

EVACTHERM[®]

Molding sand preparation under vacuum



- simultaneous cooling, mixing and activating in a single machine
- excellent molding sand quality
- consistent sand temperature after cooling
- space-saving system configuration

The EVACTHERM® process for simultaneously mixing and cooling molding sand under vacuum in a single machine has exceeded expectations over the past ten years. Advantages such as the consistent temperature of the prepared sand, no dependency on climatic conditions, substantially lower consumption of bentonite and coal dust and a long-term reduction in the environmental impact are only some of the aspects which make this process the sand preparation technology of the future.

1. System configuration

Air cooling versus vacuum cooling

Multiple process steps can be combined into a single step with the vacuum mixing and cooling system. The system configuration is much simpler compared to conventional air cooling. The following list outlines several key aspects of the system configuration (Fig. 2.1):

- The EVACTHERM® mixer-cooler eliminates the need for the bentonite storage silo and the metering equipment.
- Fewer bucket elevators are needed on tower systems.
- The surge bin for the cooler, the reversible belt conveyor and the air cooler itself are no longer necessary.
- The cooling fan which consumes considerable energy becomes unnecessary.
- The large cyclone including any equipment for avoiding condensation and caking as well as the filter dust return system are unnecessary.
- The additional PLC for adding water to the air cooler is no longer needed.

- The size of the central dust extraction filter and the amount of energy it consumes can be reduced by up to 50%.
- A reduction in exhaust air volumes reduces waste disposal costs.
- Steelwork and foundation construction costs can be reduced considerably.
- The system footprint can also be substantially reduced.

All of the equipment mentioned above is replaced by a vacuum mixer-cooler system (Fig. 3.1) which essentially consists of the following:

- The EVACTHERM® mixer-cooler (takes up no more space than the mixers in systems with air cooling)
- Condenser (mounted on the side of the mixer)
- Heat exchanger for condensed water (placed near the EVACTHERM® mixer-cooler)
- Water ring vacuum pump module (approx. 2 x 3.5 x 2.5 m, located near the EVACTHERM® mixer-cooler)
- An additional cooling tower placed outdoors near the sand processing system (if no cooling water for the heat exchanger is available)

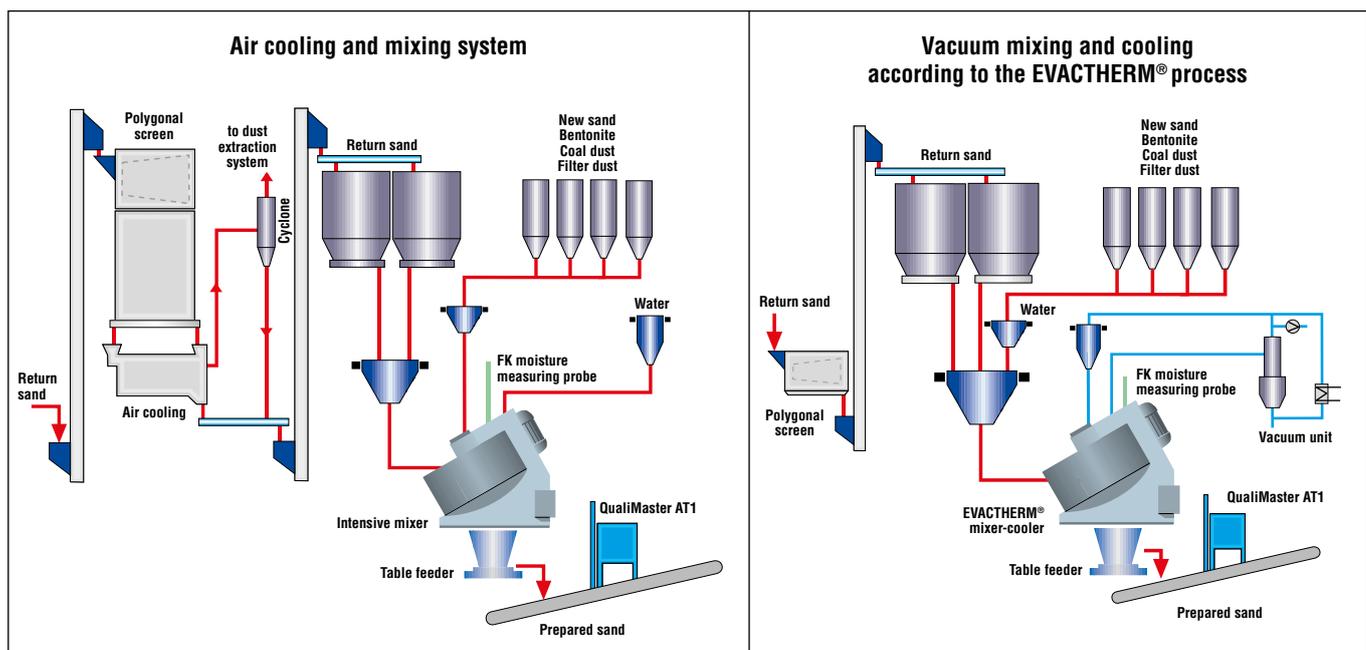


Fig. 2.1: System layout – air cooling versus vacuum cooling using the EVACTHERM® process

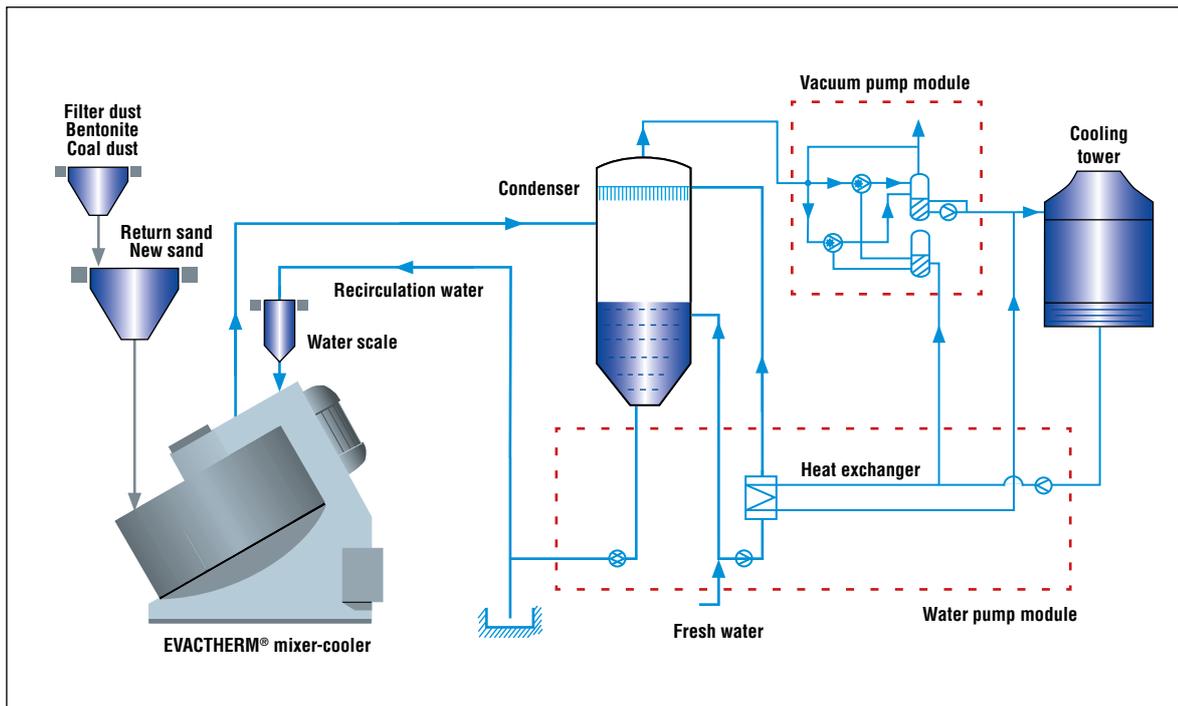


Fig. 3.1:
Vacuum mixing and
cooling system based
on the EVACTHERM®
process

2. Conventional air cooling

Sand preparation systems using conventional cooling usually employ either a fluidized bed cooler, a mixer-cooler or a cooling drum. Air and vacuum cooling systems are both based on similar physical principles. In an air cooler, water and air are added while the cooler is being continuously charged with return sand. The water has two functions:

- It evaporates and as it does so it removes heat from the sand. The sand cools.
- It moistens the sand, so that the bentonite can activate better in the return sand silos after the cooler. The maximum amount of water that can be added depends on the sand, the type of cooler and the design of the return sand silos.

Evaporation of the cooling water takes place at nearly atmospheric pressure (about 1 bar = 14.5 psi). Large blowers introduce air into the air cooler to absorb and transport the evaporated water. The amount of water that evaporates and can be absorbed by the air depends on the wet-bulb temperature (= dew point) of the air entering the air cooler. The wet-bulb temperature in turn depends on climatic conditions which vary. Steam tables are available to look up the wet-bulb temperature based on the actual ambient temperature and air humidity. The final temperature of the prepared sand thus depends on the fluctuating state of the intake air.

3. EVACTHERM® vacuum cooling system

At atmospheric pressure at sea level (air pressure around 1 bar or 14.5 psi), water starts to boil at about 100°C (212°F). If the air pressure or

atmospheric pressure is reduced to just below 0.1 bar (1.45 psi), water starts to boil at about 40 °C (212°F). This result is in keeping with the steam tables. This means that by controlling the ambient pressure, we can also control the boiling point. By accurately controlling the boiling point, we can directly control the temperature of the sand inside the mixer-cooler (Fig. 4.2). In actuality, cooling takes place simultaneously with the mixing process. Imagine a conventional intensive mixer, but with a pressure-proof casing. With this casing and a vacuum pump, we can now lower the ambient pressure inside the mixer to any level we want. We can now accurately control sand temperature and humidity. The mixer has become a mixer and cooler in a single unit - the EVACTHERM® mixer-cooler. Two different quantities of water are added to the mixer-cooler during the process:

- The water required to moisten the return sand to the desired level of the prepared sand.
- The volume of water required to cool the return sand from its initial temperature in the mixer to its final desired temperature of 40-42°C (104 – 108°F). Heat generation caused by mixing is also taken into consideration.

As dust is extracted in the polygonal screen and the sand is transported on the belt conveyors, a temperature drop of roughly 15-20°C (59–68°F) between the first bucket elevator and the EVACTHERM® mixer-cooler is not uncommon. At the transfer points of the different material handling systems and the polygonal screen (sizer), the dust extraction system removes fines from the molding sand to maintain the fines content at the desired level. The temperature of the return sand inside the EVACTHERM® mixer-cooler is normally less than 100°C. However

vacuum cooling technology can easily cope with temperatures in excess of 100°C. Because cooling takes place exactly at the saturation temperature and pressure with the EVACTHERM® mixer-cooler, evaporation of the cooling water is also referred to as vaporization. Cooling takes place essentially in the complete absence of air. Moisturizing water can be distributed more efficiently among the sand particles and additives. As opposed to air cooling, no air needs to be displaced between the sand particles for the water to reach the bentonite. Also, air is not needed as a transport medium. This eliminates the need for a cyclone, and the dust extraction filter is smaller than on air cooling systems. During vacuum cooling, the steam produced which is equal to the amount of cooling water is transferred to an injection condenser. The steam condenses inside the condenser, transferring the heat energy from the sand to the condenser (Fig. 3.1). The condensed water is cooled inside a plate heat exchanger. A plate heat exchanger facilitates the compact design of the sand preparation system. The reduction in volume of the steam during the transition from the gas to the liquid state is the driving force for the introduction of steam into the condenser. This has considerable consequences for system layout and size. The size of a conventional cooler is directly linked to sand throughput in tons/hour. As sand throughput increases, the dimensions of the cooler, blower, cyclone and dust extraction filter increase proportionally. In contrast, the size of the vacuum pump (water ring pump) is not dependent on sand throughput. The geometry of the mixer and



Fig. 4.1: EIRICH sand preparation system with EVACTHERM® RV32VAC mixer-cooler

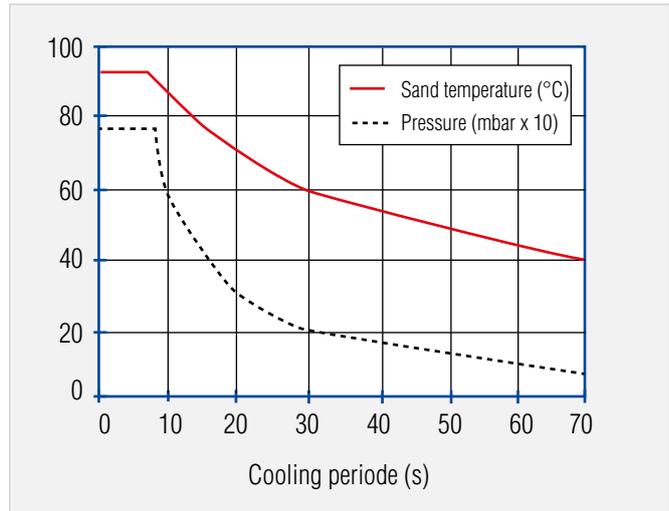


Fig. 4.2: The relationship between pressure and sand temperature inside the EVACTHERM® mixer-cooler

condenser (i.e. the volume of air to be evacuated per batch) are essentially the decisive factors. To handle higher throughput volumes, the size of the vacuum pump module and the drive power have to be increased only marginally. The incremental rise in power consumption is lower compared to conventional air cooling systems which require larger blowers for the cooler and dust extraction filter.

4. Faster activation of bentonite binding forces

Bentonite has a very tight lamella structure. The spacing between the individual layers which contain bentonite is extremely small. Water diffuses between these bentonite layers (lattice hydration) during the activation and mixing process. The bentonite increases in volume and the binding forces are activated. Conventional air cooling relies on moistening the sand as it leaves the air cooler to achieve activation of the bentonite in the downstream return sand silos.

The maximum sand moisture upon leaving the air cooler is generally between 2.0% and 2.2%. Depending on cooler type and silo design, the moisture level can be as high as 2.8%. Most of the return sand silos after the cooler are designed for a sand retention time of 1.5 – 2,5 hours to provide adequate activation time. An EVACTHERM® sand preparation system comprised of two lines with a total combined output of 90 metric tons/hour has been operating in Japan for several years. Tests at the plant have shown that sand prepared and cooled under vacuum reaches the desired compressive strength an hour before sand prepared at atmospheric conditions (Fig. 5.1). Also, the holding time for prepared sand between mixing and molding is usually only between 10 and 15 minutes. This also suggests that in practice the compressive strength of sand prepared using conventional methods can only be improved by changing the sand composition. The increased compressive strength of sand mixed and cooled under vacuum can be attributed to the relatively high volume of steam. The increased volume of steam is the result of vaporization below atmospheric pressure which is not the case with air cooling. This becomes apparent in

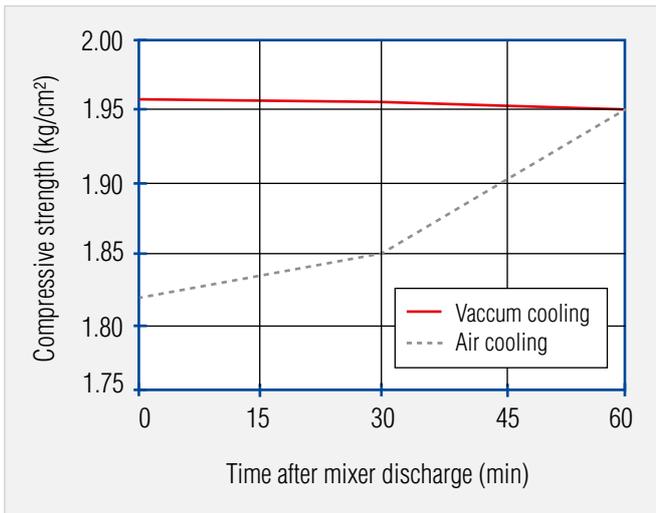


Fig. 5.1: Fast activating of bentonite under vacuum

Table 1. The comparison is based on 1 metric ton (1.1 short tons) of return sand being cooled from 80°C (176°F) to 40°C (104°F). Minor variations in the results are possible depending on ambient conditions and the type of cooler. The specific volume of steam during air cooling at atmospheric pressure and at full saturation is only 1.7 m³/kg (132 ft³/lb). During vacuum cooling, water is converted to steam at different pressures. When 1 kg (2.2 lb.) of water vaporizes at just under 0.1 bar (1.45 psi) during vacuum cooling, 19 m³ (671 ft³) of steam will be generated. No additional air is needed as a transportation medium. The steam can move freely around the sand and bentonite particles without first having to displace large volumes of air. Depending on the AFS number and fines content, the specific surface area of the sand varies. An approximate value for the specific surface area of molding sand is 28,000 – 37,000 m²/metric ton (273,000 to 361,000 ft²/short ton). From Table 1 it can be concluded that during vacuum cooling of sand with a specific surface area of 35,000 m²/metric ton (341,500 ft²/short ton), approximately 5 l/m² (0.102 gal./ft²) of steam reaches the sand coated in bentonite and in the absence of air diffuses more easily between the bentonite layers.

Table 1

Comparison of steam volumes generated during conventional air cooling compared to vacuum cooling.

Volumes per ton of sand from 80° to 40° C		
Air cooling		Vacuum cooling
air, (m³/t) (ft³ short ton)	steam, (m³/t) (ft³ short ton)	steam, (m³/t) (ft³ short ton)
240 (7690)	32 (1025)	175 (5606)

By way of comparison, with conventional air cooling only 0.9 l/m (0.018 gal/ft²) of steam reaches the sand particles which are coated in bentonite, and the steam has to displace 6.9 l/m² (0.141 gal/ft²) of

air, making it much more difficult to activate the binding forces of the bentonite. The amount of steam generated during vacuum cooling is the principle reason for the faster activation of the bentonite binding forces. These conclusions are similar to those reached in other industries such as the ceramics industry where steam is applied to clay in the mixer in order to increase plasticity prior to extrusion, much like it is applied to bentonite.

5. Multiple vacuum mixer-cooler lines with shared peripheral cooling equipment

Depending on the required throughput and the number of molding lines, it is often necessary to install two air coolers and two mixers when conventional sand preparation systems are used. In contrast, a system configuration which offers definite advantages can be deployed with vacuum technology. When mixing and cooling takes place under vacuum, the actual cooling process only takes around 70 seconds per batch. That is less than half of the batch cycle, and only one vacuum pump is needed for two mixer-coolers assuming that the mixer-coolers operate in an alternating sequence. Some of the advantages when using multiple sand preparation lines with shared peripheral cooling equipment are:

- Double the throughput with two mixer-coolers using the same condenser and vacuum unit configuration as for only one mixer-cooler. Only the capacity of the heat exchanger and cooling tower need to be modified.
- Compared to conventional air cooling, additional energy consumption when you install a second mixing line with vacuum cooling is relatively minor and energy efficiency increases even further. Air throughput for two coolers often exceeds 50,000 m³/h (1.76 million ft³/h). The dust extraction system must be resized to handle the large air volume.
- Two vacuum mixer-coolers require only 2000 m³/h (70,000 ft³/h) of inlet air which is relatively negligible. No air at all is needed for the peripheral cooling equipment.
- The central dust extraction filter is much smaller.
- The reduction in dust disposal costs is even more substantial. Raw material consumption can also be reduced.
- Considerable reduction in system size and steelwork.
- A substantial reduction in investment costs.
- Less machinery and equipment means less maintenance effort and lower operating costs.
- With proper planning, minimal retrofit work is needed to add a second mixing line to a sand preparation system with vacuum cooling when the time comes to increase production throughput.

We welcome the opportunity to sit down with customers to evaluate the efficiency implications. We can help identify potential savings in additive and electricity consumption and dust extraction air volumes.



Fig. 6.1: Two EVACTHERM® RV32VAC mixer-coolers (7 m³ = 247 ft³ per batch) for roughly 260 t/h (286.6 short tons/h) production demand.



Fig. 6.2: Partial system layout with a throughput of roughly 260 t/h (286.6 short tons/h) of finished sand. It shows two EVACTHERM® RV32VAC mixer-coolers (7 m³ = 247 ft³ per batch) for multiple molding lines with shared peripheral cooling equipment.

6. Dust control requirements

The dust extraction filter for the system shown in Fig 6.1 has a capacity which is approximately 100 000 m³/h (3.5 million ft³/h) lower than what would be necessary for conventional air cooling systems. The dust entering the extraction filter normally contains a considerable amount of active bentonite (20 - 45 %) and coal dust (10 - 25 %). Because the dust contains fireclay and fines, only a very small percentage can be returned to the process. The remaining dust including the additives is dumped, usually at considerable expense. Cutting down the airflow through the dust extraction filter reduces the amount of additives that are removed from the sand. Additive consumption and waste disposal costs can be considerably reduced when mixing and cooling are performed simultaneously under vacuum. The residual dust in the air as it exits from the extraction filter is in the region of 5 - 20 mg/m³ (2.2 to 8.7 grains/ft³). Reducing the volume of air that is released significantly reduces the volume of dust emissions. This makes vacuum cooling technology more environmentally friendly, which is an increasingly important consideration during the design of sand preparation systems which are fit for the future.

7. Conclusion

Sand preparation with the EVACTHERM® process

Simultaneous mixing and cooling is now an established technique in the foundry industry. Compared to conventional air cooling systems, the main advantages of this approach are as follows:

- The temperature of the prepared sand is not affected by ambient conditions and fluctuating sand parameters
- Reduced saltification and lower filter dust volumes translate to lower additive consumption
- Smaller dust extraction filter (by up to 50%)
- Clean, eco-friendly cooling technology
- Steam generation and (almost) complete absence of air produces faster activation of the bentonite binding forces
- Optimal energy usage and further reduction in energy consumption when using two mixing lines with a single cooling system and alternating cycles
- Circulating cooling water reduces foundry sand saltification/ calcification
- Extremely flexible and compact system configuration

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