Translation from "GIESSEREI" 99 (2012), Heft 2, Seiten 52 – 58




PHOTO: BMW GROUP, LIGHT ALLOY FOUNDRY, LANDSHUT

Series core manufacture with Inotec

# Inorganic Binder System Sandwiched Between „Technology Push" and "Market Pull"

## The basis for permanent success?

FROM JENS MÜLLER, HILDEN

The growing importance of inorganics or inorganic binders today can be seen in the number of publications, be they at national and international conferences or in trade journals. However, what factors have actually contributed to the current discussion about inorganic series production processes in the automotive field?

It cannot be denied that a whole new market has grown up here, with new products and innovations as well as product modifications - not only on the part of binder manufacturers, but also in the fields of mechanical engineering and tool systems as well as in the field of services that are offered accompanying this technology.

The welcome development of inorganic binders in the foundry market can be traced back to a mix of technology push and market pull effects. But what exactly do "technology push" and "market pull" mean? Particularly for the development of inorganic binders such as Inotec, both technology push and market pull effects were of great significance. Although the boundaries between technology push and market pull are frequently blurred, an attempt will be made below to classify the developments of the last four years in this area.

In the case of technology push, the initiative primarily comes from the company itself. Here attempts are made to enhan-

PHOTO: BMW GROUP, LIGHT ALLOY FOUNDRY, LANDSHUT

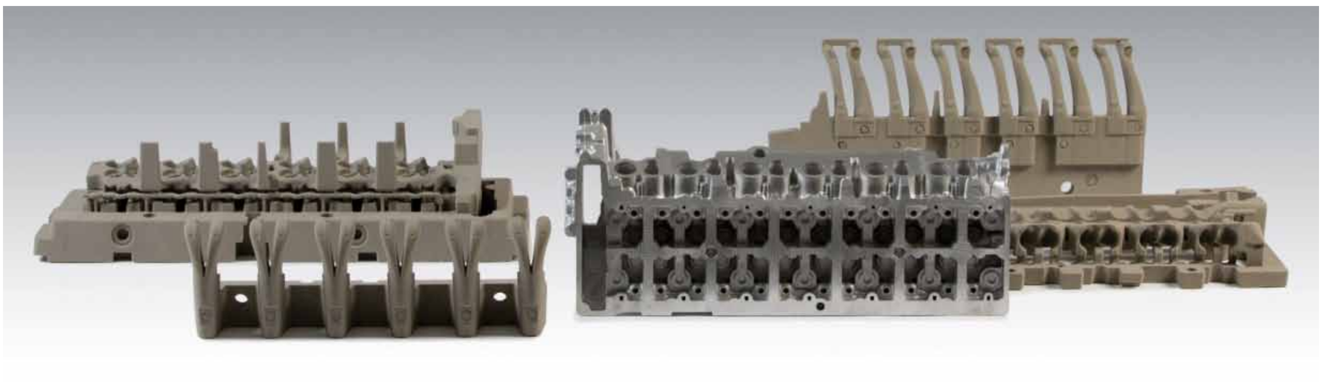

Figure 1: Cylinder head for a 6-cylinder diesel engine and sand cores.

ce innovation through technical expertise. This presupposes that the company invests considerably in research and development and provides corresponding resources. At the same time, the result of this innovation is not solely limited to products, but can also comprise services. On the other hand, the initiative comes from the customer with the market pull effect, the latter expressing their requirements and consequently receiving a new product in an optimum way that fulfills these requirements.

In general, the higher innovative creativity is derived from the technology push, while the market pull frequently results in modifications to existing products. However, the risk arises that obvious market demands are ignored during development with sole focusing on a technology push.

A known example (or, more precisely, a face standing for technology push) can be found at Apple. Steve Jobs, who was exemplary in practicing technology push, continued to create megatrends that led to a high level of innovation in the sector. An example of market pull was the development of the netbook, which has its origins in the larger laptop.

A brief overview of the latest developments for inorganic binders will be provided below:

At the Trade Show for Foundries, GIFA 2003, inorganics experienced its renaissance and attracted considerable interest among visitors. Unfortunately, the hopes and expectations aroused there could not be fully fulfilled – the core stability was not yet adequate to be used in large series processes. The quality of the casting surface was also affected too much by sand adhesions. However, the refinement of the binder system enabled the first large series productions at the GIFA 2007, for example, the water jacket cores for crankcases [1]. The intricate geometries of water jackets required further developments over the course of time in order to improve the deformation stability during casting. New solutions in binder development helped to improve the flowability of the molding material mixtures, with the result that very complex geometries such as water jackets for cylinder heads could be produced. The whole thing is supported by developments in simulation technology, which were especially helpful when designing the core boxes. Customers and providers have realized that, in contrast to conventional methods such as the cold box, the technical setup, i.e. machines and tools, is significantly more important.

The subject of sand recycling also became relevant with the first large series. The development of an initial series reclamation unit was realized via laboratory tests and pilot systems. The series plant has begun operations just recently.

SYNOPSIS:

The quantities of „inorganically“ produced cast pieces have been continually rising for six years, this in a casting segment that is so demanding in respect to productivity, such as the production of aluminum engine blocks or cylinder heads. Mutually influencing factors, such as the innovative strength of binding agent manufacturers, the solution-oriented approach of machine and tool manufacturers, the motivation and willingness of customers and new technical options like simulation are essential pillars of this development. The interaction of technology push and market pull effects led both to new considerations as well as the adaptation of existing concepts in the sense of inorganic core production. Process-induced advantages, such as the significant productivity increase in the casting process in comparison to conventional methods, or the drastic reduction in cleaning and maintenance work only truly came to fruition in this way, with the result that not only the ecological advantages point in favor of a change to inorganic core production from now on. A further technology push not to be underestimated results from the secondary effects of inorganics: By reducing ingot mold temperatures and hence attaining faster solidification times, structural properties can be improved and cast components deliberately optimized in respect to mechanical properties, a further development step towards highly charged and powerful yet low-emission engines.

If we look back over the past six years in particular, a technology push can truly be spoken of.

## Research and development

Research and development, although actually responsible for the technology push, is of course continually in comparison with the needs of the customer.

The starting point for the development of the latest inorganic binders was the hot hardening of silicate systems. However, as already mentioned at the beginning, the strength level (in particular the removal strength) was by far not enough to achieve a series production process. This problem provided the impetus for the development of the promoter, a mineral-based additive that dealt with this inadequacy. Also in respect to further requirements, for example for the surface quality of castings or the deformation stability, the promotor was refined and modified [2]. The continuous development led to a system that was significantly improved in its flow properties and was hence suitable for the production of complex geometries (**Figure 1**).

Increasing sand consumption naturally brings about the request for a suitable regeneration method for inorganic core sands. Corresponding research and development activities resulted in the construction of an initial series plant in 2011. Every individual development was filed for patent, the patents have in part already been granted.

Table 1: **Productivity gain – calculated example based on a cast piece or core for a cylinder head of a 6-cylinder diesel engine, manufactured in the gravity permanent mold method**

| | Bindersystem | |
|---|---|---|
| | *Cold-Box* | *Inotec* |
| Solidification time in min | 6 | 5,5 |
| Casts without cleaning | 15 | 257 |
| Cleaning effort within 24 h in min | 320 | 20 |
| Cast output in pieces/h | 7,8 | 10,8 |

| | | | |
|---|---|---|---|
| Material: | EN AC-Al Si7MgO,3KT6 | Test number: | WL0040 and WL0041 |
| Sample form: | UBW fitted Ø 7mm, R=35 | Test machine: | w+b UBM 943-1 and 943-1 |
| Load: | Rotating bending change R = -1 | Remark: | ÖGI A.-no.: 47.409, ASK |

| No. | designation HCF: | lg N = | a | + | k | lg ℘ | P / % | NK | LLF: ℘A |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Cold-Box | lg N = | 21.39593 | + | -7.59070 | lg ℘ | 50 | 4324634 | 88.00 |
| 2 | Inotec | lg N = | 17.77999 | + | -5.65452 | lg ℘ | 50 | 3565890 | 96.75 |

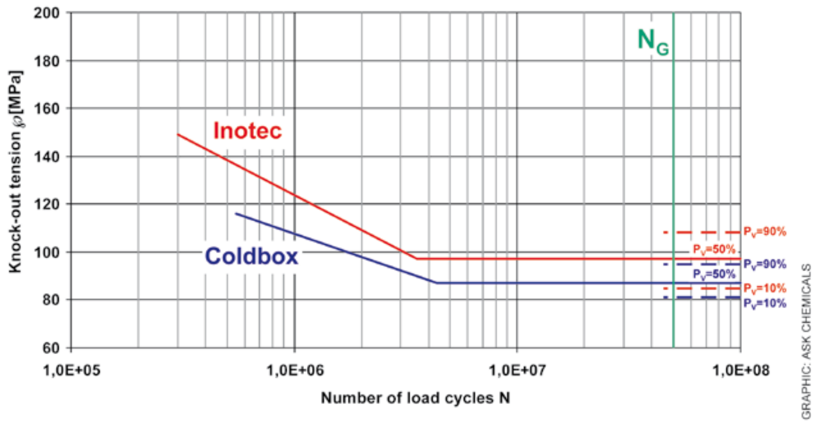


**Figure 2: Rotating bending change response – Inotec (cooler base plate temperature) and Cold-Box in comparison**

OTO: ASK CHEMICALS

**Figure 3: Core production at ASK CoreTech GmbH in Moosburg**

## Advantages in the casting process

The advantages in the cleaning and maintenance of the casting tools are essential drivers for the success of inorganics. That inorganic binders are not only ecologically effective but also offer important advantages in respect to productivity, as can be seen in the example of a cast piece or core for a 6-cylinder diesel engine, produced in the gravity permanent mold process (Table 1).

While a cast piece produced conventionally using the cold-box method requires about 6 minutes for solidification, the base plate temperature of the ingot mold, favored by the lack of condensate, can be reduced in the case of an Inotec core, with the result that the finished cast part can be removed after 5.5 minutes. In the case of the cold box core, the ingot mold must be cleaned after 15 casts. With Inotec, on the other hand, it is possible to cast 24 hours around the clock and clean the ingot mold routinely after these 24 hours. This effectively leads to a significant productivity boost. While it has been calculated that only about 7.8 cast pieces/h can be produced with cold-box, this figure is about 10.8 cast pieces/h when using Inotec.

## Improved component properties

Of course, the shorter solidification times not only have a positive effect on cycle times, but also primarily influence the structural quality in a positive manner. This was revealed in practice, but could also be verified by a study conducted in conjunction with the Österreichisches Gießerei-Institut (Austria Foundry Research Institute, ÖGI), Leoben [3]. Here a cold-box core and an Inotec core were cast simultaneously in a temperature-controlled dual-step ingot mold and the cast pieces examined in respect to their static and dynamic strength properties. Besides reduced porosity, better breaking elongation and tensile strength values were apparent. The cast pieces that were produced with Inotec also revealed significantly higher values in the alternate bending test (Figure 2). In other words, it is to be expected here that the cast parts can withstand a higher load, and there is a significantly higher certainty in the material resistance. This, in turn, opens up new perspectives in regard to the reduction of wall thicknesses and is therefore a further step towards downsizing and the development of more powerful engines with lower emissions at the same time.

The advantages of inorganics are therefore not only restricted solely to the environment, but now further benefits can also be discerned in the series production process, these concerning the areas of quality, economics and technology [4]. In other words, a technology push effect that extends beyond the original requirements for an environmentally compatible binder system has resulted here. This was not yet quite so apparent a few years ago, as the experience with inorganic binder systems in series production tended to be lacking.

In respect to the significance of inorganics, this development was a crucial transformation, as not only the environmental aspect was prioritized here [5]. It is also a sign of genuine sustainability if the ecological use is not only represented economically but even entails advantages. Advantages can be gained, above all for cleaning and maintenance. This is not only a cost benefit, but also productivity is significantly improved, as shown in the example.

Above all, the technological aspect was and is an important point for OEMs (original equipment manufacturers), which ensures that they intensify their approach to inorganic core production [6].

## Shorter development times through simulation

Inorganic core production greatly depends on the right tool design. The process window of inorganic core production is to characterized as extensively narrower than conventional core production methods. It therefore appears all the more important here to establish as optimum a setup as possible. An essential aid, which has increasingly been used recently, is simulation. Here it is possible to check in advance whether the core has sufficiently good compaction or whether weak points might be present in the core box design.

It is also possible to simulate the drying of the core by the heated tool or the hot scavenging air using suitable programs. Both help to detect critical parts in advance and initiate corresponding corrective measures. Simulation is already used as standard among many customers in order to save valuable time for new projects, which would otherwise have to be spent for tool modifications and adaptations.

## Contract core production between market pull and technology push

The commitment to inorganics is also apparent at ASK Chemicals GmbH, Hilden, from the fact that the risk has deliberately been taken to establish its own, purely inorganic core shop (Figure3). This was in line with a customer wish for external production, i.e. in response to market pull. Nevertheless, the insights gained here under series production conditions can be fully evaluated as drivers for technology push. Furthermore, this plant provides a way to give impetus to projects with other customers who do not at present have a corresponding setup for inorganic core production, without the customers having to make major investments. Two large series are currently manufactured here.

## New solutions in the fields of tool and machine technology

A new market centered on inorganics has arisen. We can describe this as having developed a certain momentum of its own. Machine manufacturers have increasingly examined the characteristics of inorganics,

PHOTO: LAEMPE

Figure 4: **Prevents drying out at the nozzles – ultrasonic atomizer near the shooting plate**

Figure 5: **Ultrasonic atomization at the sand conveyer**

PHOTOS: LUEBER

Figure 6: **Cover for sand funnel**

Figure 7: **Screw feeder with electronic weighing cell**

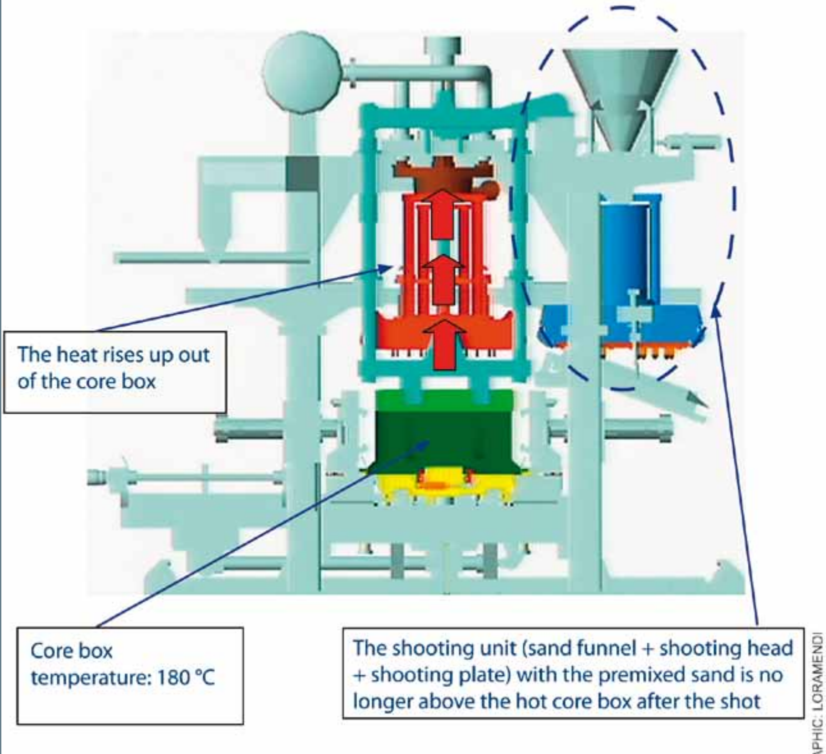


**Figure 8: Core shooting machine concept for processing inorganic sand mixtures**

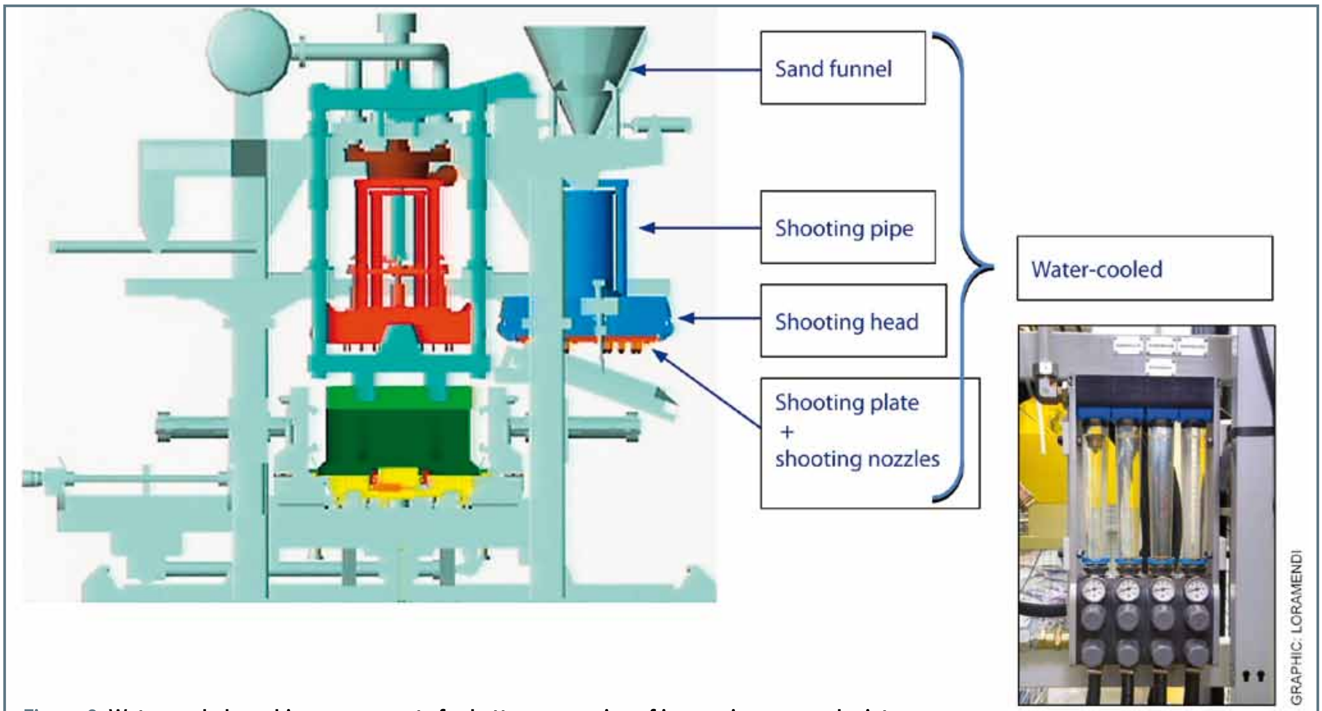


**Figure 9: Water-cooled machine components for better processing of inorganic core sand mixtures**

with the result that new solutions have been developed from meetings on site at the customer which take inorganics into consideration.

Only a few examples will be outlined briefly below. These technical innovations are not a must for the use of inorganics, but nevertheless provide a series of advantages that make working with inorganics easier and further boost the performance of the systems.

**Figure 4** shows an ultrasonic atomizer near the shooting plate. These minutely atomized water drops prevent the sand in the shooting nozzles, which come into direct or indirect contact with the hot tool, from hardening prematurely and blocking these nozzles. Here an actual weakness of the system is effectively utilized, namely sensitivity to moisture.

The same also applies for various other points coming into contact with the mixed sand, whether in the shooting pipe or as shown in **Figure 5** at the mixer or sand conveyer, which ejects the sand mixture into the machine. The service lives and availabilities of the relevant machine parts can also be increased considerably by these measures. Cleaning effort is minimized and costs can be reduced in comparison to conventional core production methods.

There are also some minor modifications to existing system technologies that have been changed specifically in terms of inorganics, even if it is only minor points, such as the cover of the sand funnel shown in **Figure 6**. These prevent the continuous air exchange and a drying out and reaction of the molding material mixture by air or $CO_2$.

The weighing system of the screw feeding system in **Figure 7** is equipped with an electronic weighing cell in order to dose the smallest amounts of additive – also called Promotor – as precisely as possible. Small variations and inaccuracies could otherwise make the difference between a good cast part and a reject here.

New concepts for core shooting machines (**Figure 8**) are also subject to the requirements of inorganics and help to deal optimally with the strengths and weaknesses of the system. The aim of this concept is to keep all machine parts coming into contact



Figure 10: **Powerful gassing unit for generating the hot air**

with the sand mixture away from the thermal contact zone. The tool has a temperature of about 180°C, which means the heat naturally rises. This inevitably leads to a premature (partial) reaction in which the sand benchlife of the molding mixture can be affected. Although this does not lead to problems at the first or second shot, it can result in a shorter availability of the machine under series production conditions. The shooting unit is only above the hot core box during the shooting time, which consequently minimizes the contact time.

A further technical innovation is that, in principle, all areas are water-cooled, whether in the sand funnel, shooting pipe, shooting head or also the shooting plate through to the shooting nozzles (**Figure 9**). It is thus optimally ensured that there will be no undesired preliminary reactions in the shooting unit. The sand's benchlife is extended tremendously by this.

It is also important to harden the cores optimally, on the one hand by the heated core box and also by the hot scavenging air. Thus cycle times that are comparable with or better than existing methods can be achieved.

To ensure constant temperature control, gassing devices, etc., that are able to reliably withstand a temperature between the cycles of >150 ° C in series production have been designed (**Figure 10**). This is especially important to avoid fluctuations in the process and hence avoid fluctuations in the hardening and consequently core quality

## Waste sand regeneration

An essential subject of previous years is the reclamation of inorganic waste sand. Of course, this subject only occurs if sufficient amounts of sand that has to be disposed of and reclaimed in the best way are available. It is also clear that a real sustainability of the inorganic process is only ensured if the sand cycle represented here from core production to casting and reclamation is closed.

Extensive investigations in conjunction with the BMW Light Alloy Foundry, Landshut, and the TU Munich, which had corresponding amounts of sand to be reclaimed, have finally led to a reclamation concept that meets the demands of core and casting quality [7].

The development was conducted in stages from the first laboratory tests and a pilot system through to the now commer-



Figure 11: **Reclamation of inorganic core sands (5 cycles) – transverse strengths with the reclaimed sand in comparison to the new sand mixture**

PHOTO: BMW GROUP, LIGHT ALLOY FOUNDRY, LANDSHUT

**Figure 12: Series production system for the reclamation of used inorganic sands at the BMW Group, Light Alloy Foundry Landshut**

cial system, which has recently been commissioned and which is therefore the world's first reclamation unit for such a process. **Figure 11** shows that no restrictions in respect to the strength level of the cores are to be expected. The test specimens produced with the reclaimed sands reveal tremendous strength properties both after the first cycle and after the fifth cycle. The strengths are even above the level of new sand, which even permits the thought of working with reduced binder content in the series production process.

We can confidently talk of a symbiosis of technology push and market pull when it comes to reclamation. On the one hand, it was the requirement of the market to offer a solution here, while on the other hand, a great deal of time was invested by Research and Development in order to match the process and parameters to inorganics.

**Figure 12** shows the world's first reclamation unit for an inorganic core production in the automotive sector, set up in the BMW Light Alloy Foundry Landshut. The plant comprises two parts, a mechanical stage and a thermal stage.

## Application for the production of cast iron

One market pull effect that more or less results from the technology push in the aluminum casting method is the interest by many foundries in an equivalent product tailored to cast iron [8]. The advantages certainly tend to be ecological in character here, as positive effects such as low cleaning effort for ingot molds and the resultant increased productivity naturally do not apply in the sand casting method. Nevertheless, it is apparent that inorganic binders can also offer technical benefits in this area. **Figure 13** shows a dome core test casting in cast iron with lamellar graphite with an Inotec core (blue circle). The other castings, sometimes with significant casting faults, originate from differing cold-box sand mixtures. It is clear that inorganics can offer advantages here, e.g. no veining, as revealed by a series of practical tests. Here there is a further focus on research and development, namely transferring the innovative potential to these applications..

PHOTO: ASK CHEMICALS

**Figure 13: Dome core casting in GJL (casting temperature: 1420 °C) – the casts produced with Inotec do not exhibit any signs of veining in comparison to those produced in the cold-box method**

## Summary

In the past four years, inorganic binders have undergone tremendous development in the foundry market through a series of various market pull and technology push effects. Although the focus was "only" on the environmentally relevant advantages in the early days of inorganics, the situation has changed to the extent that other advantages, above all the productivity increase in the casting process through lower cleaning effort as well as new casting system options by reducing the ingot mold base plate temperature, are nowadays also associated with the method.

The increasing interest in inorganic core production has led tool and machine manufacturers to tackle the subject intensively and to create individual solutions to eliminate the process-dependent drawbacks. The advantages of inorganics can now be utilized optimally.

The commitment of the first series production users to inorganics, and the determination to take a certain risk in introducing a new, yet promising, technology was and is crucial for the latest development. Only in this way can subsequent companies be convinced to take the same route (first follower), to ultimately be able to recognize and say: „It really works“

*Dr. Jens Müller, ASK Chemicals GmbH, Hilden*

**References:**

*[1] Giesserei (2008) Nr. 6, S. 32-35.*
*[2] Giesserei-Praxis (2007) Nr. 5, S. 192-194.*
*[3] Giesserei-Praxis (2009) Nr. 11, S. 359-366.*
*[4] Giesserei-Erfahrungsaustausch (2009) Nr. 11, S. 6-7.*
*[5] Giesserei (2010) Nr. 8, S. 66-69.*
*[6] MTZ 72 (2011) Nr. 6, S. 484-489.*
*[7] Giesserei (2009) Nr. 11, S. 40-44.*
*[8] Giesserei (2011) Nr. 4, S. 36-40.*