum dryers are that they are largely insensitive to fluctuations in the starting moisture content of the material to be dried and to fluctuations in the feed mass flow rate, to the size of the particles, or to unwanted lumps or foreign coarse materials. With appropriate design of the internal fittings, even very abrasive materials can be processed. In rotary drums for abrasive materials, the drum walls, the blades, and vanes inside are made from thick-walled steel.

Drum dryers are especially tolerant to operating errors and therefore optimally suitable for installation in areas of poor infrastructure. The cost for automation of the dryer-control system is comparatively low. In the event of a power outage, it is usually possible to resume operation when power supply is restored. In the event if the supply of drying air cuts out, the solid in the drum dryer is reliably conveyed just by the rotation of the drum. Due to comparatively simple setup of a drum dryer, end users can perform dryer assembly on the construction site themselves.



Figure 1. Big rotary drum from stainless steel at the manufacturing hall (4.5 m in diameter, 35 m length) for drying of 320 tph fertilizers.

This is advantageous in global markets where locally available exhaust air filters are used or air ducts are installed by local companies themselves. Additionally, drum dryers can usually be commissioned in a relatively short time.

Technical requirements for heating drum dryers are relatively low. Modern burners have only small combustion air fans. The moisture-laden exhaust air is extracted from the dryer by means of a draught fan, fed through a bag filter to remove any entrained dust, and emitted into the environment through a chimney flue. The system of pipes for the exhaust air from the drum dryer is a comparatively simple arrangement as the air only has to be extracted from one point on the dryer casing.

The combustion gases are partially mixed with ambient air to obtain average drying air temperatures between 600 °C and 900 °C. For thermally insensitive materials (e.g. silica sand, slag), the flame can burn directly into the rotating drum (Figure 2). For the drying of temperature-sensitive materials (limestone, clay, bentonite, recycled plastic, or organic waste), firing chambers are used.

In general, rotary dryers have low specific heating energy consumption if the process can be run with a high inlet-air temperature. Hence, a key feature is their extremely energy-efficient operation. High hot-gas temperatures result in low amounts of drying air and less heat losses by the exhaust. All the above-mentioned features gave rotary drums a renaissance in the industrial praxis at present.



Figure 1. View into a dryer drum with flame in the interior of the drum.

## Advantages of rotary drum dryers

For a required application, suppliers often promote their particular own technology no matter of rotary dryers, fluid bed dryers, flash dryers, paddle dryers, or other. This has led to uncertainty among users selecting an optimal drying system.

Rotary drum dryers have multiple advantages in comparison with other drying technologies. As drum dryers are suitable for both fine and coarse particle sizes, and for very coarse bulk materials as well, it is not necessarily imperative to adjust the amount of air into a drum dryer for a change of product. The material in the drum is transported by means of the rotation of the drum regardless of the air flow. As a result, drum dryers can be operated with high reliability.

A special advantage of drum dryers is that it is possible to adjust both the hot-gas inlet temperature and the amount of drying air in periods when a drying system designed for a specific throughput is operated for a long time at a significantly reduced performance. Reduction of the drying air amount makes it possible to keep the hot-gas temperature high, close to design value. As described above, this means that the low-specific fuel consumption per ton of dried solid is maintained even when the dryer is not operating at its full rated power.

The specific electricity consumption of a drum dryer is relatively low. As the specific fuel consumption per ton of material to be dried increases if, due to a continuously low amount of material or low moisture content of the material, the drying system is not operated at the rated drying air temperature for which it was designed, rotary drum dryers are characterized by the advantage that the control of the dryer can be done by the air mass flow rate and must not be done by the inlet drying air temperature.

### Advantages of Drum Driers at a glance

- ▮ Suitable for both coarse and fine solids
- ▮ Largely insensitive to coarse or heavy solids
- ▮ Low expenditure for the inlet air equipment
- ▮ Insensitive to changes in the particle size
- ▮ Insensitive to fluctuations in the moisture content and the mass flow rate
- ▮ Insensitive to cutout of the drying air
- ▮ High drying air temperatures combined with low heat losses
- ▮ Low-specific electrical energy requirement
- ▮ Constant specific heating energy requirement even at only partial loads
- ▮ Straightforward installation and quick commissioning
- ▮ Tolerance to operating faults
- ▮ Very rugged and thick-walled equipment with long lifetime
- ▮ Moderate wear and low spare parts requirement

However, some disadvantages of rotary drum dryers should not be neglected.

### Drum Dryer Disadvantages

- ▮ Requirement of heavy equipment (thick-walled design of the drum)
- ▮ The design of the internal fittings requires many years of experience
- ▮ Solid materials are only partially de-dusted during drying
- ▮ Counter-flow applications are limited to coarsegrained materials

### Selection criteria for the use of dryers in the process industry

For practical applications, the decision must be done on the basis of a couple of main criteria which are of particular importance to the client. Selection criteria from which a decision in favor of rotary drum dryers can be taken[1,2] are summarized by the below listing :

- ▮ Wide range of material from fine to very coarse
- ▮ Non-uniform particle distribution
- ▮ Non-uniform solids quality
- ▮ Non-sensitive product against heat
- ▮ Use of direct gas or oil burners required
- ▮ Fast load changes to be expected
- ▮ Mild steel application sufficient
- ▮ No space for a complex supplied inlet air system available
- ▮ Outdoor installation required

### Energetic and geometrical design of rotary drum dryers

Due to the scarcity of resources and increasing price of energy, an even more efficient design and operation of dryers becomes more and more important.

The design of a rotary drum dryer is traditionally done by means of a thermal balance for the energetic design of the dryer and by the use of empirical models that are based on the specific water evaporation capacity  $x$  for the geometrical design. By a thermal balance in the first-step operating parameters such as temperatures of gases and solids, air flow velocity, burner power and bulk material mass flow, and the temperature of the hot heating gases are calculated.

The latter inlet drying air temperature is used to estimate the corresponding specific water evaporation capacity  $x$  of the dryer that is used to determine the required inner volume of a drying drum. It is known for decades that the value  $x$  shows a good correlation to the heating gas temperature and, moreover, to other key determinants as the moisture content of the wet solids or the temperature of the exhaust air gases and the hot product temperature.[3,4]

In literature, the latter determinants are often neglected although they have a great impact on drying characteristics and the resulting drum size. In numerous experiments carried out,[5,6] the drying characteristics of various products that mainly carries surface moisture and those products, that carry inner moisture as well were investigated. Different grain size ranges, moisture contents and alternating wet material mass flow, exhaust air temperature, and dried product temperature were tested.

## Thermal balance

In (Figure 3), the measuring points of temperatures, air flow velocity  $v_{a,mix}$ , and burner power  $P_B$  at a semi-industrial test plant in the Allgaier test center are shown. At the beginning of the process, wet product is entering the drum with a mass flow of  $m_{Pr}$  at a temperature  $t_{Pr,f}$  and moisture content  $x_{Pr,f}$ . This material gets in contact with the burner flame and hot gases  $t_e$  that are obtained by burning gas. The power of the burner  $P_B$  is measured by means of a gas meter. Besides the hot gases and the wet material, ambient air at a temperature of  $t_{amb}$  is entering the process. The total air mass flow is described by  $m_L$ . In the drum dryer, the material is dried and heated up to a temperature of  $t_{Pr,tr}$  and a residual moisture content of  $x_{Pr,tr}$ . In accordance with this, during drying the air is cooled down to  $t_{a,real}$  and its humidity rises. At the outlet of the drying drum, there are unavoidable leakages so that the drying air at a temperature of  $t_{a,real}$  gets mixed with ambient air at a temperature of  $t_{amb}$ . The resulting exhaust air temperature  $t_{a,mix}$  and the air flow velocity  $v_{a,mix}$  are measured in the exhaust air duct.

These parameters are entered in Equations (1), (2), and (3), where  $Q_{tot}$  is the total thermal heat input that is required for the drying process. It should be noted that these equations are simplified:

$h_{1px}$  represents the enthalpy of humid air,  $h_{Pr}$  the enthalpy of the solids,  $Q_r$  the thermal radiation losses, and  $m_{LL}$  the leakage air mass flow. As a result, the hot inlet gas temperature  $t_e$  is calculated, which cannot get measured directly due to irregularities in the flow of flue gases and ambient air and the mixing of both.

$$Q_{tot} = \frac{1}{4} \left( m_L \sum_{1px} h_a - \dot{Q}_r - \sum_{1px} m_{Pr} \dot{Q}_{Pr;a} - h_{Pr;e} \right) + \frac{1}{4} \left( m_{LL} c_{p,L} \dot{Q}_{a;mix} - t_{amb} \right) + Q_r \quad (1)$$

$$Q_{tot} = \frac{1}{4} \left( m_L c_{p,L} \dot{Q}_e - t_{a;real} \right) + Q_r \quad (2)$$

$$-P_B = \frac{1}{4} \left( m_L c_{p,L} \dot{Q}_e - t_{amb} \right) + Q_r \quad (3)$$

## Tests and results

Within all tests, wet sand and some other products with inner moisture were dried to a residual moisture content  $x_{Pr,tr}$ . Unnecessary overheating of the solids was generally avoided which means that the drying process works in the most efficient way.

In a first test period, drying of natural sand with three different grain size ranges (0.1–0.4 mm, 0.4–1.0 mm, and 1.0–2.0 mm) was investigated in the

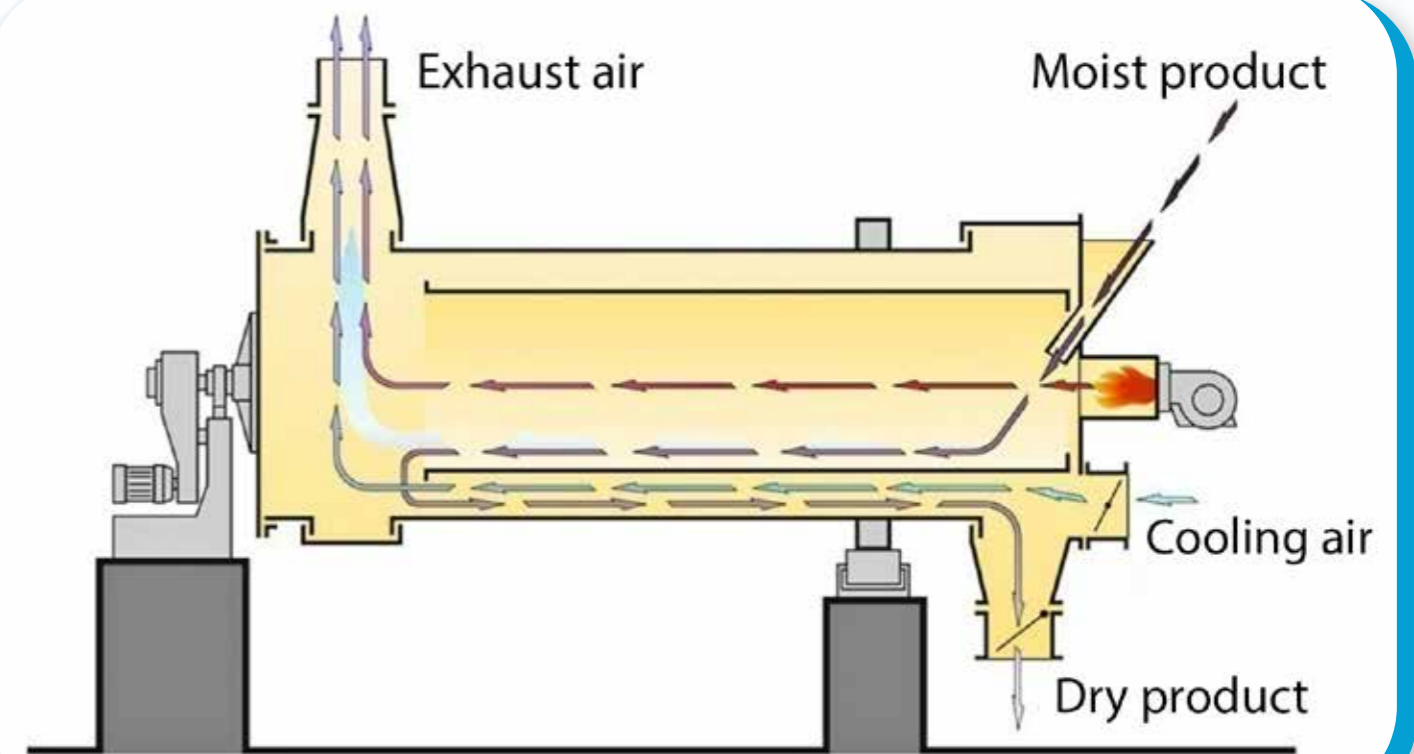


Figure 3. Scheme of the semi-industrial test plant TT 20/4 at Allgaier in Ugingen.



Figure 4. Silica sand with three grain size ranges

rotary drum dryer in order to find out whether there is an impact of the grain size range on the specific water evaporation capacity  $x$ . In Figure 4, exemplary silica sand and its appearance are shown.

The tests were carried out at inlet moisture  $x_{Pr,f}$  of 4% and 8%. The mass flow was varied during the tests, and it was found that the impact of the grain size is negligible for products with surface moisture only.

In total, together with the first test row, 72 experiments were carried out. Figure 5 contains an excerpt of these tests, while the black line "before" shows the presently known evaporation capacities, Figure 5 shows the general behavior of sand (grain size 0.4 ... 2.0 mm) at different moisture contents. The measurement point with the highest water evaporation capacity is characterized by the maximum conveying capacity of the dryer. It might be seen that the water evaporation capacity of sand at a moisture content of 4% (red squares) is significantly higher than the values at a moisture content of 2%. It follows logically that an increase in the feed moisture

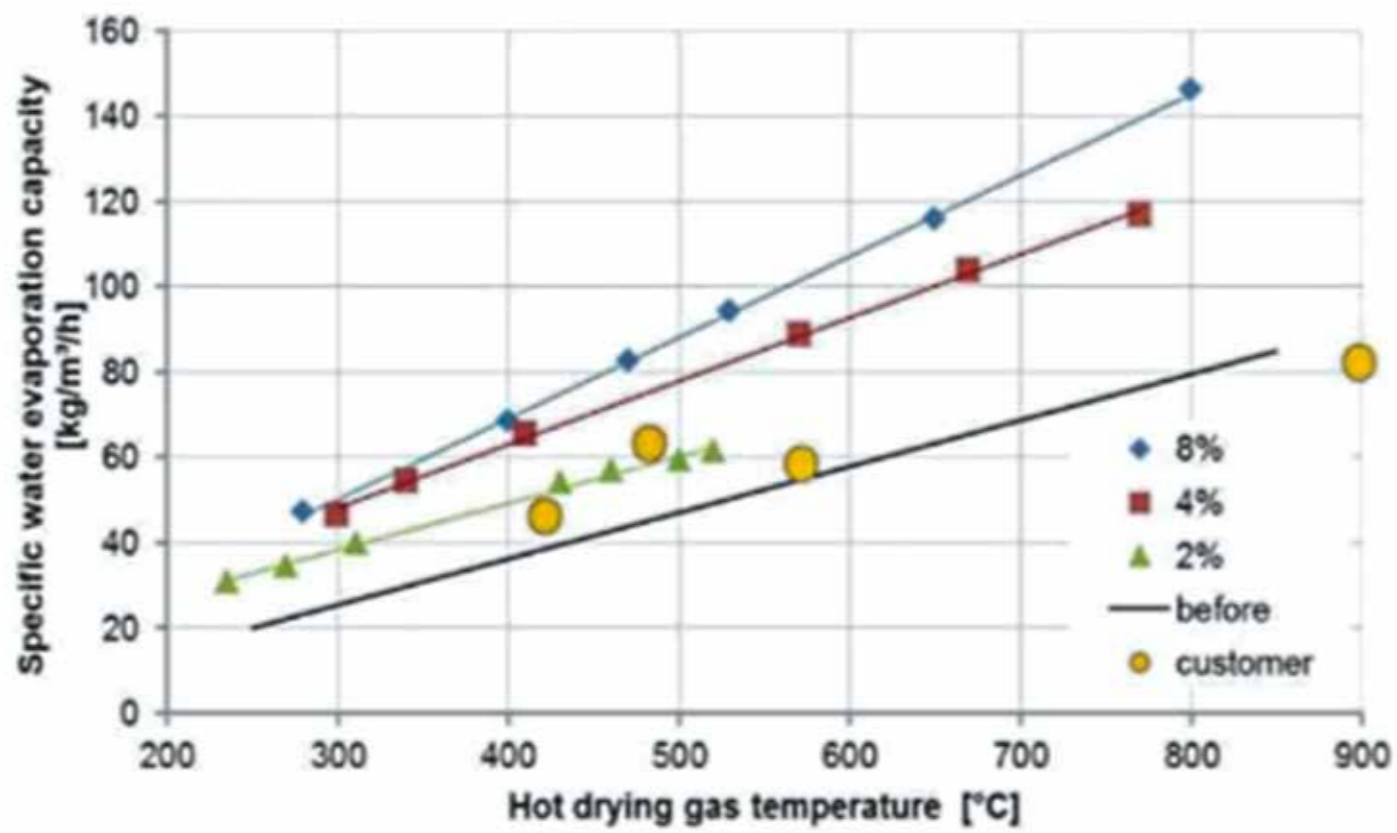


Figure 5. Specific water evaporation capacity  $x$  vs. heating gas temperature in sand drying and results from customer's plants. [6]

For both red squares and blue diamonds, the limiting factor was also the conveying capacity of the present drying drums. It is significantly higher than the limit at a moisture content of 2% since the mass flow needed to reach a high specific water evaporation capacity is lower.

Moreover, high moisture contents of silica sand are not usual and so the impact of moisture contents higher than 4% have been neglected in the past.

Further to the tests with sand additional tests with pumice and with bentonite as exemplary products with inner moisture were carried out. The same procedure to measure the maximum drying capacity and to calculate the specific water evaporation capacity per volume of the dryer was used. As for the sand, higher values of the specific water evaporation capacity  $x$  for the solids with inner moisture were established than found in the literature (Figure 6). The black line "before" represents the presently used evaporation rates.

## Tests at industrial plants

The laboratory tests were carried out at conditions that usually do not exist in praxis:

constant mass flow, constant moisture content of silica sand, etc. However, the mass flow of material and its moisture content vary significantly in everyday praxis operation mode. In order to show the opportunities and limits of the new empirical correlation to design rotary drum dryers, the authors [5,6] investigated existing industrial drying plants in everyday operation. Results from three different customer's drying plants are presented in (Figure 5) as well.

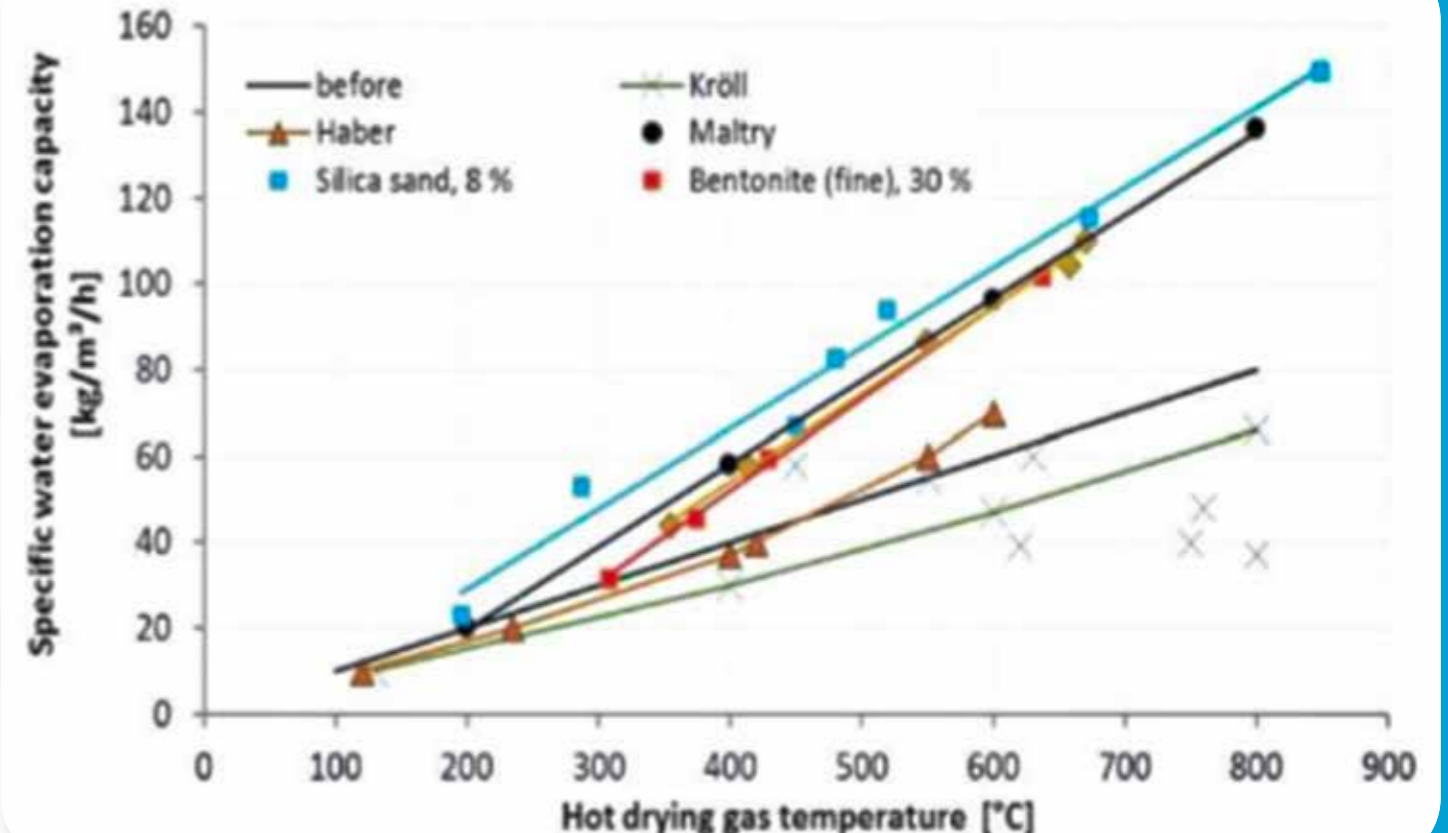


Figure 6. Specific water evaporation capacity  $x$  vs. heating gas temperature in sand drying and results from customer's plants. [5]

The two spots marked 1) show two different operation modes of a rotary drum dryer (type: Allgaier TT 90/6.5) that dries silica sand with a grain size of about 4 mm and a moisture content of 7%. The dried silica sand that leaves the dryer at the outlet is completely dry ("technically zero" moisture). As it can be seen in (Figure 5), both measurement points are significantly below the maximum possible specific water evaporation capacity.

Normally, the dryer should be able to operate close to the red or blue line. The operation mode of the left of those two points ( $t_e \approx 420^\circ\text{C}$ ) is characterized by an too high air stream that is sucked through the drying drum. Hence, the temperature of the heating gases  $t_e$  is rather low and the drying plant is operated in an inefficient way. On account of reducing the air flow by a reduction of the exhaust air fan power and an increase in the mass flow, the operating point moves to a higher water evaporation capacity at higher inlet gas temperature.

So the efficiency of the drying plant was significantly increased. The analyzed dryer's operation is still not perfect since the  $t_e$  and the water evaporation capacity could be further increased theoretically. However, this is not possible because the dew point was already very high in this special case and a further increase in the water load of the exhaust air would lead to water condensation in the exhaust air duct.

Another drying plant (marker: 2 at Figure 5, type: Allgaier TT 120/9.5) is run at the original design point. Silica sand with a grain size of 0.1–2 mm is dried from a moisture content of 6–0%. This plant could be run with a higher wet material stream in order to increase the drying efficiency and capacity



**Figure 7. Rotary drums for combined drying and cooling of sand**

The third plant (marker: 3 at Figure 5, type: Allgaier TT 120/11) is operated at a rather high hot gas temperature of 900°C. The specific water evaporation capacity is lower than designed. In this case, it was easily possible to recognize by just measuring temperatures, powers, and mass flows (cf. Figure 3) that there must be a technical problem at the specific plant. The problem was an erroneous control of the exhaust air fan. This leads to a high drying air stream in the drum.

## Conclusions

In a semi-industrial laboratory rotary drum dryer, several experiments with silica sand, pumice, and bentonite were carried out. It was shown that for products with only surface moisture common grains (particle sizes 0.4, 2.0mm) have no practical impact on the drying behavior. With the help of a thermal balance and the measurement of the moisture content and mass flow of the solids at the entrance and the outlet of the rotary drum dryer a relation between the heating gas temperature  $t_e$  and the specific water evaporation capacity  $x$  was established and compared with data from literature. [3,4] The specific water evaporation capacity increases significantly with the increase in the moisture content of the solids. At moisture contents of 8%, a maximum of the specific water evaporation capacity is reached and a further increase in the moisture content does not lead to higher specific water evaporation capacities. The specific water evaporation capacity in modern rotary dryers for various specific cases was found up to 60% higher than usual values in the literature. With these results, rotary drum dryers can be designed more compact today and at the same time more efficient.

As a side effect, it was found that the method can be used as a service tool to decide easily whether there are any severe errors in the operation of existing industrial plants.

## Combined drying and Cooling in rotary drums

After drying, the heated product must often get cooled. Cooling is necessary because of subsequent processing steps such as conveying, screening, storing, mixing, or packing, which permit specific maximum material temperatures. Cooling is also required if temperature sensitive additives are to be added to the dried solid, e.g. certain resins, for the manufacture of high-quality “ready mix” materials from sand for instance. As the equipment costs and energy costs are related to the technological design, cooling should only be undertaken to the actual temperature required. For applications in the construction material industry, this temperature is often approx. 55–60 °C and less frequently approx. 40–45 °C.

## Drying and cooling in double shell rotary drums

While drying and cooling were done in separate drums in the past, combined drying and cooling in one rotary drum of special design is a well-established technology at present. Best known are the double-shell rotary drums. Hundreds of applications can be found in the worldwide minerals and building materials industry for drying and cooling mainly of sand and crushed lime stone.

Examples are shown in Figure 7. While drying takes place in the inner tube of the drum with parallel flow of the solid product and drying gas, cooling is done in the outer shell using ambient air in counter flow to the dry and hot product to be cooled. The working principle of combined double shell dryers/coolers is shown in Figure 8.

An advantage of the system is the compact design of short length and the possibility to drive the drum directly by a front-mounted gear motor, one barrel ring, and one pair of rollers only. The wet feed product inlet and the dry product outlet at the same side of the plant can be advantageous, when optional solid by-passing of the dryer/cooler is required for instance.

Since the hot inner drum gets in contact with the dried solid to be cooled, the cooling efficiency of the system is limited to final product temperatures of about 55–60 °C depending on the ambient conditions.

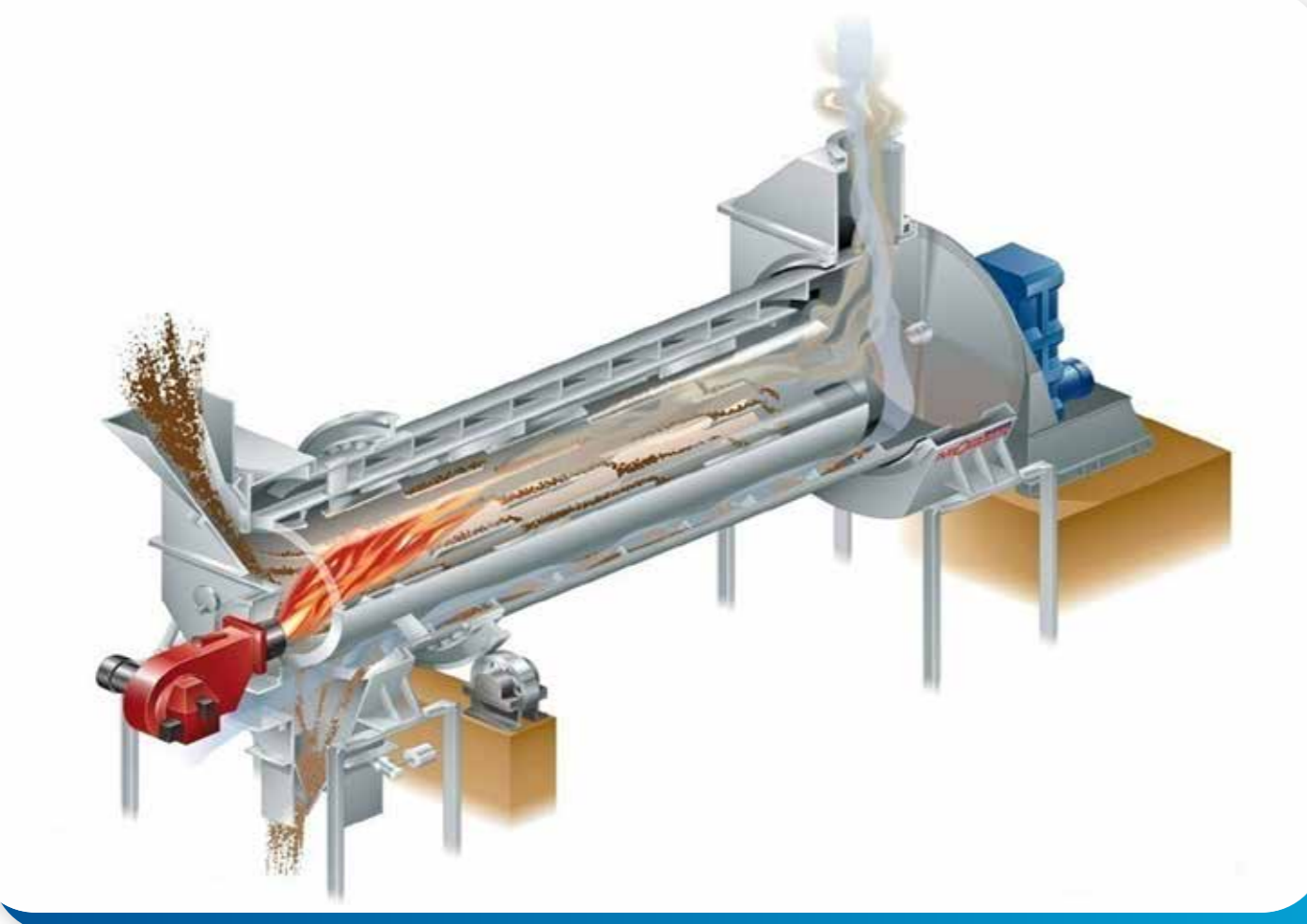
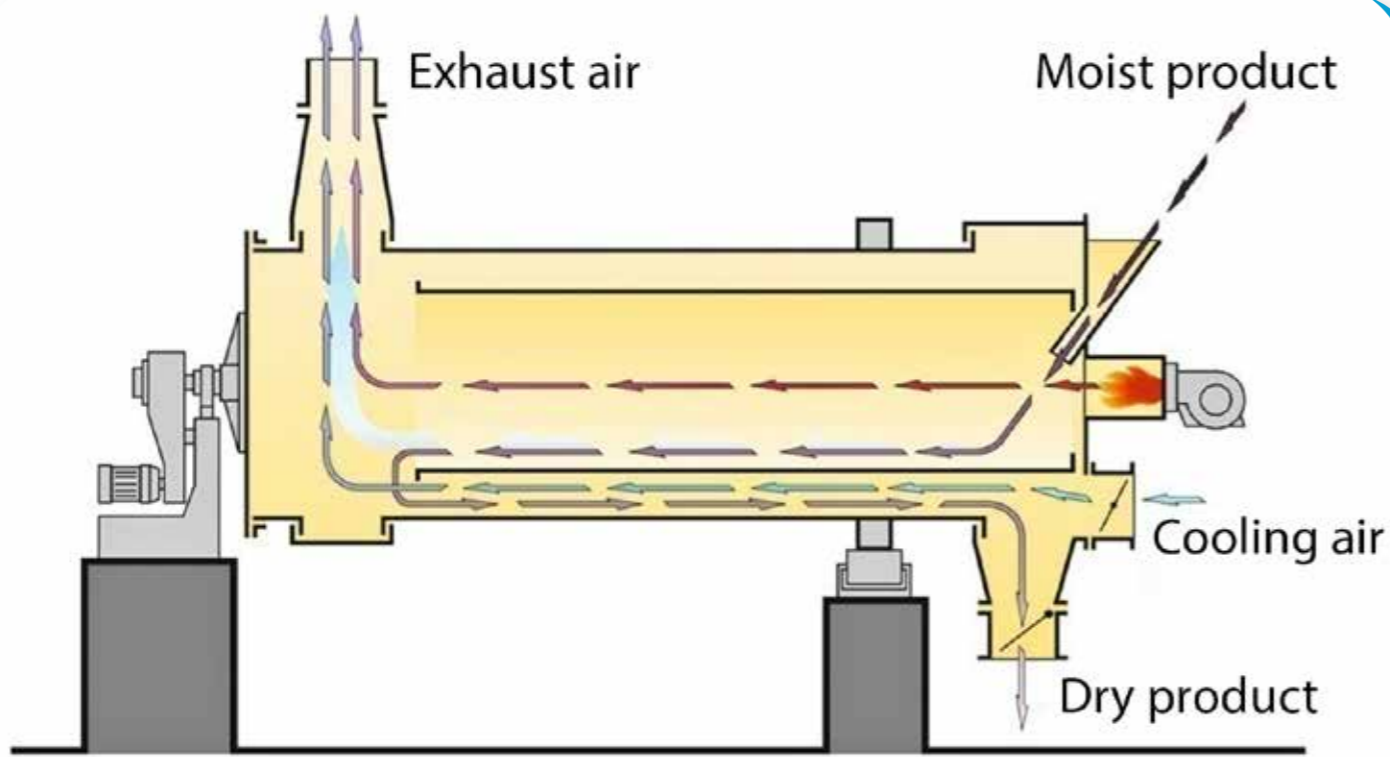


Figure 8 . 2D and 3D principle drawing of a drum dryer system TK with aircooling.

However, those cooling temperatures are sufficient in most cases of the mineral industry

## Drying and cooling in single-shell rotary drums

In some cases, lower temperatures near the ambient (30–45 °C for instance) are required for the dried out-put materials. Adding the option of cooling to particularly low-solid temperatures and efficient heat recovery with the resulting energy savings makes the TK-D Series a welcome complement to the TK double-shell dryers/coolers.

In contrast to the double-shell TK drying/cooling drum, the TK-D is a single-shell drum, which has no contact points between the solid to get cooled and any hot inner drum surface in the entry area of the dryer. The dried solid is passed by a specially designed solid transfer compartment from the drying zone to the cooling zone, where the solids gets cooled by a countercurrentflow of ambient air (Figure 9). Thanks to this design, the TK-D drying/cooling drum outputs low-temperature dried solids approaching ambient air temperature used. In standard applications, both exhaust airstreams from the drying and from the cooling compartment are draught from the transfer compartment through a single-chamber bag filter by the exhaust air fan (Figure 10).

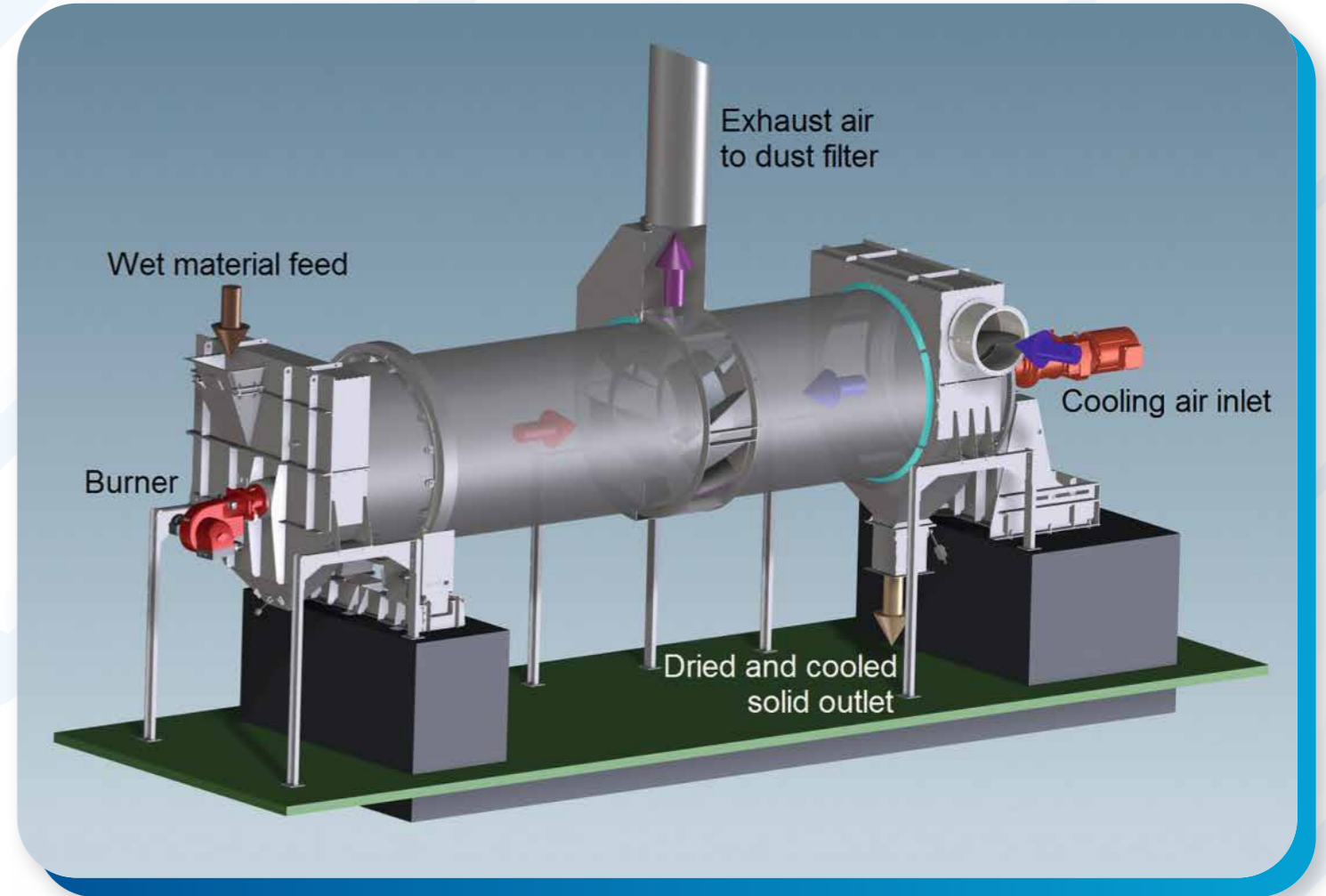


Figure 9 . Rotary drum dryer system TK-D with counter-current aircooling

With a two-part configuration of the central transfer compartment, exhaust air streams from the drying zone and from the cooling zone can be individually

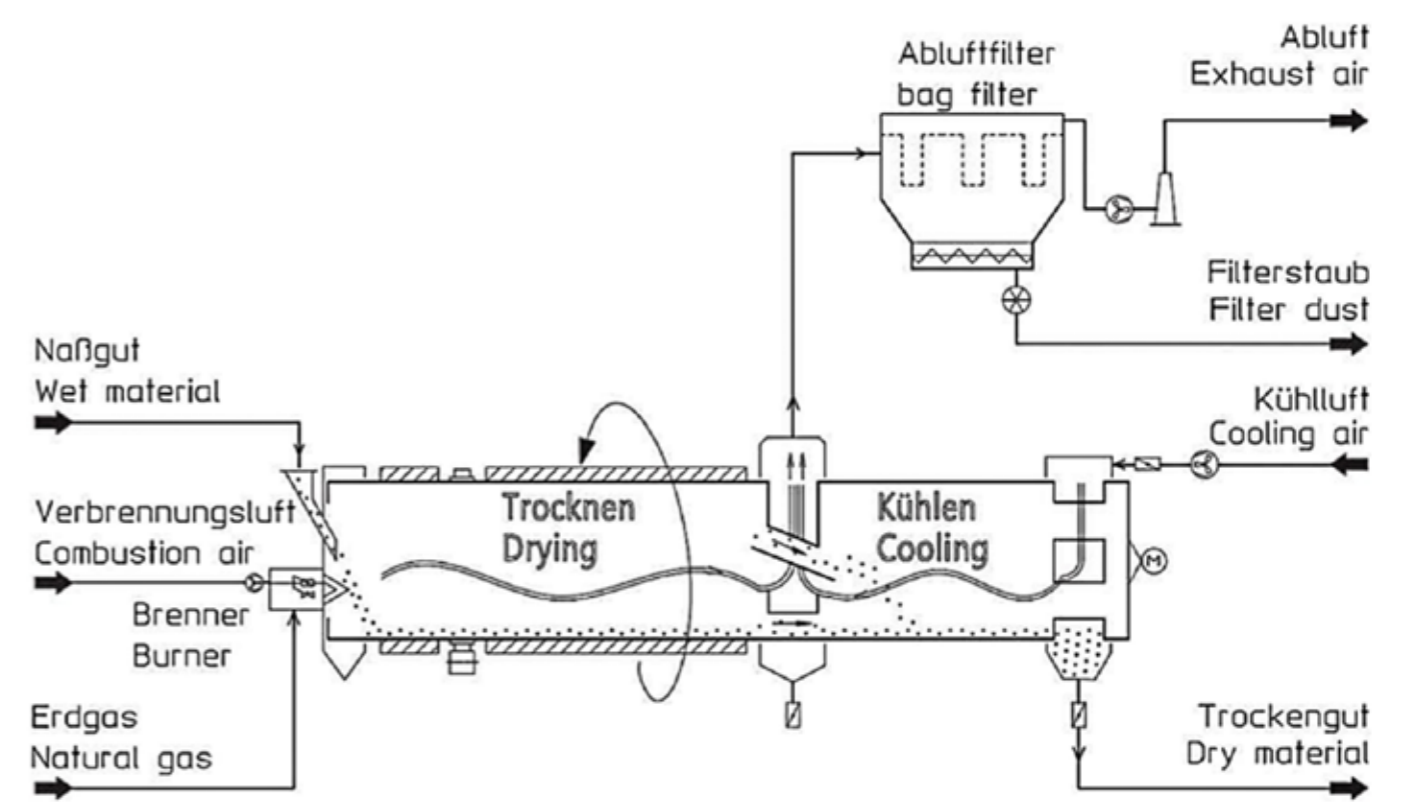


Figure 10 . Single extraction of the exhaust air streams at TK-D

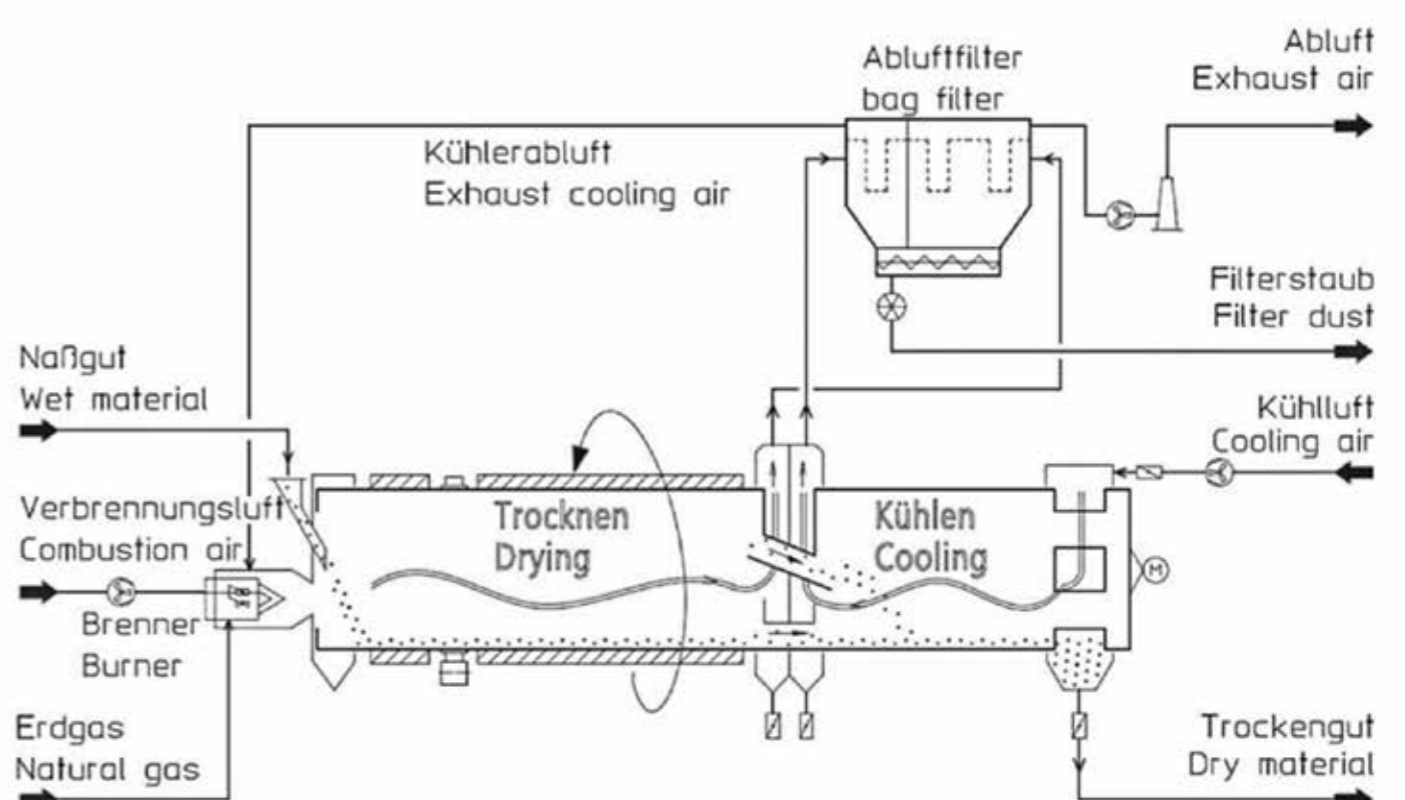


Figure 11 . Separated extraction of the exhaust air and heat recovery.

extracted and de-dusted. While the moisture-laden dryer exhaust air is de-dusted and released to the atmosphere, the warm, dry, and de-dusted cooling exhaust air can be returned to the process as preheated drying air resulting in heat recovery from the dry, warm solid (Figure 11). This provides savings of the primary heating energy such as gas or oil up to 10%

The separate supply and exhaust of the gas streams additionally allow different processing possibilities for the solid and the gas (air):

- Co-current flow or counter-current flow drying, independent of one another, can be combined with
- Counter-current flow or co-current flow cooling

The use of counter-current flow routing of the air and the stream of solids allows a particularly efficient high-temperature process for example calcining of solids immediately followed by cooling. The heating zone can be configured and optimized completely independently of the cooling zone.

## Evaporative cooling in TK1

In times of rising energy prices, the efficient usage of resources is an important method of increasing cost-effectiveness and the competitiveness of production. Because thermal drying requires up to ten times more energy compared to purely mechanical water removal, there is particular interest in using drying systems that are as energy-efficient as possible. In addition to the aforesaid methods, evaporative cooling is another method to reduce the energy consumption. Progress toward this issue is supported by Allgaier's MOZER VR TK  $\beta$  technology. It is mainly used for products with surface moisture only. The combined drying and cooling drum system TK  $\beta$  offers a concept that effectively cools the dried sand by means of evaporative cooling and leads to a fuel-saving of up to 15%.

While in the majority of cases, cooling of the hot sand is undertaken using dry ambient air, during evaporative cooling, cooling of the solids is done by evaporation residual portions of remaining moisture from the particles. Thus, instead of exchange of measurable or "sensible" heat between air and material, evaporative cooling is the cooling of the material using "latent" heat, which is the heat of evaporation or vaporization of the water. Theoretically, cooling to the "wet bulb temperature" in accordance with the psychrometric principle is possible. As a consequence, the advantage of evaporative cooling is that energy is saved during drying by using the residual heat in the material while the product is also cooled simultaneously.

On the TK  $\beta$  system, a primary flow of about 85–90% of the moist sand is dried in the inner tube of the double-shell dryer/cooler. After the drying in the inner tube, the remaining subflow of moist sand is applied to the system in a controlled manner. The hot dried product is mixed with the cold product that has not yet been dried, referenced as "bypass product" (Figure 12). The hot dry product from the inner drum and the bypass product are intensively mixed in the outer drum by lifting plates.

The combined material is conveyed against a very small flow of cooler ambient air. During this process, the water contained in the bypass material evaporates, while at the same time, the hot product is cooled by the effect of evaporative cooling.

A proportionally smaller amount, 85–90%, of fuel (natural gas, light heating oil, liquefied petroleum gas) is required to dry the reduced main flow of moist sand. Also, the quantity of cooling air required is reduced due to the effect of evaporative cooling. Consequently, system TK  $\beta$  requires significantly smaller draught air fans and bag filter plants. In addition to the reduction in the amount of fuel required, there is also a reduction in the consumption of electrical energy. It is also possible to convert the standard TK system to the TK  $\beta$  system without the need to modify or replace the existing dust removal plant.

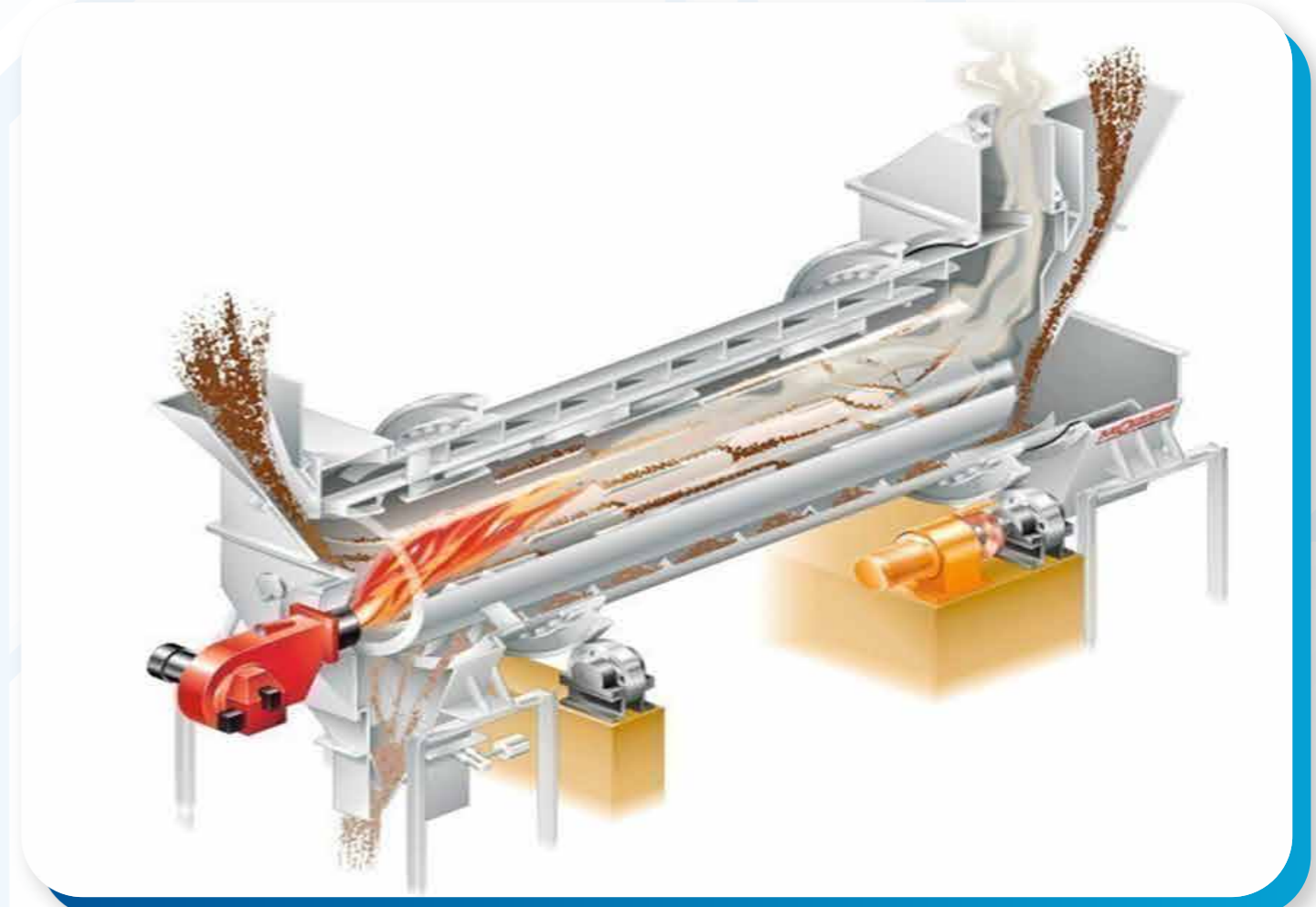
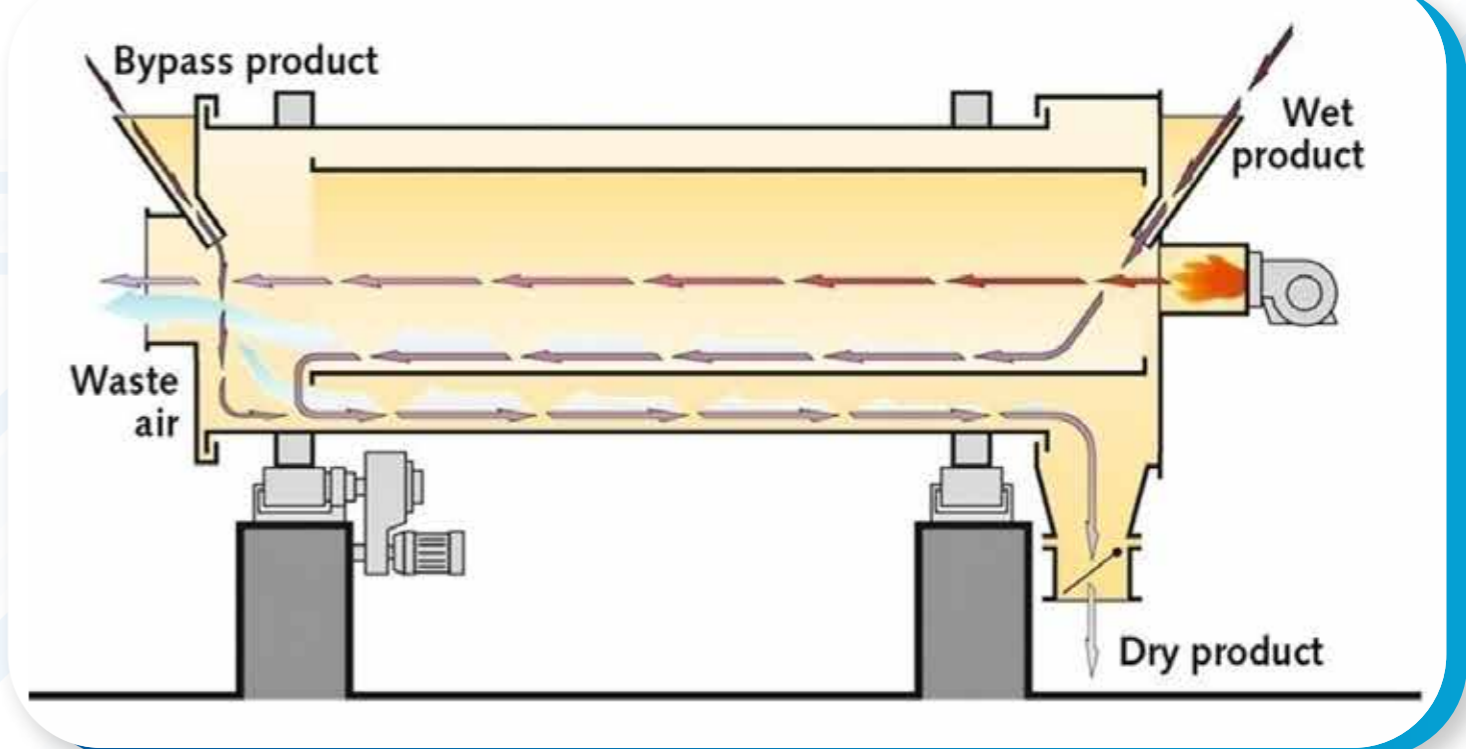


Figure 12 . 2D and 3D principle drawing of a drum dryer system TK  $\beta$  with bypass feed and evaporative cooling.

## Study confirms energy saving due to evaporative cooling

Many years of experience and sophisticated calculation programs make it possible to calculate the effects described above. Therefore, it is possible to tailor the plants to be delivered to each customer. An intensive study has been undertaken on a total of eleven plants supplied by Allgaier to verify whether the actual plant operations confirm the predicted energy consumption. [8]

All available process and consumption parameters are measured with plants being able to supply information for several years in some cases. Both MOZER TK system dryer/coolers and also TK þ system plants were studied. Comparative assessments of the parameters, determined using the existing design programs and the values measured on the plants, have shown close agreement with the original theoretical plant design. The study confirms that fuel savings of between 10% and 15% can be achieved with the aid of evaporative cooling on the usage of the TK þ system plants. It has also been confirmed that the electrical power consumption on TK þ plants with evaporative cooling is almost halved, due to the reduced amounts of waste air. (Figure 13) shows the different fuel costs in absolute and relative terms (referred to as TK þ and 4% sand moisture content) on the TK and TK þ systems with example sand moisture contents of 4%,5%,and6%. (Figure 14) shows the electricity costs for both systems, resulting from the different amounts of air (shown in absolute and relative terms referred to a TK þ and 4% sand moisture content). (Figure 15) shows the mean total energy costs for drying one metric ton of sand based on the example of an initial sand moisture content of 5%.

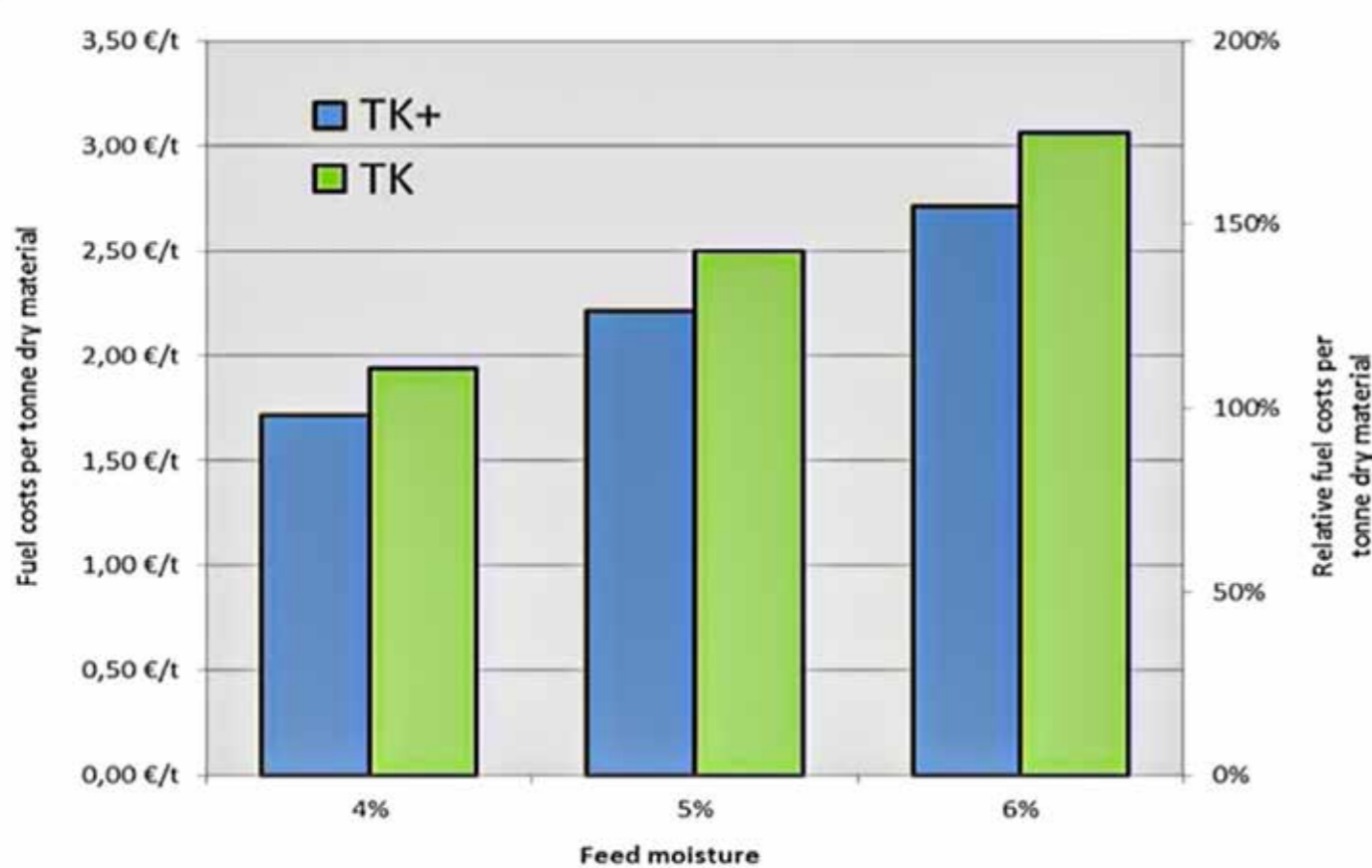


Figure 13 . Comparison of fuel costs per metric ton of dry material in TK and TK þ at different solid's feed moistures.[8]

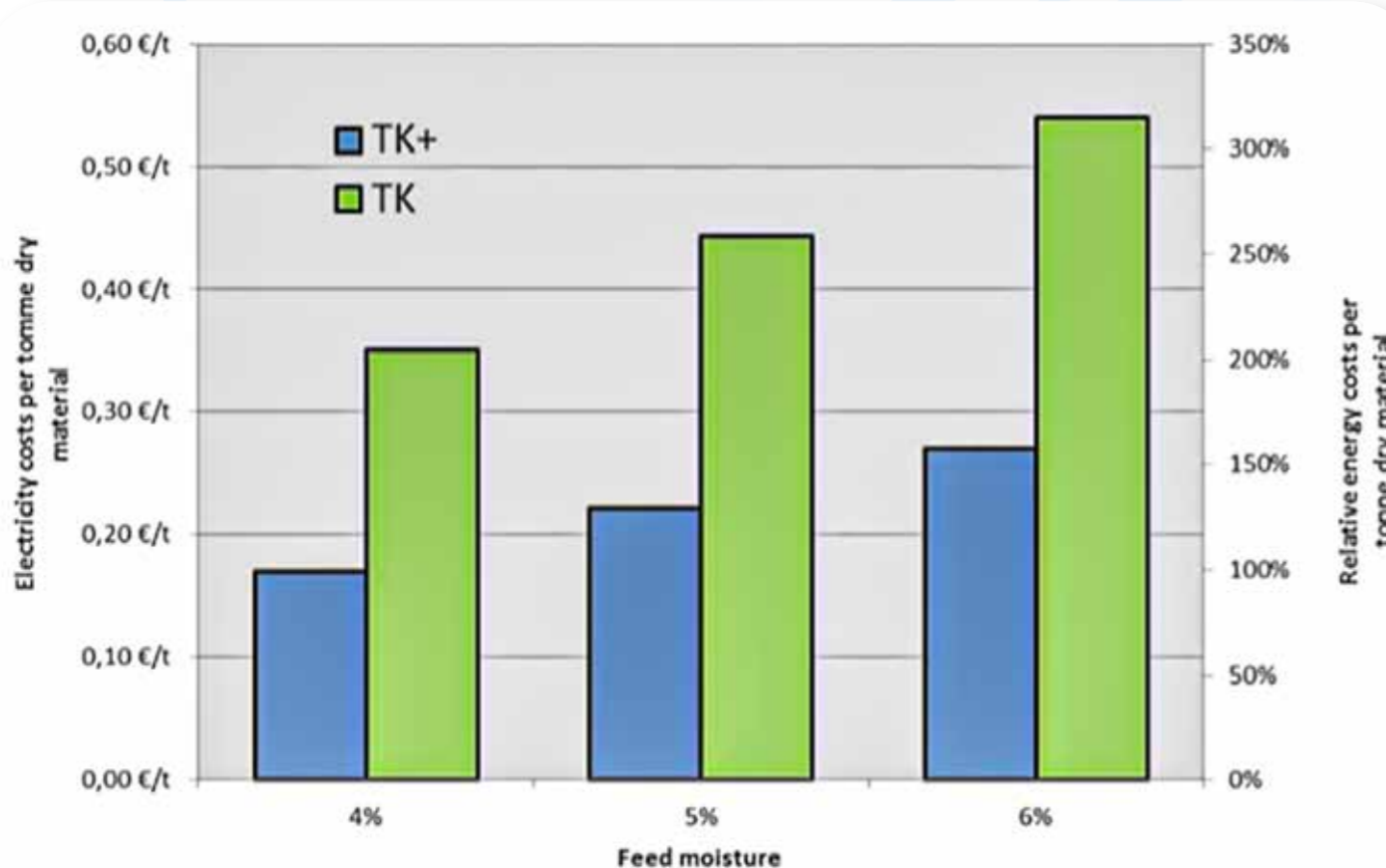


Figure 14 . Comparison of electricity costs per metric ton of dry material in TK and TK þ at different solid's feed moistures.[8]

It therefore becomes clear that the potential savings with a system TK þ drying-cooling drum are dependent on the sand moisture content. Higher sand moisture content increases the advantages of a TKþ. However, it should be generally noted to start drying with the lowest possible sand moisture content. The initial sand moisture content can be influenced, e.g., by storage of the sand at a pile for several days for natural water drainage or by roofing the storage facility and the resulting protection against the rain.

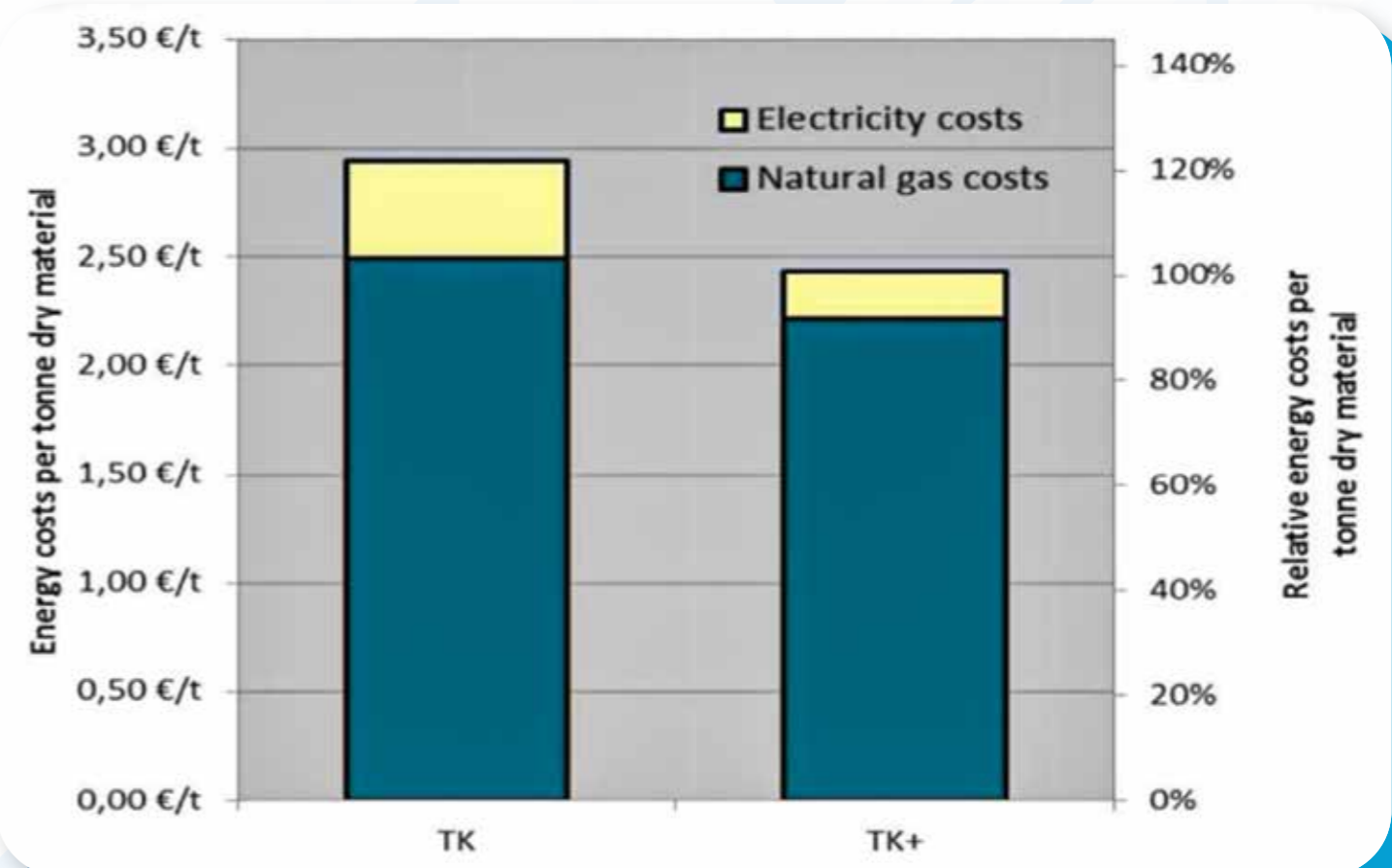


Figure 15 . Total energy costs per metric ton in TK and TK þ at solid's feed moistures of 5%.[8]

## Evaporative cooling or air cooling ?

A decision as to which of the available dryer-cooler systems is optimal for a specific task must be made depending on several factors on case-by-case basis. An amortization calculation can be used to show which system is optimal for the related application. A drying plant based on the drying-cooling drum TK þ requires greater expenditure for the controlled feed of the main flow of moist sand and dosing the bypass flow. Several technical variants are available for this controlled moist material dosing. It is possible to use matched bucket conveyors, belt conveyors, or a solution with a controlled material gate. The additional expense for the material feed, the mature electronic control program, and the higher process equipment-related expenses for the manufacture of the combined drying-cooling drum TK þ result in a somewhat higher plant price for the TK þ systems compared to the standard TK systems. In general, the fixed investment costs of a technology diminish proportionally with increasing overall plant size. As the additional expense for the detailed aspects of a TK þ is also reduced relative to plant size with increasing plant size, the additional costs for a system TK þ drying cooling plant have less impact at higher capacities.

(Figure 16) shows as an example the procurement costs for both systems normalized to a system TK plant with a dry product massflow of 15 t/h. Due to the significantly lower energy costs (fuel costs & costs for electrical energy) on the usage of evaporative cooling, the additional costs for the bypass flow distribution and the control of TK & plant can be generally amortized after 5000–8000 operating hours. The amortization periods shown in Figure 17 were calculated using German energy prices from 2013. If energy costs as expected continue to increase in relation to labor and material costs, the amortization period will reduce further.

Particularly on plants with high-throughput and high initial moisture content, it is worthwhile to use VR energy-saving technologies like that of the MOZER TK & system. However, it is to be noted that low sand moisture content reduces the absolute investment and energy costs for any drying plant. Hence, the above statement should not be misunderstood that any mechanical pre-drying or dewatering of wet products will always be reasonable, if that is possible.

## Rotary driers for drying seriously abrasive products

Rotary driers can also be used for very robust applications such as abrasive products which might cause significant wear to the dryer's body and the blades and vanes inside. An interesting example is the drying of glass waste prior to color sorting.[9] Today, glass waste is a major secondary raw material. In fact, the glass industry can use it as cullet to make new glass products while simultaneously reducing the energy consumption levels of glass melting furnaces. Reduction in the molten glass temperature when using recycled glass allows the energy costs of glass production to be

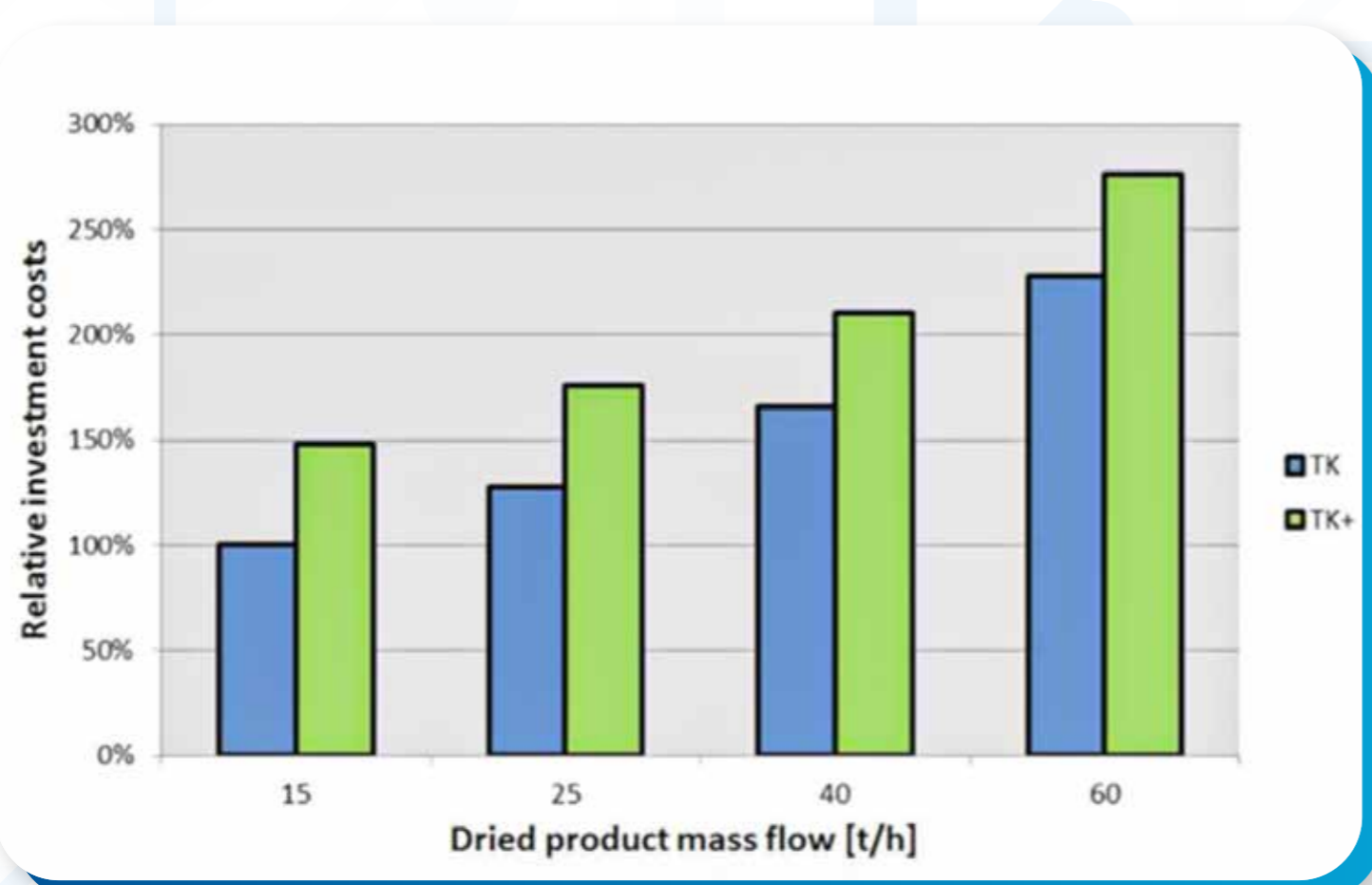


Figure 16 . Relative investment costs versus dry product massflow.[8]

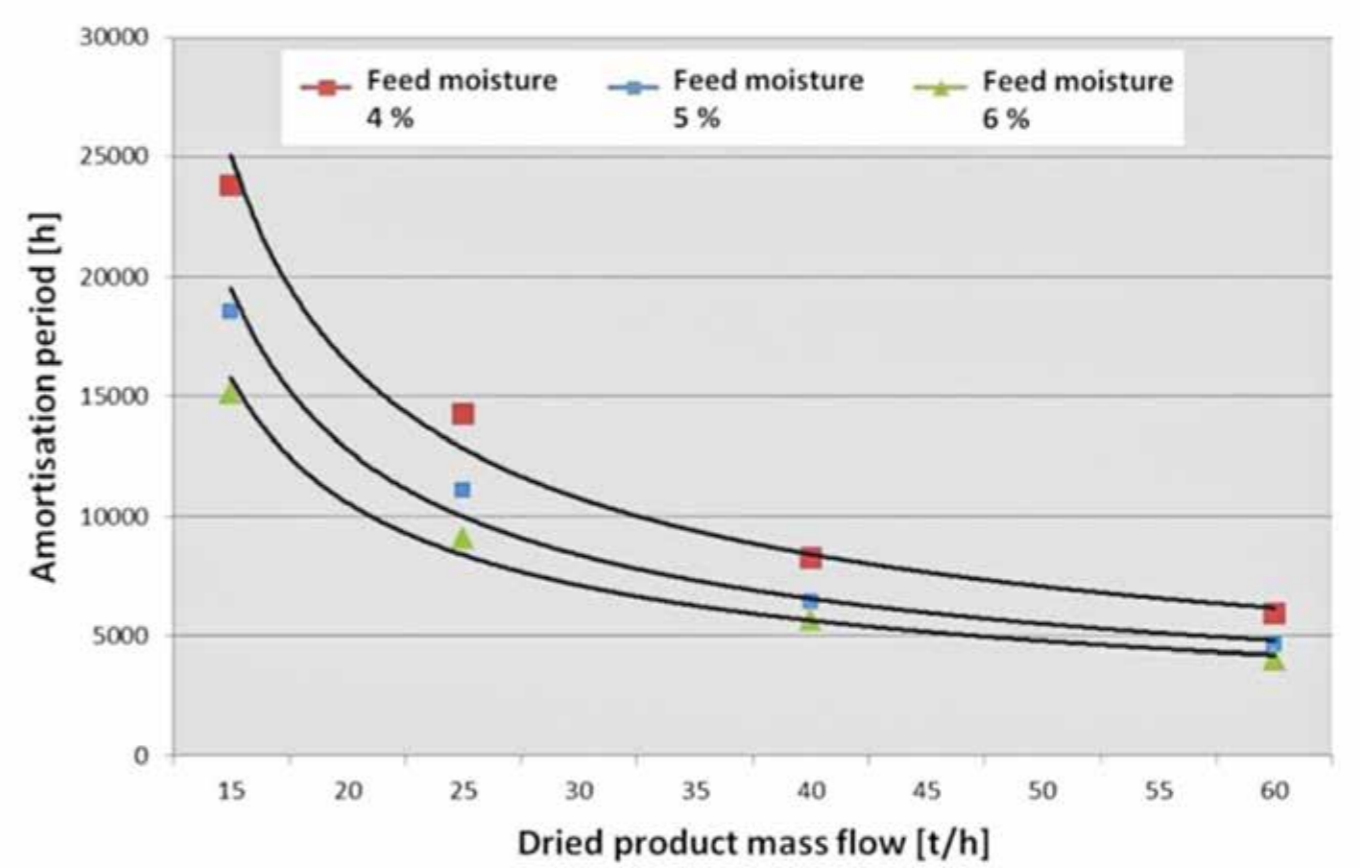


Figure 17 . Amortization periods versus dry material throughput at different solid feedmoistures.[8]

reduced considerably. Each 10% of recycled glass used as a raw material in the molten glass represents an energy saving of about 2%. The requirements on achieved glass quality have risen significantly over recent years in the business of preparing recycled glass. Higher and higher recycling rates are being achieved in the molten glass used for producing bottles, while a low scrap rate continues to be demanded. Therefore, efficient and high-performance sorting systems are required for glass processing and color sorting. Today, modern color sorting systems are able to separate individual particle sizes as small as 2.5 mm effectively – however only if the raw material is provided in dry and clean condition. Additionally, the recycled glass contains other disruptive substances such as ceramics, stones, porcelain (CSP), corks, plastics, metal caps and adhesive labels, as well as all other kinds of rubbish. Recycled glass is predominantly stored outdoors; therefore, greater or smaller amounts of water also get into the outdoor storage facility depending on the season and the associated quantity of rain. As a result, recycled glass has a foreign matter, must first be dried and preferably simultaneously cleaned and de-labeled. moisture content between 1% and 6%, which fluctuates throughout the year. In order to sort collected glass waste (bottles and glassware, as well as the contaminants and foreign matter they contain) with an optoelectronic color sorting system, such as an MSort for example, the wet raw material, which is also soiled and mixed with foreign matter, must first be dried and preferably simultaneously cleaned and de-labeled.

Drum dryers usually meet all the product-specific criteria for drying recycled glass, which explains why over recent years there have been more and more drum dryers entering service for drying recycled glass. One side effect during the drying of recycled glass in drum dryers is the associated cleaning of the material by galling of the material during drying. An impressive example of product received from a rotary dryer (see Figure 18) is shown in Figure 19.

The hot drying air is cooled down very quickly in the input area of the rotary dryer due to contact with the moist product, thereby minimizing the danger of deflagration of the organic components due to the burner flame. Nevertheless, the waste air pipe is equipped with a spark monitoring system and extinguishing device for safety's sake, in order to prevent the possibility of a fire in the waste air filter. External hot air generators are used if particularly high proportions of organic material are present in the contaminated raw glass. That way the very hot flue gases from the burner are mixed with ambient air to a rather homogeneous air flow of moderate inlet drying air temperatures. During the drying process, the glass is heated up to temperatures between 60 and 75 °C and dried to residual moistures between 0.5% and 1%.



Figure 18 . Rotary drying system for recycled glass.



**BEFORE**



**AFTER**

Figure 19 . Recycled glass <10 mm before and after drying.

## Wear protection

Recycled glass is a very abrasive product, which explains why the materials used for its processing must be selected very carefully. Suitable design of the installed components allows the wear to be reduced. In order to extend the service life of dryers for glass processing, extra thick walls are used in the drums. Areas where there is direct contact between glass and the apparatus wall are exposed to particularly high wear; therefore, they are lined with wear protection plates. The wear protection plates may be designed to be bolted on so that they can be exchanged easily (see Figure 20).

Attention is paid to avoiding the solid material from sliding on the lifting and guidance paddles, or else keeping this level of sliding low, and also, care is taken to ensure that when the material falls it drops onto a bed of the dried solid material. All this makes it possible to achieve durable dryer solutions even for highly abrasive solids such as recycled glass.

Recycled glass should be smashed up as little as possible during the preparation process; therefore, the heights through which the glass falls at the transition points and within the dryer are minimized. As a result, drying drums for glass are optionally equipped with special crossways installed components. The crossways installed components (see Figure 21) achieve very good results with regard to retaining the particle size during the drying procedure.



Figure 20 . Bolted-on components installed in a drum dryer.



Figure 21 . Rotary drying system for recycled glass.

## Combined cleaning and drying of recycled glass

Cleaning and label removal can be significantly improved by a combined drying and cleaning drum dryer RTT, which combines both useful properties for glass processing. For this purpose upstream the drying zone of the rotary drum, a compartment of bigger drum diameter and consequently longer duration time for the glass are used. This patented technology involves the glass material to be cleaned being churned in a cleaning drum ahead of the drying compartment for up to 20 min without significant product damage (see Figure 22 as a view into the cleaning zone of an RTT).

The individual glass particles rub against each other due to the churning, at the same time as removing the adhering labels. This is deliberately done while the raw material is still damp and involves a long holding time, because numerous experiments carried out have shown that this method achieves the best cleaning results. Following this, the cleaned glass material moves into the drying zone of the drum, where it is dried (Figure 23 shows a flowchart of the process). Drying glasscullet in the drum dryer offers the advantage that the necessary amount of energy is low, and thus, drying is very effective, in both the counter-flow and parallel-flow principles.

## Drying limestone and cleaning it without the use of water



Figure 22 . View into the cleaning compartment of a combined drying cleaning drum.

limestone in a rotary drum. At many of the quarries used to mine limestone for the construction materials industry and for making fillers and pigments, the processing that follows yields screened stone with a size of 0–60 mm. In most open-pit mines in Europe at least, this stone has large amounts of loam silt and clay stuck to it as a result of the composition of the soil layers found above the corresponding limestone deposits.

Until recently, this screened limestone required the use of expensive stone washers in order to be further processed into high grade materials and accordingly was often taken without any additional processing and used as low grade screened stone for road building instead. In heavy frost or in arid regions the lack of processing water stone washing plants limits their usability. Moreover, the use of stone washing plants requires costly sludge treatment, waste water removal, and waste disposal.

However, the very unique TRH drum dryer shown in (Figure 24) is a method that dry screened limestone and simultaneously free it from silt and clay without any need for water or expensive stone washer systems. As in the aforesaid RTT system, the TRH system uses a drum compartment of increased diameter but with some special blades and vanes. In the TRH, the cleaning compartment follows the drying compartment of very quick drying at increased temperatures (Figure 25). Loam and clay is loosened from the surfaces by the combination of quick drying and intensive attrition of the stones. The fines are removed from the dryer together with the exhaust air or can be separated from the good product by rather simple screening machines downstream the dryer. In fact, the high-grade lime stone obtained with this method is of equal or even better quality to those obtained with the usual complex stone washer plants despite considerable lower capital costs, as well as significantly lower operating costs that result from not having to use water or deal with wastewater. In addition, the use of this system significantly reduces the amount of equipment and conveyor units needed while also requiring a lot less installation space.

Flow Chart Cleaning- Drum- Dryer Type RTT D ZL OB K G

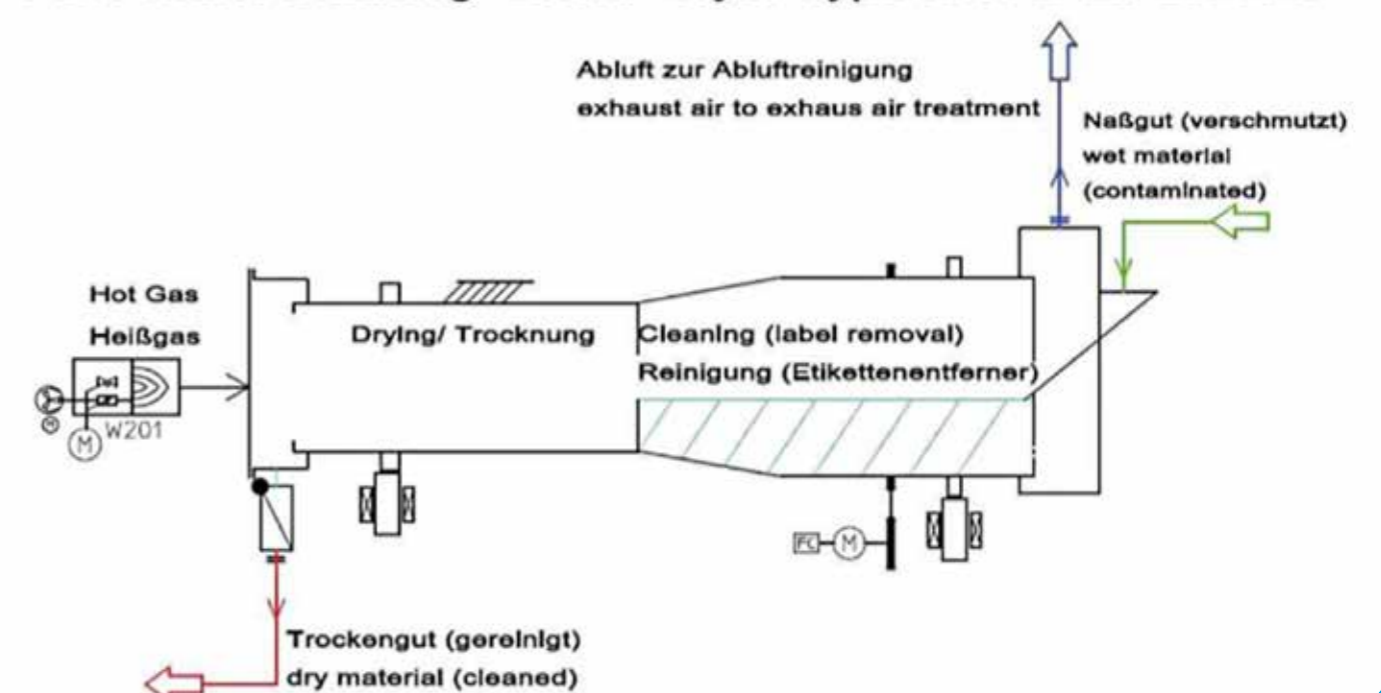


Figure 23 . Process diagram of the cleaning drum dryer RTT.

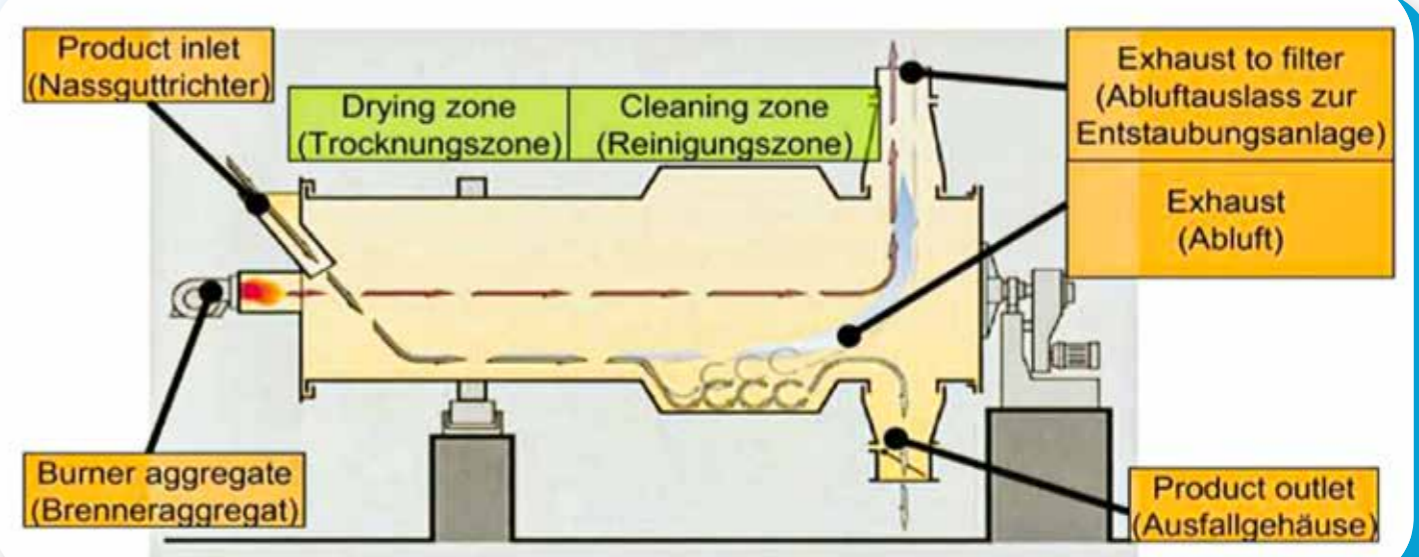


Figure 24 . Scheme of system TRH for dry cleaning of stone.



**Figure 25 . Drying system TRH for screened limestone.**

(Figure 26) shows an exemplary product sample received from the TRH (right) versus the dirty product fed to the plant (left). The abovementioned advantages were proven by a study in cooperation with customers. The efficiency of this innovative, technological solution was compared with stone washer systems with and without drying for the washed material. The results show clear advantages in terms of power consumption, capital costs, operating costs, and maintenance costs (Figure 27).

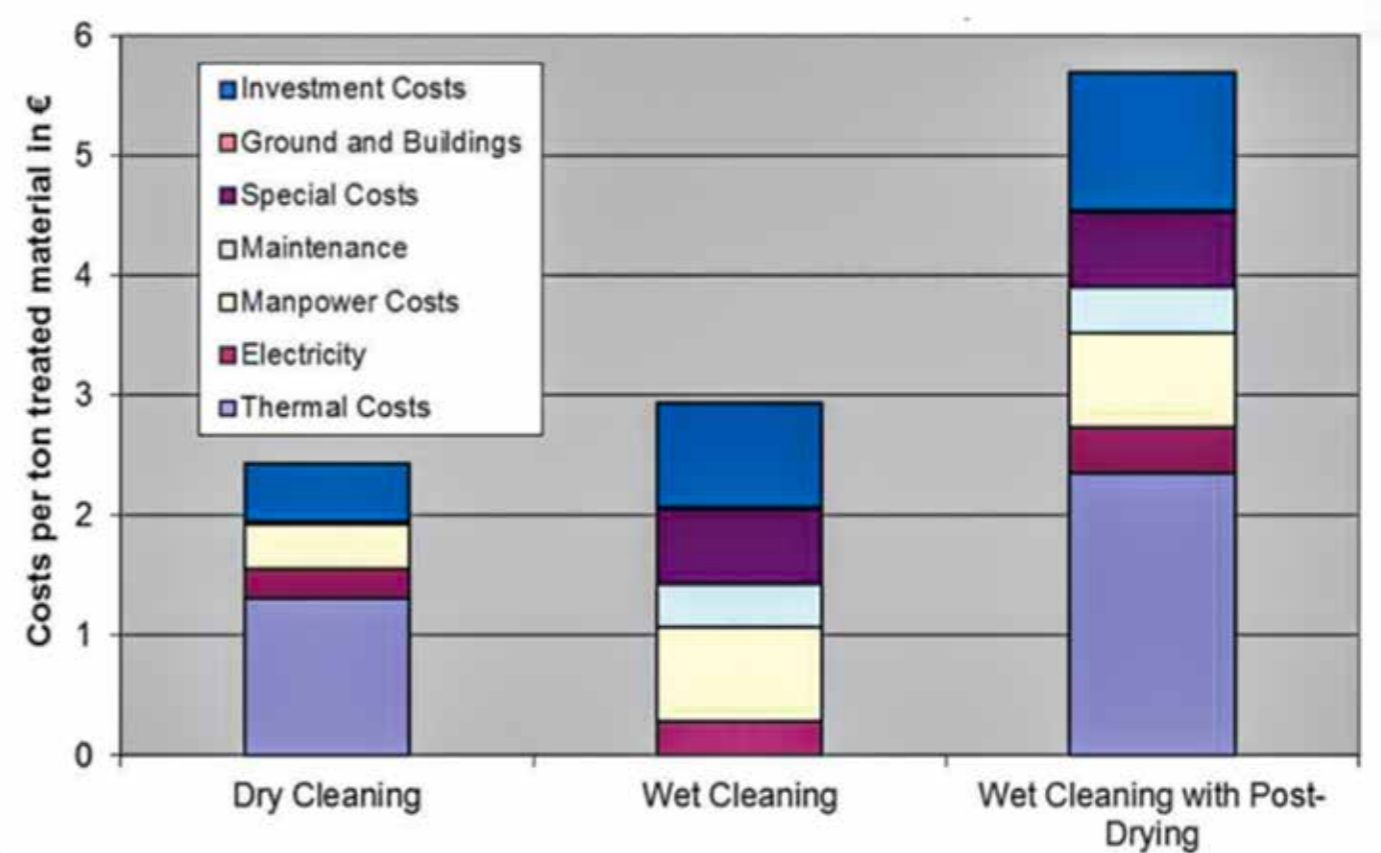
### Development of a new indirect rotating tube cooler for bulk materials

In many industrial cases, it is necessary to cool warm or hot product from drying. Particularly hot bulk materials from high temperature processes such as calcining, oxidation, or combustion processes require a special cooling from temperatures of about 700 °C or even 1200 ... 1400 °C. Examples of products are pigments (e.g. titanium dioxide), slags, metal oxides and hydroxides, cement clinker, sponge iron, scale, activated charcoal, catalysts, and waste material from smelting plants. Further processing is often not possible without cooling products down to about 100–150 °C. In many cases, at least some thermal energy contained in the solids is to be recovered during the cooling that is necessary for engineering purposes. Besides using coolers with direct contact between ambient air and the material to be cooled, indirectly operated rotating tube coolers are also used with air or water. The term “indirect” means that the coolant does not come into direct contact with the hot product to be cooled. Instead, the heat is exchanged from the hot product to the coolant by way of a wall in the device that separates the media.

Indirect planetary rotary coolers of different designs using ambient air as coolant have been known for decades. Very efficient cooling technology is given by a rotating tube cooler that operates with water as coolant. This new planetary cooler, named RK-W, provides many advantages over the previously known solutions.



**Figure 26 . Lime stone samples from before and after the dryer/cleaner TRH**

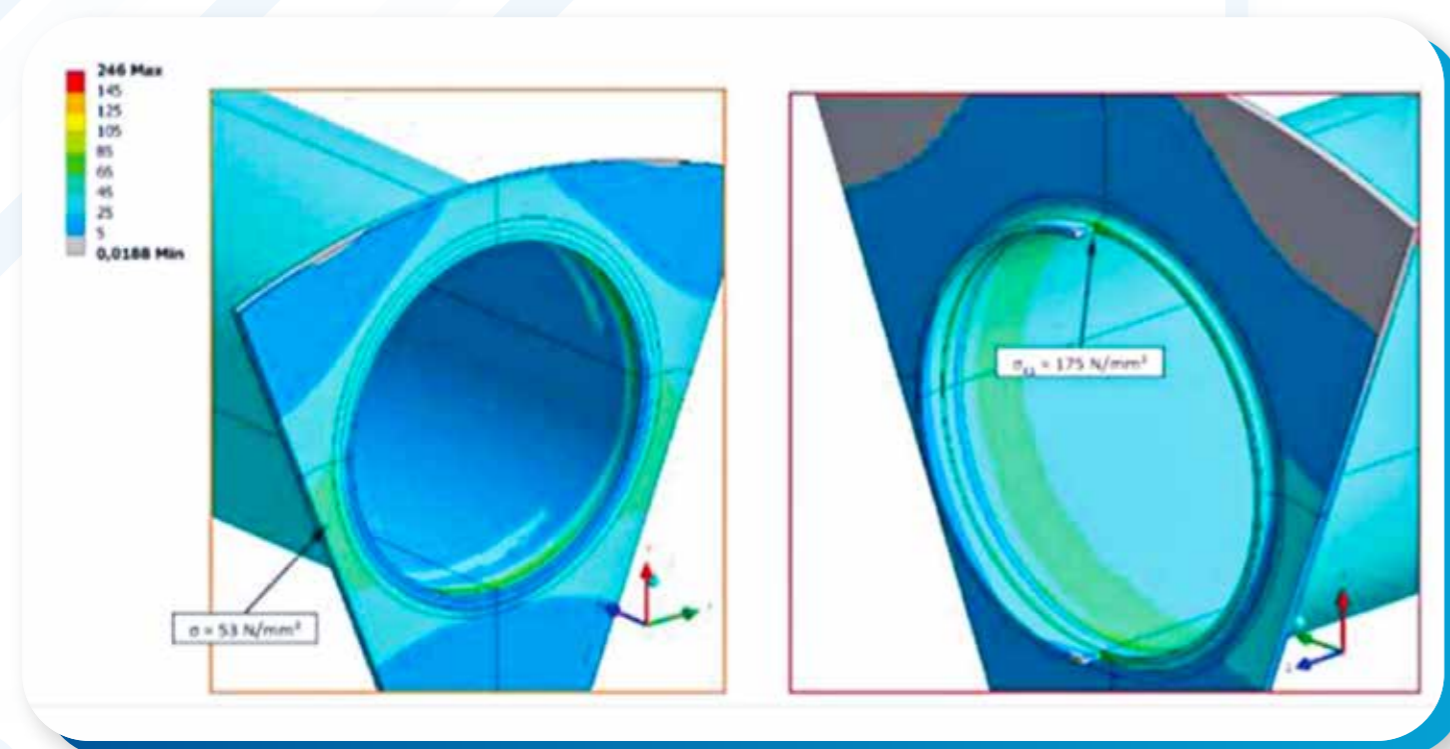


**Figure 27 . Processing costs of TRH versus costs of stone washing without and with subsequent drying.[13]**

(Figure 28) shows a three-dimensional drawing of a cooler for an exemplary customer’s project for cooling 40 tph metal oxide from 800 °C inlet to less than 150 °C outlet temperature. The cooler is built using several, for example, 6 or 8, double-walled tubes configured like planets with the cooling water flowing in the tube gap. This eliminates the necessity of using heavy- and complex welded rotating drum housing as this was known from the so-called Sectional Coolers proposed by BSH decades ago. In the latter coolers, pronounced thermal stresses may result in the material used because of the solid implementation with little flexibility. These thermal stresses can result in material fracture and cracks in the welded structure. However, the implementation of the new cooler results in a design that is tolerant to expansion by using commercially available tubes. This design led to a reduction in the weights and a decrease in the welding work required during manufacture. The structure of the new rotating tube cooler was optimized in terms of thermal stresses and service life using modern finite element calculations (Figure 29).



**Figure 28 . Indirect planetary rotary cooler for 40 tph solid.**



**Figure 29 . Results of FEM-calculation of the new cooler design.**

In the new cooler, all gaps of the double walled tubes are completely filled with flowing water, which is not the case at the Sectional Coolers. This constantly cools all available heat exchanger surfaces carrying the hot product achieving an improvement in the cooling performance. The cooling water is supplied and removed by means of a sealed swivel joint and pipe connections running to and from the individual cooling tubes that carry the product and are designed as double-walled tubes. The hot solids introduced into the cooler move from the inlet to the outlet by means of the rotation and a slight slope of the cooler.

To reliably design the processes, two laboratory test systems were built during the development period. Using these systems, it was possible to determine product-specific bulk material data and the heat transfer coefficients of real solids (Figures 30 and 31).

In cooperation with an external engineering office, DEM simulations were performed for a solids cooler using the bulk material and heat transfer properties of the real product determined during calibration tests. Calibration was done at a small rotating cylinder of 180 mm diameter and a solid filling of 2.5 kg metal oxide with bulk density of 2300 kg/m<sup>3</sup>. The front end and back side of the cylinder were made of transparent plastic material that the movement of the solid could be observed.

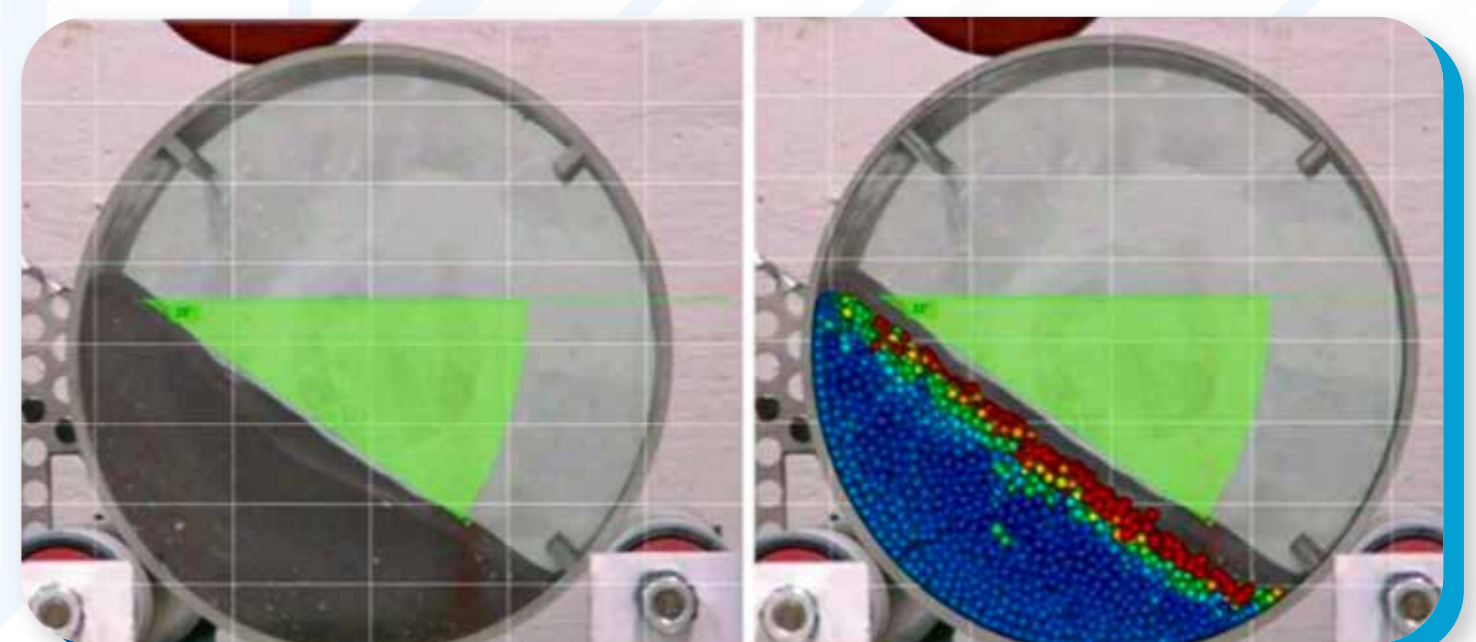
The cylinder was driven at a rotational speed of 4.08 min (0.068 s ) as an example. An angle of response of 330 was measured. By various DEM simulation procedures of this test equipment, corresponding parameters of the bulk characteristics have been examined to a particle-particle-friction coefficient of  $f_f \approx 0.4$  and a rolling-friction coefficient of  $f_r \approx 0.2$ . (Figure 32) show the profile of real product on the left side versus the result of the simulation on the right side with the use of the abovementioned friction coefficients for DEM simulation.



**Figure 30 . Batch laboratory cooler for determining the properties of bulk materials and heat transfer of real solids.**



**Figure 31 . Test plant for continuous solids cooling.**



**Figure 32 . Results of calibration tests to determine bulk characteristics (Example: Zinc calcine, rotational speed 4.08 min angle of response 330 ).**

In the same way, the parameters characterizing the thermal conductivity of the particles  $thCoP$  and the thermal conductivity of stainless steel  $thCoW$  were determined from the batch cooling experiments described above.

Finally with the elaborated calibration parameters, which show the characteristic of the real solid, full scale plant was simulated. (Figure 33) shows the resulting solid temperature profile along the cooler length for a cooler of 10 m length, solid capacity of 40 tph Zink calcine with 700 °C solid feed temperature. By comparing the simulation results with thermal balances and heat transfer numbers to a traditional evaluation of Technical Center tests, it was possible to confirm the reproducibility of the results. Heat transfer coefficients between 124 and 237 W/m<sup>2</sup>K for zinc calcine, 120–208 W/m<sup>2</sup>K for silica sand, and 81–126 W/m<sup>2</sup>K for iron oxide were examined. These results correspond with data from the literature[16] exemplarily shown in (Figure 34).

In future as a result of the investigation, both continuous tests in the Allgaier Technical Center and the method of DEM simulation based on calibration tests for the properties of bulk materials and heat transfer of real products can be used to design a full-scale cooler system.

## Summarization and perspective

As shown by the various examples, rotary drums for processing bulk material in general and for drying and cooling in special still become steadily improved. Experimental investigations about the value of the specific water evaporation capacity are described by the article in detail. New applications for the use of rotary drums are presented such as different methods for combined drying and cooling, drying of extremely abrasive solids such as glass cullet, combined drying and label removing, dry lime stone cleaning, or indirect cooling of very hot solids with water by a new planetary rotary cooler. Results from experimental investigations at various full-scale customer plants are presented, which show the praxis effects and give recommendations for end users. Finally, an example for the use of modern simulation methods in the period of a development process is described by the example of a new indirect planetary rotary cooler.

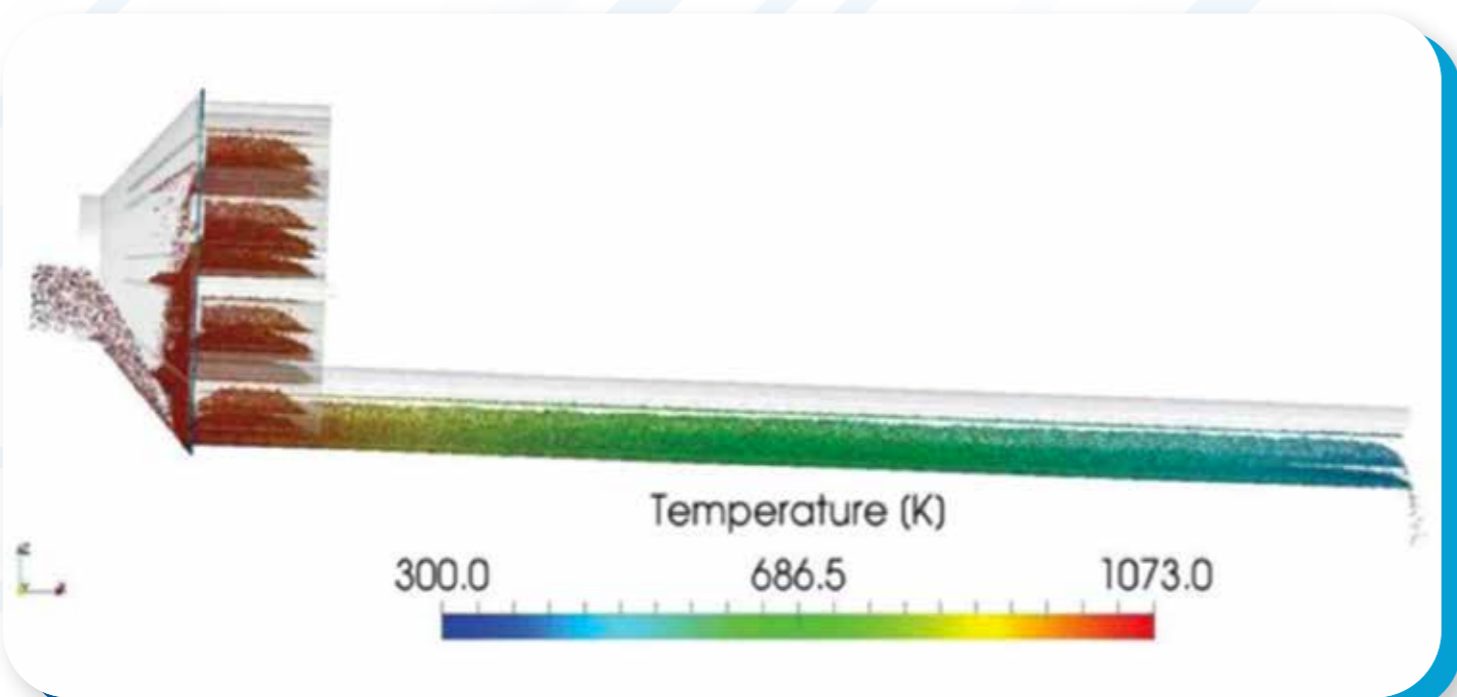


Figure 33 . Results of a DEM-simulation of the rotary cooler (Zink calcine, 40 tph, 700 °C inlet solid temperature)

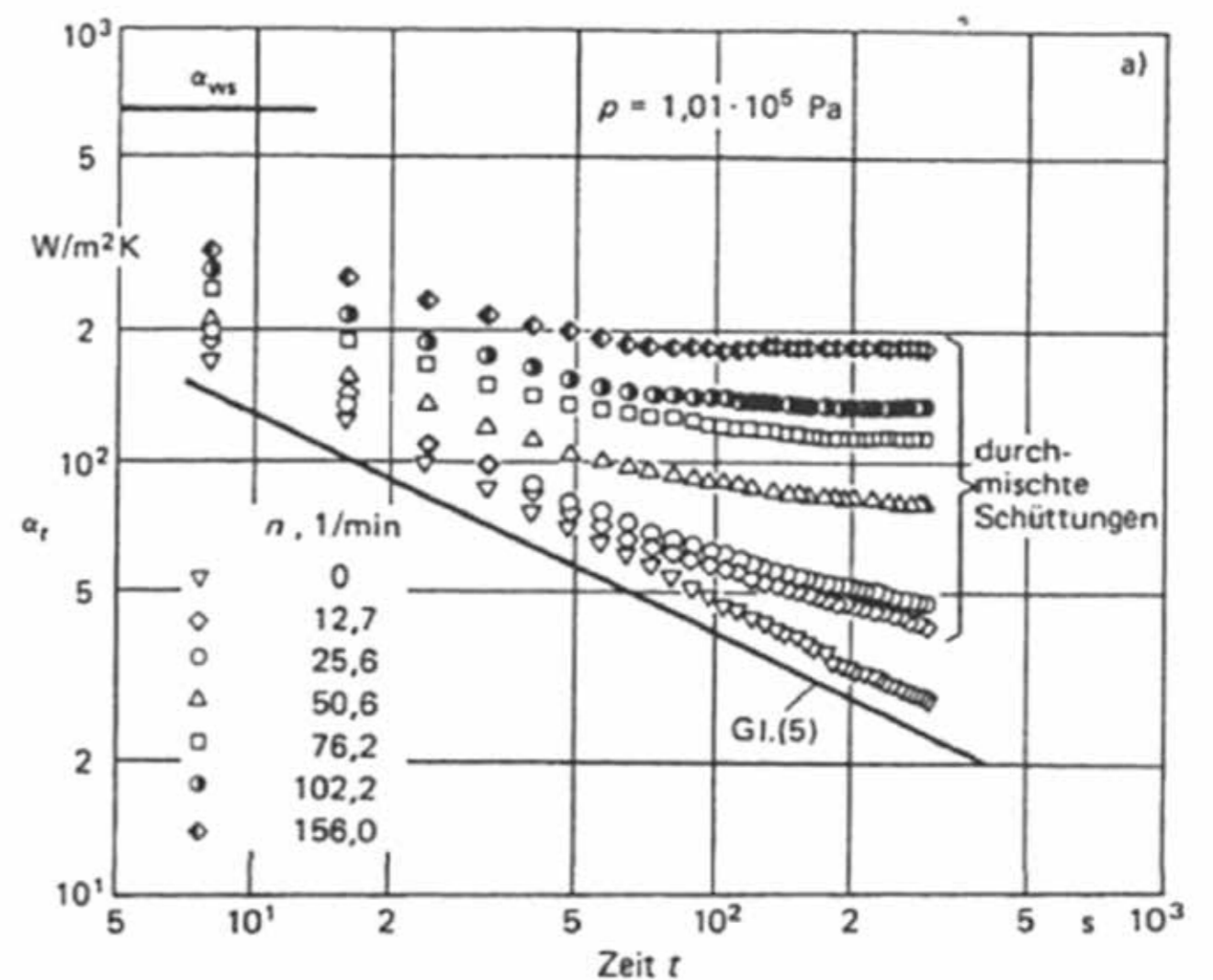


Figure 34 . Heat transfer coefficients from a wall to mixed bulk materials Data by Wunschmann.[16]

However, the efficiency of rotary processes can always be improved. It is always a matter of long lasting experience and the use of modern calculation and design methods to find the right solution in the advantage of a client.

## Disclosure statement

No potential conflict of interest was reported by the author.

## Notes on Contributor

Born in 1960, the author studied chemical engineering at the Technical University "Otto von Guericke" Magdeburg, did PhD about heat and mass transfer in liquid sprayed fluid bed drying and started professional career at GEA Wiegand GmbH Esslingen. Since 1995, the author is working at ALLGAIER Process Technology GmbH, Uhingen, and the current position is Director R&D.

## Nomenclature

$ff$	Particle–particle–friction coefficient for DEM simulation
$fr$	Rolling–friction coefficient for DEM simulation
$h_{1px}$ , [J]	Enthalpy of humid air
$h_{Pr}$ , [J]	Enthalpy of the solids
$m_{L}$ , [kg/s]	Total air mass flow rate
$m_{LL}$ , [kg/s]	Leakage air mass flow rate
$m_{Pr}$ , [kg/s]	Solid mass flow rate
$P_B$ , [W]	Burner power
$Q_{r}$ , [W]	Losses by thermal radiation
$t_{amb}$ , [K]	Ambient air temperature
$t_{a,mix}$ , [K]	Resulting exhaust air temperature
$t_{a,real}$ , [K]	Cooled drying air temperature
$t_e$ , [K]	Hot inlet gas temperature
$thCoP$ , [W/(m K)]	Thermal conductivity of the particles
$thCoW$ , [W/(m K)]	Thermal conductivity of stainless steel
$t_{Pr,f}$ , [K]	Solid feed temperature
$t_{P,tr}$ , [K]	Solids product temperature
$v_{a,mix}$ , [m/s]	Air flow velocity
$X_{Pr,f}$ , [–]	Solid inlet moisture
$X_{P,tr}$ , [–]	Residual solid moisture
$x$ , [kg/(s m <sup>3</sup> )]	Specific water evaporation capacity

## References

- Trojosky, M. Selection Criteria for the Use of Dryers in the Mineral Raw Materials, Chemical and Recycling Industries. *Cem. Int.* 2009, 3, 58–68.
- Trojosky, M. Auswahlkriterien für Die Verwendung Von Trocknern. *Steinbruch und Sandgrube.* 2009, 3.
- Kröll, K. Die Vorgänge in Trocknungs- und Erwärmungstrommeln für selbsttätige Güter; Springer-Verlag: Berlin/ Göttingen/ Heidelberg, 1950.
- Maltry, W. Untersuchungen an Trommeltrocknern mit Kreuzeinbauten. *Deutsche Agrartechnik.* 1969, 19, 45–46.

## Abbreviations

DEM	Discrete element method
RK-W	Indirect planetary rotary cooler
RTT	Combined drying and cleaning drum dryer
TK	Trocknen/Kühlen 1/4 Drying/cooling
TRH	Dry cleaning of limestone

## Indices

amb	ambient
$a_{mix}$	air, mixed
$a_{real}$	real outlet
B	Burner
$e$	inlet
$f$	wet
L	Air
LL	Leakage air
Pr	Product
$r$	radiation
$t$	dry

Ruoff, M. Experimentelle Untersuchung der spezifischen Wasserverdampfungsleistung im Innenraum von Trommeltrocknern. Bachelor Thesis, Allgaier Process Technology, 2017.

Kindler, A.; Ruoff, M.; Stoßlner, G.; Trojosky, M. M. Specific Water Evaporation Capacity of Rotary Drum Dryers. Presented at 2nd Nordic Baltic Drying Conference NBDC, Hamburg, Germany, June 07–09, 2017

Trojosky, M.; Roller, R.; Frey, M. Evaporative Cooling  $a_{mix}$  air, mixed as a Method for Reduction of the Energy Consumption on Drying Sand. *Cem. Int.* 2015, 3, 56–60

Frey, M. Vergleichende Ermittlung der Verbrauchswerte von ALLGAIER-Trocken-Kühl-Trommeln der Systeme MOZERV TK und TKp. Bachelor Thesis, Allgaier Process Technology, 2013.

Frey, M. Vergleichende Ermittlung der Verbrauchswerte von ALLGAIER-Trocken-Kühl-Trommeln der Systeme MOZERV TK und TKp. Bachelor Thesis, Allgaier Process Technology, 2013.

Hesse, J.; Trojosky, M. Aufbereitung Von Recyclingglas. *Schüttgut.* 2012, 201, 8–10.

Trojosky, M.; Hesse, J. Method and device for preparing broken glass. Patent WO 2011/054418 A1, September 23, 2010.

Trojosky, M.; Autenrieth, B.; Stoßlner, G. Aufbereitung Von Kalkstein-Siebschutt Mittels Einer Kombinierten Trocken-Reinigungs-Trommel. *Aufbereitungstechnik* 2012, 3, 12–13

# OUR CLIENTS









# THANK YOU

## UNIT 1

4 & 5, Marudhar Industrial Estate, Gas Godown Lane, Goddev Fatak Road, Bhayander (E), Dist. Thane - 401105. (India)

Contact Us  
+91-22 48255071,  
48255072

## UNIT 2

Plot No. B-47, Addl. Midc Anandnagar, Ambernath (E), Dist. Thane (India)- 421506

Contact Us  
+91(0251)26205  
42/43/44/45/46

## KRDC

Plot No K2, Industrial Gala F4A, D- Wing, MGN Properties, Opposite Godrej Co., Addl MIDC Anand Nagar, Ambernath (E)- 421506 (India)

Contact Us  
+91-2512620543/44

## UNIT 4 (EUROPE)

Kerone Engineering Solutions LTD. (EMitech) Viale della Palma, 7, 70033 Corato BA, Italy (Europe)

## UNIT 5 (THAILAND)

Thailand Representative:  
163 Rajapark Building,  
18th floor, Sukhumvit 21  
Road (Asoke), Wattana,  
Bangkok - 10110, Thailand

Contact Person  
G.Vivekanand  
+6689 500 9821

## Uzbekistan / Kazakhstan (Office)

TIT Company LLC: 100060,  
2, A. Kahhar, Tashkent,  
Uzbekistan

Contact Person  
Mr. Slava  
+998 903540963

## Israel (Office)

Ornatus Industrial Tech  
Ltd: Dam Hamac bim 36,  
7178602 Modiin, Israel

Contact Person  
Omri Fabian  
+972 584844887

## Australia & New Zealand (Office)

Linetech Pty Ltd:  
Po Box 3046, Browns  
Plains, Qld 4118. Australia

Contact Person  
Eric Quevauvilliers  
+61 (0)418 871 005

## Bangladesh (Office)

House-10, Road-5 Priyanka  
City, Sector-12, Uttara,  
Dhaka-1230, Bangladesh

Contact Person  
Md. Emtiaz Morshed  
+8801747762200



SCAN HERE

## Our Mails

info@kerone.com  
sales@kerone.com  
marketing@kerone.com

## Website

www.kerone.com  
www.kerone.net  
www.keroneindia.com