Knowledge of Coatings
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Introduction to mould coatings

Foundry or mould coatings are a mixture of very fine refractory (high temperature resistant) minerals and special additives in suspension with a liquid carrier and show the characteristics specified as follows:

- Enhancing casting strip
- Enhancing metallurgical properties
- Increasing the temperature stability of the mould material
- Preventing metal-mould reactions (penetration, veining, erosion etc.)
- Optimising surface finish

In summary, mould coatings generate vendible castings without or just with little rework.

Common liquid carriers are fresh drinking water or organic solvents (e.g. Isopropanol). Coatings can be supplied in ready mixed form as a stabilized suspension that needs to be adjusted to its application state with usually small amounts of carrier liquid, whereas coatings supplied in powder form need to be mixed up properly at the customer. The success of this mixing procedure is very sensitive in respect of the used equipment, the different mixing times for each phase and, last but not least, the mixing operator. Hence, most foundries prefer a ready mixed supply where the supplier guarantees that the different additives are already activated and the coating is ready to be used. Additionally, not all additives can be supplied in powder form, restricting the application of such powder coatings.

Coating composition

Apart from the carrier liquid, the main components of mould coatings can be grouped as follows:

- Refractory fillers (inert and stable towards formation of intermediate compounds)
- Binding agents (ensure wear resistance at room temperature)
- Ceramic agents (sustain suspension and ensure wear resistance during casting)
- Additives (control colour, foaming, preservation, penetration etc.)

Composition of a typical mould coating

- Fillers
- Binders
- Ceramics
- Additives
Refractory fillers
Minerals are usually inorganic chemical compounds that form and grow in dependence of the surrounding pressure and temperature. They are grouped by their composition and atomic coordination. The crystallinity of minerals describes an ordered atomic arrangement, allowing most of their beneficial but anisotropic (directionally dependent) physical and chemical properties. The main refractory fillers of a coating are silicate minerals and oxides. The general characteristics of all common refractory minerals are discussed on the following pages.

Carbon
The very first water-based mould coatings date back to the 4,500 BC Chinese Han Empire and were based solely on carbon and the addition of ceramic agents. Today, such coatings are generally traded as blackings. As soon as the composition gets more complex than carbon and binders, and especially when the rheological properties are actively controlled, one should use the term coating. Carbon can be supplied in the two modifications, amorphous coke and crystalline Graphite.

Coke
Coke can be produced from bituminous coal low in ash and sulphur by pyrolysis at approx. 1,100 °C. The melting point of coke is very high (approx. 3,000 °C) and it shows almost no wettability against all alloys. Coke has a high porosity resulting in very good gas permeability and heat insulation. However a coating with carbonaceous fillers dry slower and at higher temperatures coke loses elasticity which may promote the formation of cracks. As coke grains break unevenly and develop sharp edges that stay upright, coatings on the basis of coke do not enhance a smooth surface, but show superb insulation and separation properties. Furthermore coke is one of the cheapest refractory filler materials and hence is mainly used for producing large and thick-walled iron castings.

Graphite
Graphite is a crystalline polymorph of carbon and can be mined from geological deposits. Like coke it shows almost no wettability towards all common alloys. The melting point of Graphite is similar to coke (approx. 3,000 °C). Graphite grains are more rounded and the amount of fine particles is higher that of coke, resulting in drastically smoother casting surfaces. The main disadvantages are the high thermal conductivity and heat absorption which may promote distinct surface defects when casting very large pieces.

Oxide minerals
Oxide minerals are compounds of oxygen and a metal with different ratios of both components. The two most important oxides, alumina and magnesia are described in this section.

Alumina
Alumina is produced from the calcination of different raw materials including the production of primary Alumina from Bauxite. High alumina used for mould coatings contains approx. 98% Corundum (Al₂O₃) and has a high melting point (approx. 2,000 °C) and a high density. Minor components are traces of Sodium-containing β-Corundum and a silicate glass. Alumina in mould coatings can act like Periclase (MgO) and protect the acidic mould material from an alkaline melt. Mould coatings with Alumina are mainly used as an alternative to Zircon where the requirements towards thermal resistance is very high. The application of Alumina in these mould coatings is limited to flow coating and brushing as a result of the irregular and angular grain shape from Corundum’s crystal habit and conchoidal to uneven fracture.
Magnesia
Magnesia is produced from the calcination of Magnesite (MgCO$_3$) that is mined from sediment rocks or synthetically processed from salts at temperatures up to 1,900 °C. High refractory grade magnesia contains approx. 98% Periclase (MgO) and has a high density (> 3 g/cm$^3$) and a very high melting point (approx. 2,800 °C). As Periclase forms hydroxides in aqueous systems that promote the formation of hard sediments, the use of magnesia as a refractory filler is limited to 100% solvent based mould coatings which gives very high requirement towards all other used components, production as well as storage and handling. The most valuable benefit from using magnesia is to protect an acidic mould (silica) from an alkaline melt (containing Mn, Ni etc.). Due to the extreme high refractoriness, magnesia mould coatings are commonly used in the production of manganese steel castings.

Iron Oxide
Whereas the refractory filler should be inert and not react in any form, iron actively suppresses the formation of pinholes and acts as a refractory binder and rheological additive. Iron is also used in mould coatings as a colour pigment, as it has a very high opacity and is available on mineral basis both in red as Hematite (Fe$_2$O$_3$) or yellow as Goethite (FeOOH), actually a hydroxide. Some sources report from the reduction of nitrogen and hydrogen contents in the melt due to the bonding properties of oxygen released by the iron oxides from the coating during the casting process. The addition of iron oxide is limited as the high density (> 4 g/cm$^3$) leads to increased settling.

Silicate minerals
Silicate minerals represent approx. 90% of the Earth’s crust, a solid layer of 5 – 70 km thickness. All silicates are structurally based upon Silicon tetrahedrons (pyramid with a triangular base) where the Silicon atom is surrounded by 4 oxygen atoms. Not all silicates are useful as refractory materials (e.g feldspars) and some need a special treatment. Common silicates as used for mould coatings are discussed in this section.

Nesosilicates

Olivine
Olivine is a very primitive (simple) and hence common mineral that can be mined from basic and ultra-basic igneous rocks (e.g. Dunites), consisting of 60% MgO and Fe$_2$O$_3$ and 40% SiO$_2$. To define precisely, Olivine is a solid solution between two end members of the Olivine group, namely Forsterite (Mg$_2$SiO$_4$) and Fayalite (Fe$_2$SiO$_4$) and has – depending on its iron content – a high to very high in density (> 3 or 4 g/cm$^3$). Burn-on usually contains large amounts of Olivine, as it is the first mineral that forms during cooling of melt systems that are saturated in iron and silicon (mould-melt boundary). The theoretical melting point for the Magnesium end member Forsterite is high (approx. 1,800 °C), but pure Forsterite is rarely used in mould coatings. Hence, mould coatings with Olivine offer good and usually cheap solutions for very simple grey iron castings where the need for a smooth surface is not a priority.

Zircon
Zircon, a Zirconium silicate with the chemical formula ZrSiO$_4$ containing approx. 66% ZrO$_2$ and 33% SiO$_2$, has a very high density (> 4 g/cm$^3$), high melting point (approx. 2,200 °C) and the crystal habit allows very isometric grains, similar to a football. This shape allows a very high packing density which, relevant for mould coatings, directly reduces the amount of binding agents needed to develop a very strong and stable wet film thickness. This mineral shape also allows the application of Zircon coatings by all common methods (brushing, flow coating and dipping). Zircon has an excellent thermal shock resistance and a very small thermal expansion. Additionally the heat conductivity of Zircon is higher than that of silica from the mould, allowing a quick formation of a solidified metal layer with a fine grained structure. Zircon shows almost no
reactivity with all alloys containing non-alkaline elements (Mn, Ni etc.), but due to its very high price is mainly used in mould coatings for the production of steel castings where most other materials would not withstand the extreme refractory conditions.

**Mullite**
The calcination of clay minerals (alumo silicates) at temperatures up to 1,500 °C results in the loss of crystal water (hydroxides) of the raw materials and their transformation into Mullite, an aluminium silicate with a typical composition of 72% Al₂O₃ and 28% SiO₂. The product of this process is called schamotte or fireclay and usually contains a high amount of a silicate glass and Cristobalite, a high temperature modification of Quartz (crystalline SiO₂). The grain shape usually is very inhomogeneous with sharp edges. The refractoriness of the material also varies depending upon the applied calcination process and final composition of the product, but the theoretical melting point is quite high (approx. 1,700 °C). Nevertheless, a coating made purely out of high quality schamotte can be used even for steel castings. Natural occurrences of aluminium silicates include the three polymorphs Sillimanite, Kyanite and Andalusite.

**Phyllosilicates**
Phyllosilicates (leaf or layer silicates) are hydrous minerals that erode directly from igneous rocks or form from the hydrothermal alteration of those host rocks and are used for mould coatings as mined from the deposit. These minerals always contain hydroxides up to an overall water content of usually 4-5% and – most important – grow with a layered structure, resulting in plate-like grains. Besides the plates’ capability of providing a very strong surface at thin wet film thicknesses, the benefits from these minerals are their adhesion capability, chemical inertness and low thermal conductivity. The most common used refractory minerals from this class are Talc (32% MgO and 63% SiO₂) and Pyrophyllite (28% Al₂O₃ and 67% SiO₂) from the Talc-Pyrophyllite mineral group as well as Muscovite and Philogopite from the mica mineral group, which contain approx. 11% K₂O reducing the melting point and limiting its use to smaller quantities. Because of the structural and compositional differences towards aluminium silicates (e.g. Mullite), phyllosilicates containing Aluminium should be called alumo or alumino silicates.

**Special refractory fillers**
Other refractory fillers are used for special applications, e.g. directly altering or influencing the surface layer of a casting. Such materials are used only in small quantities. Tellurium, bismuth and chromium: might produce a primary chill on the surface layer of the casting by the absorption of heat, thus increasing the wear resistance. Tin and antimony are commonly used to support the formation of a pearlite layer at the castings’ surface.

**Binding agents**
Natural and artificial resins and polymers act as low temperature binders in mould coatings. They create a solid and smooth coating surface and enhance its resistance against abrasion. As the commonly used agents do not withstand heat, they sublimate between 300 – 600 °C. Usually the binding agents don’t get in direct contact with the melt itself, as the hot air that is pushed forward by the melt has enough energy for the mentioned sublimation. As both the absolute amount of binding agent in a dried mould coating as well as the total weight of coating in comparison to the weight of the mould are very small, the absolute amount of gas released from these agents is considered negligible.

**Ceramic agents**
Natural clay minerals with very small particles sizes, a high melting point (approx. 1,700 °C) and – most important – swelling properties are effectively used both as refractory binders and a suspension agents. They
sustain the suspension of the usually heavy refractory fillers in the carrier liquid of the wet coating. During the casting they work above 600 °C, where these minerals lose their crystal water (hydroxides) and form metastable phases that create a ceramic matrix which bonds the refractory fillers and guarantee a good adhesion of the coating on the mould and core substrate. Due to the thixotropic properties of the distinct clay suspensions, these agents also act as a stabiliser that prevents the wet coating from rapid settling.

Additives
Additives include a wide range of products that alter a specific property of a mould coating. The most important additives control the rheology (flow behaviour) of the wet coating, setting the preferred method of application (brushing requires a long flow where dipping requires the opposite). Other additives control the formation of foam and bubbles in water-based coatings, act as preservative to prevent the biological degradation or simply alter the colour of the wet coating.

Carrier liquid
Organic solvent
Technical reasons for the use of organic solvents as a mould coating carrier liquid is to avoid a loss of strength on CO₂-bonded moulds, which may be caused by the use of water-based coatings. Alcohol also works much better than water especially if high amounts of release agents such as silicone oils are used on moulds and cores. A third technical reason for using alcohol as the carrier liquid are refractory fillers that form hydrates in aqueous systems, demanding water free systems.

Isopropanol, ethanol or a mixture of both which is sold by the James Durrans Group under the trade name Dursol, is commonly used as organic solvent in mould coatings. Both materials are characterized by favourable threshold limit value (TLV). Furthermore their evaporation rates are relatively high, reducing the risk for the formation of explosive alcohol -air mixtures during handling.

Water
All water-based coatings should use fresh drinking water which is free of particles that alter the properties of the mould coating system. Also in a foundry fresh drinking water should be used for the dilution of a mould coating to its application state.

Quality control
Carrier liquids
Both water and organic solvents are always used in pure form and fresh from a tank or reservoir. The suppliers of alcohols guarantee defined ranges for all parameters that are vital for the applicability of the product. A simple test to distinguish between pure isopropanol and a possible mixture is the density (at 20 °C), which is below 0.79 g/cm³ for pure isopropanol. Mixtures of isopropanol and ethanol usually measure 0.8 g/cm³ where water has the highest density of 1 g/cm³.

Refractory raw materials
All refractory materials used for the production of our mould coatings must pass high standard quality control tests focusing on the grain size distribution and moisture as well as volatile and ash contents in the case of carbons. Radiological and optical analyses confirm the applicability based on the mineralogical composition or purity that is certified by the supplier as well as the relevant geometrical features of the mineral grains.
Coating production
All ready mixed mould coatings produced at our different production sites must pass quality control tests with the same high standards valid for our raw materials. To guarantee that a packaged and supplied coating fulfils your very requirements, all relevant properties for your application are tested directly after production. Some properties are measured after at least 24 hours to assess the performance during transport and storage.

All parameters are tested both for the undiluted material as supplied as well as a dilution that is close to the application at the customer and these include

- Temperature, as all relevant parameters change with temperature
- Amount of solids after drying using a weighting scale
- Density tested using a pycnometer (mass per defined volume) or Baumé hydrometer
- Viscosity tested by means of the efflux time from a DIN cup (4 or 6 mm)
- Settling tested by means of volume per time in a glass scale
- Flow behaviour and wet film build-up on different substrates

Choice of the right coating
Many factors influence the technical requirements towards a coating system. For example in a foundry that produces ductile iron castings at 1450 °C from small and medium size walled automotive moulds and cores in cold box where veining is a big issue and there is enough hot-air drying capacity, a water-based but fast drying, ready mixed coating with Mullite and phyllosilicates offers good prerequisites for initial trials. RWB 8361-FD would be your coating of choice. But this coating is also suited for flow coating application as the following picture demonstrates

![Figure 1: Flow coated RWB 8361-FD gives a superior surface finish.](image)
How do we know?

Casting type
The type of casting plays the major role in selecting basic properties like the dry or wet supply, carrier liquid and the refractory type (carbon, oxides or silicates). Die castings have different requirements than permanent mould castings and these of course have very different requirements towards a coating system than sand castings. The latter include many different parameters like material of the mould, type and amount of binder, reclaimed or new sand, settling type that also affect the applicability of different coating systems.

Casted alloy
Usually the casted alloy and the casting temperatures affect the exact composition of the refractory fillers. As experience teaches, particle size, density, thermal conductivity and expansion as well as the sintering and melting point help to evaluate possible reactions of the refractories with the alloy and mould material. In the best case, the refractory filler should not show any wettability with the molten metal. Of course price also matters in some cases, resulting in a trade-off between technical benefits and cost savings which, for example, can be attained by a better coating-dilution ratio for the product.

TABLE 2: Approximate melting points of different refractories.

<table>
<thead>
<tr>
<th>Refractory</th>
<th>Refractoriness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phyllosilicates</td>
<td>900 – 1500 °C</td>
</tr>
<tr>
<td>Olivine</td>
<td>1600 °C</td>
</tr>
<tr>
<td>Mullite</td>
<td>1700 °C</td>
</tr>
<tr>
<td>Alumina</td>
<td>2000 °C</td>
</tr>
<tr>
<td>Zircon</td>
<td>2200 °C</td>
</tr>
<tr>
<td>Magnesia</td>
<td>2800 °C</td>
</tr>
<tr>
<td>Carbon</td>
<td>3000 °C</td>
</tr>
</tbody>
</table>

TABLE 2: Common casting temperature ranges for different alloys.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Temperature range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>420 - 580 °C</td>
</tr>
<tr>
<td>Aluminium</td>
<td>620 – 740 °C</td>
</tr>
<tr>
<td>Magnesium</td>
<td>620 – 740 °C</td>
</tr>
<tr>
<td>Copper</td>
<td>1150 – 1290 °C</td>
</tr>
<tr>
<td>Iron</td>
<td>1340 – 1480 °C</td>
</tr>
<tr>
<td>Steel</td>
<td>1500 - 1700 °C</td>
</tr>
<tr>
<td>Titanium</td>
<td>1700 - 1800 °C</td>
</tr>
</tbody>
</table>

Application method
Not all refractory fillers can be applied with the same performance with all different application methods. The crystal habit of Zircon allows these coatings to be applied via brushing or even by dipping. But the rheological properties are predefined by special additives. Very rarely can one coating be used for all methods, or at least it has to use different dilutions.

TABLE 3: Key characteristics of common refractories used in mould coatings.

<table>
<thead>
<tr>
<th>Refractory</th>
<th>Key characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phyllosilicates</td>
<td>Anti-veining</td>
</tr>
<tr>
<td>Olivine</td>
<td>Simple castings</td>
</tr>
<tr>
<td>Mullite</td>
<td>Good refractoriness and application range</td>
</tr>
<tr>
<td>Alumina</td>
<td>High refractoriness, flow coating</td>
</tr>
<tr>
<td>Zircon</td>
<td>High refractoriness</td>
</tr>
<tr>
<td>Magnesia</td>
<td>Basic alloys or mould materials</td>
</tr>
<tr>
<td>Carbon</td>
<td>High separation effect</td>
</tr>
</tbody>
</table>

Experience
To summarize it is always good to know that a specific coating worked well in a foundry with similar requirements. The James Durrans Group supplies many foundries around the world, and the one that produces similar products like yourself is of good starting point.
Mixing methods

Ready mixed form
The ready mixed supply guarantees that the swelling properties of a coating are established and that a supply of carrier liquid is needed to achieve the coating’s application state. Although “paying” for the carrier liquid, a ready-mixed coating relatively high in solids content (usually between 50 – 80%) guarantee for both stability and ease of use, increasing a foundry’s process stability where possible and minimizing the most severe errors at source. Different packaging sizes from 25 l drums to 1,000 l stainless steel tanks allow an easy integration to your process chain. Most of the coatings the James Durrans Group sells today are ready mixed.

If the coating is supplied in a bulk container, mixing parameters should be observed to avoid settling and ease of use. Our recommended mixing instructions are as follows:

- Before using a new container, the coating should be mixed for 1 to 2 hours, depending on the length of storage time.
- Before each shift, the container should be mixed for 15 minutes.
- During a shift, mix the container for 5 minutes every 30 to 60 minutes.
- After a standing time of more than 12 hours (eg weekend), a mixing time of 30 minutes is recommended.

It is recommended that a low speed mixer is used to maintain the coatings properties.

Powder form
Usually blackings are supplied in powder form to allow an extremely extended shelf life compared to the normal shelf life of water-based carbon coatings. Modern powder coatings or blackings contain all necessary refractories, suspending and binding agents and need just a supply of fresh drinking water to achieve optimal performance. However it is important to follow exactly the recommended mixing procedure. Our basic mixing instruction for powder blackings is as follows:

To maintain the swelling system of the coating, a high shear mixer must be used for the initial dispersion of the powder in water to create a thick slurry within 15 minutes. In the second phase, slightly more water is added to create a less viscous coating. In the third step, the coating should be diluted to its application state with a low shear mixer.

Tips:

- If a low shear mixer is used (e.g. simple paddle) for the initial dispersion phase, allow the prepared coating to swell for 24 hours before use.
- The mixer should be moved up and down and in a circular motion – it should not be left in a static position to allow a homogeneous suspension of all ingredients.
• Whilst high shear mixing is required for the initial dispersion, the ready mixed product should not be subjected to prolonged high shear mixing as this will gradually reduce its viscosity and ultimately reduce its effectiveness.

Application methods
Several variables influence the choice of application method: complexity and size of the moulds or core packages, desired coating finish, and – last but not least – the production rate. The transfer efficiency describes the ratio between the amount of consumed coating and the amount of coating that actually adheres to the substrate. The higher the transfer efficiency, the better. In this section, different application methods and their transfer efficiency potentials are discussed.

Brushing
Brushing helps to wedge the fine refractory fillers in the relatively big pores between the Quartz grains of a silicate mould, hence representing a very effective application method for coating of pockets and inaccessible angles. Nevertheless, brushing strongly depends on the operator’s skills and promotes uneven wet film thicknesses. In the worst case, brush marks may be visible on the casting surface. Usually, hot spots are pre-coated by brushing. Coating consumption can be controlled very easily, resulting in a very good transfer efficiency.

Dipping
Core packages with low complexity (i.e. few cavities) are usually dipped into a coating dip tank. The application is very well suited for automatic applications and commonly found in automotive foundries where extreme high production rates and high transfer efficiencies (99%) are required. Usually coatings that are optimised for dipping performances have a very short flow, limiting the formation of drips and runs on the mould surface. The special additive system demands for a high dilution rate with a small parameter window, requiring a continuous checking of the application state. For non-automated dipping stations the operators should note that with a faster withdrawal speed a fast interruption of the contact between the substrate and the coating tank less material flows back, ultimately increasing the wet film thickness.

Flow coating
Flow coating is a very fast and reliable application method for large and complex moulds and core packages that are impossible to dip. For a good application, the piece is put into an angle of approx. 20 to 40 ° (relative to vertical). The operator then applies the coating using lateral movements from top to bottom. Flow coating requires a medium flowing coating system, hence the coated piece must be turned or rotated several times to remove unnecessary material. In some foundries, compressed air is used to remove drips and runs from the casting surface. Although flow coating is a fast and easy application method, it requires the installation of a flow tank and to increase the transfer efficiency, a closed circuit for the ready mixed coating. Usually mould coatings with optimized flow coating performance also penetrates the surface of a mould or core, applying further protection against metal penetration.

Spraying
Flat surfaces can be coated very effectively by spraying from a vertical angle. The application with spraying requires especially designed guns to transform the usually thick coating into a fine spray. This ultimately leads to very low transfer efficiencies, as most coating material does not reach the substrate at all. Furthermore, coatings based on organic solvents cause hazardous spray mists. Like with brushing, deep cavities cannot be coated properly using conventional spray guns. Additionally, spray guns that are not put into solvent when
not in use, the nozzle usually tends to block. To overcome the negative side effects of the back pressure of air, airless spraying instruments were introduced into the market some years ago.

### Die coating

Die coating is a special application method for spraying permanent moulds with rotational symmetry as is commonly used in the centrifugal casting process. The coating is diluted to a sprayable application state and then applied using typically a 360° nozzle which moves slowly either manually or automatically into the rotating mould. As high thermal insulation and low gas emissions are the dominating requirements needed in those coatings, special foam control agents (e.g. soaps) are sometimes used in these coating systems.

### Drying methods

#### Organic solvent

Since organic solvents or alcohols pose health and safety hazards, coatings containing those solvents are usually supplied if the drying capabilities at a foundry are limited or non-existent, e.g. in the Automotive industry where very high piece numbers are handled. Although the high vapour pressures would remove solvents much faster out of a ready mixed coating than water, the generally preferred way for drying alcohol based coatings is flaming-off after the gloss of the coating surface has gone. This timing is important as especially room temperature binders would be flamed-off, reducing the wear resistance of the coated surface dramatically.

#### Water

Water requires long drying times, even when using air drying or conventional ovens. Due to water’s boiling point, the drying temperature for silicate substrates should exceed 100°C but stay below 250°C where the low temperature binders sublime. Polystyrene as commonly used in the full-mould process cannot withstand temperatures exceeding 60°C, limiting the applied drying method. Of course the water does not penetrate into a polystyrene model, but stays inside a relatively thick coating layer. The two main types of dielectric heating as interesting alternatives to conventional ovens are discussed briefly as follows.

A general advantage of dielectric heating is that the applied electromagnetic field interacts with the material as a whole and is not determined by the mass concentration gradient between a wet interior and a dry surface, allowing a reduction of the needed drying time from days to hours.

Microwave drying uses non-ionizing radiation with high frequencies (MHz up to a few GHz) where the energy is absorbed by the water. The penetration depth depends on the selected frequency and the complexity. A lower frequency will penetrate sand cores deeper and might cause them to disintegrate. Infrared (IR) ovens, however, dry the coated cores or moulds using extreme high frequencies (several THz) quickly without damaging the sand bodies as the penetration depth is negligible.

One benefit using IR heaters is their controllability, which brings the mould surface to the desired temperature and then cycles off in a predetermined time sequence. Hence, less heat is dissipated to the surroundings and the heat is directed at the mould more effectively, allowing to dry even deep cavities and pockets.
Surface defects

Veining

The word “silica” when used with foundry moulds usually refers to the low temperature polymorph quartz of SiO$_2$. Low-or alpha quartz has a thermal limited stability and transforms at 573 °C into high or beta quartz. This solid phase change from alpha to beta quartz is accompanied by a volume increase of about 0.8%. The kinetics of this transformation is largely dependent not only on temperature and time but also on the size and distribution of the individual quartz grains in the mould. The resulting stress from the rapid expansion of the grains, combined with the brittle nature of many binder systems allows the mould or core to crack. These tiny cracks then enable molten metal to penetrate into open cavities between the coating-mould boundary as well as into the mould itself. Upon cooling and solidification, metal fins occur, called veining.

![Figure 2: Metal fins usually derive from the quartz transformation.](image)

The occurrence of veining usually is derived from the previously described quartz transformation, but can be attributed to a variety of parameters, where the slightest optimization may already have visible effects on the casting surface. These optimizations include:

- The grain size and the grain size distribution of the mould sand should be checked.
- The used core binder should suit the process.
- Reclaimed sand must be thoroughly controlled and monitored.

In the end, veining can also be avoided by different coating systems. If the reduction of the casting temperature is not an option, a good insulating coating might help. Special refractory fillers counteract the volume increase of quartz and actively prevent cracking of the mould or core. Applying a coating with higher wettability can improve the strength of the mould surface and prevent cracking build-up.

To prevent veining, we suggest the use of our range of anti-veining coatings 3321. They belong to the coating systems which suppress the volume increase of the Quartz grains and guarantee a uniform coating layer throughout the contours of the casting. These coatings are available in both water and alcohol based ready mixed form.
Forms of penetration
If the wetting tension of the mould sand cannot withstand the metallostatic pressure, metal can penetrate the mould material. If this penetration only occurs near-surface interstices (i.e. sand), a roughness ("grooves") below the mean grain diameter of the mould material is formed. If the melt penetrates deeper into the mould and the resulting surface roughness exceeds the mean grain diameter of the mould material, one should speak of real penetration. If whole grains of the mould material are surrounded by melt and a thin crust is formed (usually not thicker than the mean grain diameter), these surface defects are grouped under the term sintering phenomena. Further intensification of the penetration of melt leads to a chemical reaction between the trapped grains and the surrounding melt, and it usually form silicate reaction products as a function of pressure and temperature, which in turn grow to partially mighty encrustations, so-called burn-on mineralization, with considerable fetting.

FIGURE 3: Burn-on is a very common casting defect that can be prevented with the right coating.

The usual cause for the formation of mineralization can be a technically induced lack of compaction of the mould material in critical areas such as its edges and cores. Even the quartz inversion may increase vulnerability to the mould material surface, penetrates through which melt. Sintering phenomena are caused in most cases by an excessively high moulding temperature for the applied coating and can be avoided by the choice of another filler of higher refractoriness. The occurrence of real penetration can be counteracted by the careful application of a suitable coating with slightly increased layer thickness.

In critical cases, we recommend a combination of high refractory coatings in order to systematically counteract the possible causes of casting defects.
Literature


# TYPICAL COATING PRODUCTS

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