A coremaking revolution

Introduction

Increasing demands for greater productivity and lower overall costs are forcing foundries to examine how existing processes and technologies can be redesigned to become more cost-effective and environmentally more acceptable.

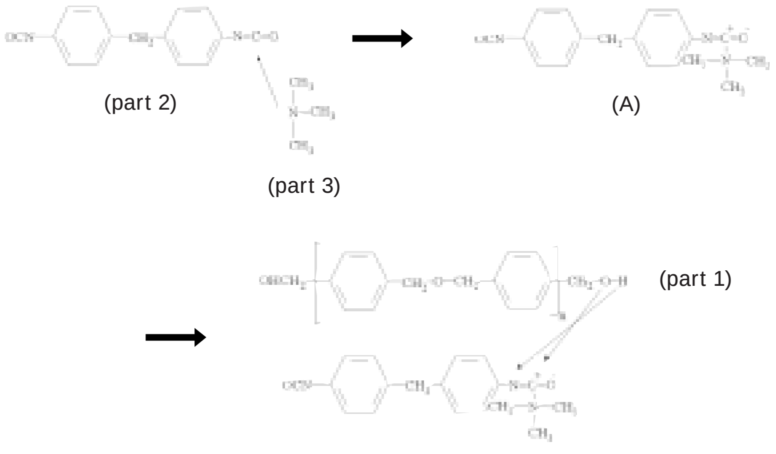
The core room is a critical area for high production ferrous and non-ferrous foundries and corebinder technology has been the focus of intensive development effort by both Foseco and SMC in recent years.

This article describes two of the latest gas-cured core making techniques which are perfectly suited to meet the highest demands in terms of quality, productivity, and environmental considerations - the ESHAMINE Plus phenolic-urethane cold box process and the ECOLOTEC process.

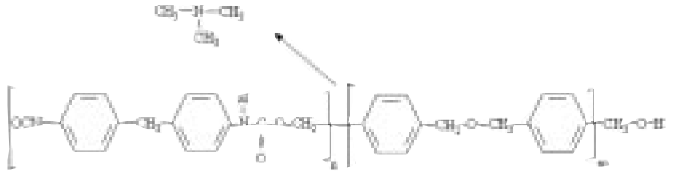
The ESHAMINE Plus process

Principles

The phenolic-urethane cold box (PUCB) process is the most widely used gas cured binder process in the foundry industry and has been the preferred core making process for high production foundries for the past 20 years or so. In this process a tertiary amine (part 3) catalyses the reaction between the phenolic resin (part 1) and polyisocyanate (part 2) through the formation of an intermediary complex (A), i.e



to the cured polyurethane binder



The speed of this reaction, and therefore the core hardening reaction, is essentially determined by the rate of formation of the amine intermediate complex. This, in turn, is determined by the size of the amine molecule.

Until now the following chemicals have typically been adopted in the phenolic-urethane cold box process;

- TEA (triethylamine)
- DMEA (dimethyl ethyl amine)
- DMIA (dimethyl isopropyl amine)

All these substances exist as liquids at ambient temperature and must be vapourised to function effectively in the core making operation. Under cold ambient conditions problems of amine condensation in the gas supply lines or in the core box itself are not uncommon.

In contrast, the patented ESHAMINE Plus process utilises specific phenolic-urethane binder part (1) and (2) components and a tertiary amine which exists as a gas at room temperature and is the most reactive of the tertiary amine family.
This chemical is:

- TMA (trimethylamine).

Key characteristics of the tertiary amines commonly used in the phenolic-urethane cold box process are shown in table 1 overleaf.

Process benefits – production experience

The use of trimethylamine in the phenolic-urethane process has received very little attention over the past 20 years due to difficulties in controlling and optimising dosing levels.

However, the recent development by SMC of a novel gassing equipment design now facilitates the use of TMA and enables substantial benefits in terms of productivity and reduced amine catalyst levels.

Production tests to date with the ESHAMINE Plus process have shown gassing times reduced by up to 78% and purge times reduced by 54% compared to conventional DMEA or TEA catalysed core making operations. These reductions have been found to have a significant impact on the overall cycle time of the core machine and core output has increased by 30% on average (see figures 1 and 2).

Formula	**TEA** $(C_2H_5)_3N$	**DMIA** $(CH_3)CHN(CH_3)_2$	**DMEA** $C_2H_5N(CH_3)_2$	**TMA** $(CH_3)_3N$
Mol. Weight (g/mol)	101,2	87,1	73,1	59,1
Boiling Pt. °C	89	65	35	3
MAC Value	10	25	25	5 (Note 1)
Flash Point°C	-11	-27	-45	-65
Ignition Temp. °C	215	190	190	190
Vap. Pressure Mbar (20°C)	69	170	580	2200
Solubility g/l (20°C)	133	Unlimited in Water	Unlimited in Water	Unlimited in Water
Density g/cm3 (20°C)	0,73	0,72	0,66	0,63
Note 1 – American classification. No value yet established in Germany				

Table 1.

In addition to improved productivity, the quantity of amine catalyst required is significantly reduced resulting in material cost savings and a cleaner environment. Measurements in the core storage area for example have indicated that amine emissions can be reduced by in excess of 50% when compared to DMEA or TEA cured cores.

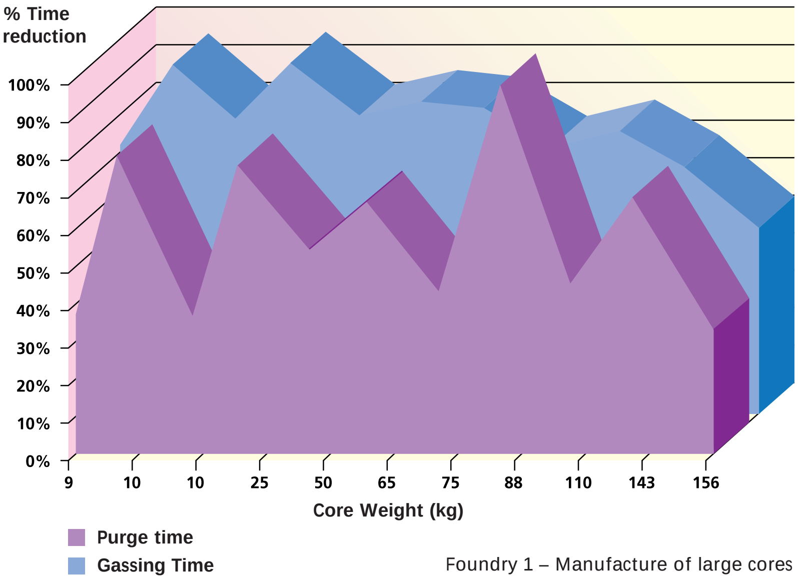
A further benefit of the ESHAMINE Plus process is that amine scrubber unit maintenance and service costs are significantly reduced due to the lower quantity of amine required for the curing process. A summary of benefits is shown in figure 3.

Furthermore, due to the faster and more efficient curing mechanism in the ESHAMINE Plus process, it has been observed that cores made using the process possess superior moisture resistance compared to conventionally catalysed phenolic-urethane cold box processes, e.g with DMIA. Figure 4 shows typical lab. results.

Process conversion

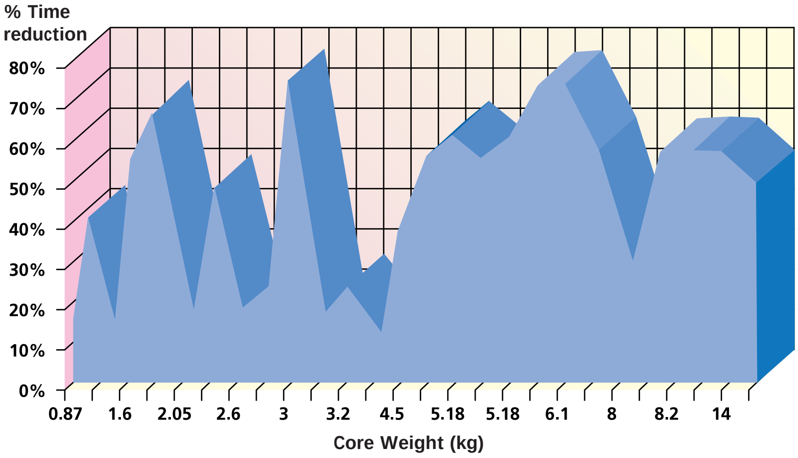
As TMA exists in the gaseous state, clearly changes must be made to the existing core machine's gassing installation, or alternatively, additional new equipment must be installed. Advice on process conversion and equipment requirements can be provided by Foseco and SMC in collaboration with established and reputable core machine suppliers.

The use of easily re-useable and re-fillable gas cannisters for the TMA provides further significant environmental benefits over conventional liquid amines which are often supplied in tanks, drums or containers and which require significant cleaning of residues before being re-used.



Foundry 1 – Manufacture of large cores

Figure 1: Reduction of gassing and purging times through the use of the ESHAMINE Plus process in place of conventional DMEA-cured PUCB process.



Foundry 2 – Manufacture of complicated cores

Figure 2: Reduction of gassing and purging times through the use of the ESHAMINE Plus process in place of conventional DMEA-cured PUCB process.

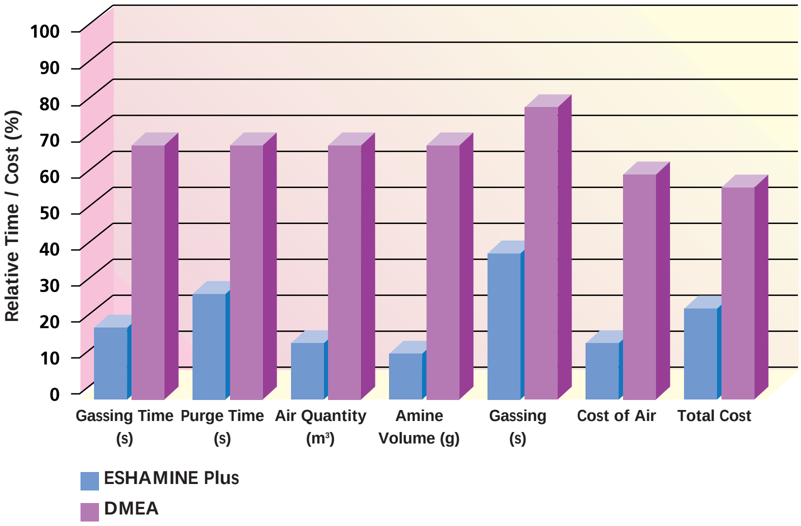


Figure 3: Benefits of the ESHAMINE Plus process compared to conventional phenolic-urethane cold box process.

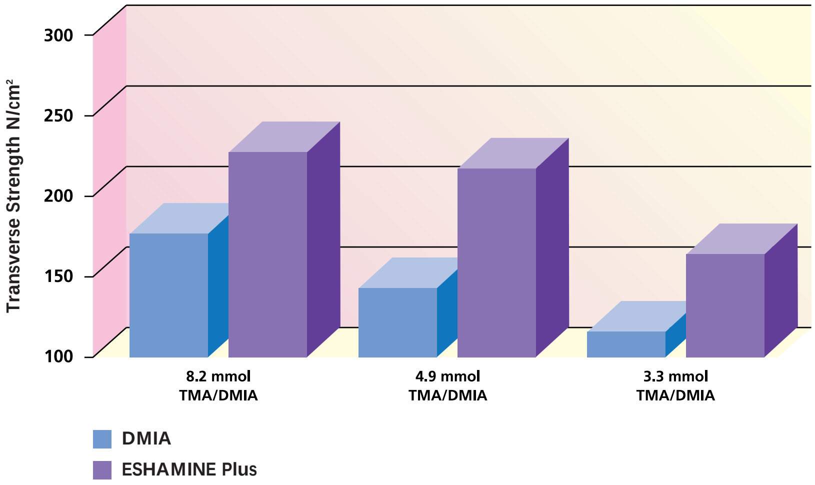


Figure 4: Effect of amine quantity on moisture resistance; 24 hours @ 100% relative humidity.

The future outlook

The ESHAMINE process facilitates greatly enhanced productivity and reduced overall process costs due to:-

C Shorter core making cycle times and more efficient machine utilisation

C Improved core and casting quality

C Lower amine usage

Furthermore, due to the lower amine consumption and usage, the conditions for the operators and overall working environment in the core room can be greatly improved, thereby enabling existing environmental standards and legislation to be more easily adhered to.

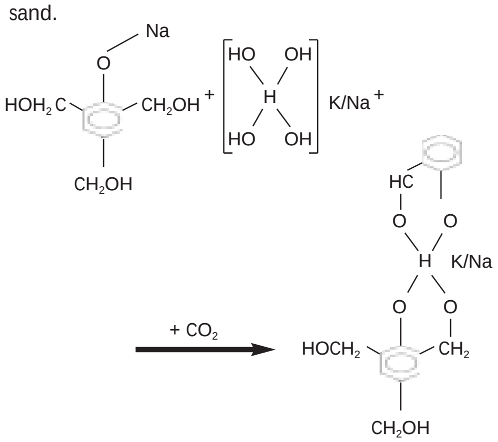
Another alternative core making process which can be adopted to satisfy increasingly demanding environmental legislation is the ECOLOTEC process which was developed and patented by Foseco in the early 1990's, and this technology continues to be the focus of intensive research and development activity.

The ECOLOTEC process

Mechanism

In the ECOLOTEC process, a water-based alkaline phenolic resole resin is mixed with sand and then hardened by gassing with carbon dioxide. The carbon dioxide acts to reduce the pH of the resin, thereby initiating a cross-linking reaction with a complexing agent present in the resin solution.

As this reaction mechanism is between a gas and the liquid resin, the rate of reaction is dependent on the temperature, pressure and flow rate of the carbon dioxide gas and temperature of the mixed sand.



Properties

As with most sand binders, the characteristics of the base sand have a significant effect on the ultimate strengths of ECOLOTEC bonded cores. In addition to sand purity and chemistry, particle shape and particle size distribution are especially important factors.

Ideally, the sand should be round grained or have rounded edges and have a particle size distribution spanning 3 sieves.

As the quality of core depends on an effective reaction between the carbon dioxide gas and the ECOLOTEC(r) resin binder, an AFS of around 55 - 60 is most suitable as this promotes natural pressure build up within the core box during gassing (see figure 5).

Where coarser sands of AFS 45 - 50 are unavoidable for whatever reason, then a more reactive ECOLOTEC resin should be used to ensure strength development in a sufficiently rapid time. Higher reactivity ECOLOTEC resins have been developed for applications where higher immediate strengths are required, or faster cycle times are desirable (see figure 6).

Though the ECOLOTEC process involves curing with carbon dioxide, the mechanism for curing is completely different to that of a sodium silicate system. In the case of silicate the objective tends to be to gas at very high flow rates in order to obtain a certain degree of dehydration. In contrast with the ECOLOTEC process, it is is very important to avoid dehydration of the binder and to ensure that it is the cross linking bonding mechanism which takes place through optimised carbon dioxide temperature, pressure and flow rate.

Positioning of gas ingates and vents is also important if dead areas of uncured sand are to be avoided (see figure 7).

Sand flowability

The flowability of phenolic resole CO_2 mixed sand is slightly inferior to that of phenolic-urethane cold box mixed sand. However in most cases, satsifactory core compaction can be achieved through minor changes to core box venting or machine blow pressures.

Recent development work in the laboratory and in pilot production trials has also shown that the addition to the mixed sand of flowability agents can also have a significant impact on core compaction, core strength and the ease of strip and release of cores from the core box. Work in this area is continuing.

Thermal properties

ECOLOTEC bonded cores demonstrate outstanding thermal properties and are capable of excellent casting quality on all alloys. In the iron test casting (see figure 8), the ECOLOTEC process shows clear benefits compared to sodium silicate bonded cores and phenolic-urethane cores.

ECOLOTEC cores show neither sand burn-on, nor finning defects. The breakdown of the cores is noticeably better than sodium silicate, whilst finning defects common with the phenolic-urethane system are not generally observed.

Effect on green sand

Due to the alkaline nature of ECOLOTEC bonded sand, there is clearly an effect on the re-circulating green sand system of mixed core sand. The inflow of alkaline salts into the green sand from ECOLOTEC cores can result in strong activation of the bentonite clay.

In those green sand systems where a fully activated bentonite is being used, conversion to ECOLOTEC for cores would normally necessitate a move to a partially activated bentonite to counteract the activating effect of the ECOLOTEC core sand.

Productivity

Due to the avoidance of the purging or flushing time necessary when using the phenolic-urethane cold box process, core cycle times with the ECOLOTEC process are often shorter than with the PUCB process.

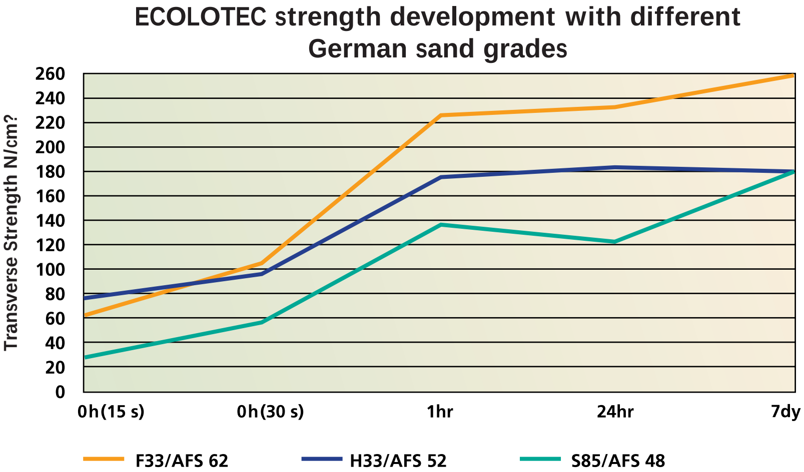


Figure 5: Strength development with different foundry sands used in Germany, (at 2.2% ECOLOTEC binder addition).

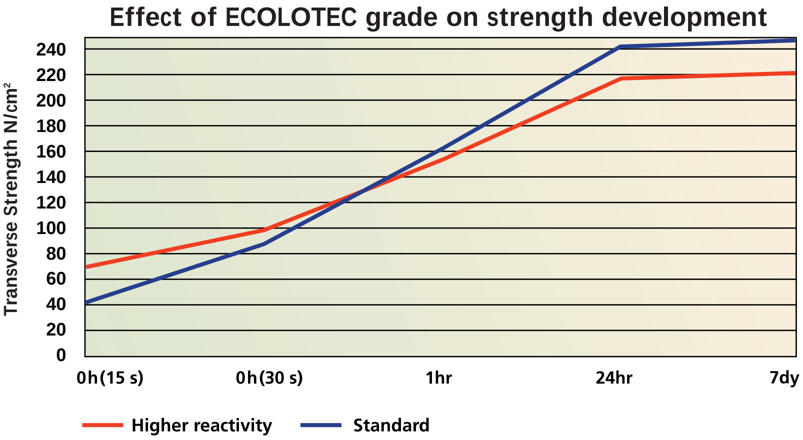


Figure 6: Strength development behaviour of standard and reactive ECOLOTEC resins (at 2.2% addition) on German AFS 45 sand.

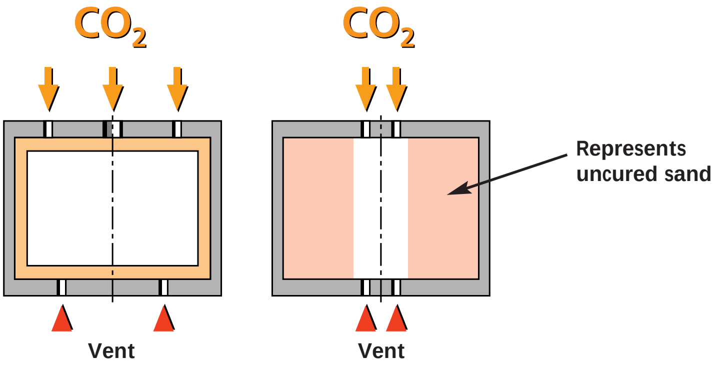
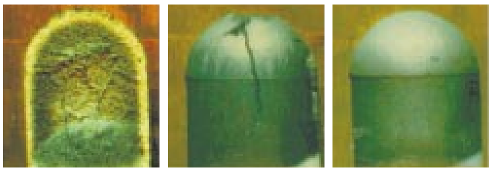


Figure 7.



Sodium Silicate 3% | *PUR CB 0.8%* | *ECOLOTEC 2.8%*

Figure 8.

Production experience

Case Study 1 - Improved casting quality

The valve body core and casting shown in figure 9, was originally made in phenolic-urethane cold box. Despite the use of specialist coatings, finning defects were found in the valve body leading to high scrap rates. With ECOLOTEC cores, castings were produced free from fins and scrap levels were reduced.

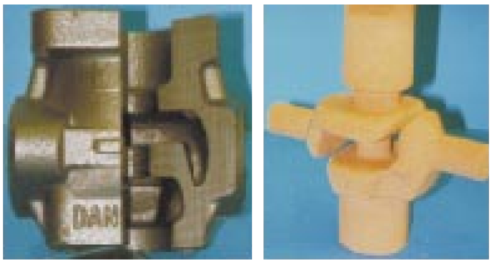


Figure 9.

Case Study 2 - Avoidance of capital investment

Again, the core in this example (see figure 10), was originally made in phenolic-urethane cold box. Coremaking production was restricted however, as the core room could only operate when the exhaust air was channelled to the cupola and the foundry only melted on five days per week. The foundry avoided the purchase of an amine scrubber by converting to the ECOLOTEC process. In addition to a more flexible and lower cost coremaking process, an added benefit was that – unlike with the urethane process – cores could be cast uncoated with excellent results.

Figure 10.

Case Study 3 - Replacement of methyl formate process

Figure 11.

Due to hazards associated with the methyl formate process and difficulties in obtaining operating permits in certain regions, foundries have been looking for an alternative process. In the example shown in figure 11, production costs were reduced by 20% after converting to the ECOLOTEC process.

Case Study 4 - Improved breakdown compared to sodium silicate

Figure 12.

In this example (see figure 12), the amount of time in the fettling and cleaning area to remove the core from the finished casting was dramatically reduced when using ECOLOTEC rather than sodium silicate.

Environmental considerations

Increasingly nowadays aspects of the environment are becoming a priority for foundries. Compared to other core making processes, the ECOLOTEC process provides significantly improved environment with respect to VOC emissions on core making and on casting. In terms of certain key compounds, emissions with the ECOLOTEC process lie below the allowable limiting values in Germany, i.e.

phenol	12 mg per m^3	limiting value 20 mg per m^3
benzol	3 mg per m^3	limiting value 5 mg per m^3
amine	1 mg per m^3	limiting value 5 mg per m^3

Residual materials from the ECOLOTEC process can be disposed of as follows:

- Sand exposed to heat can be disposed of as Disposal Class 1 (phenolic-urethane core box sand is Class 2)

- Sand not exposed to heat can be deposited on a domestic rubbish tip.

- Initial pilot tests have also indicated that thermally regenerated sand can be re-used as core sand – work in this area is ongoing.

It should also be noted that the carbon dioxide required for the hardening process is produced by extraction from the atmosphere – consequently there is no reinforcement of the "greenhouse" effect by use of the ECOLOTEC process.

Summary

Production foundries today are under increasing pressure to reduce costs and improve core room efficiency, whilst at the same time ensuring compliance with ever demanding environmental legislation.

The ESHAMINE Plus and ECOLOTEC processes provide foundries with viable options to face up to this challenge.

Acknowledgements:

SMC, a division of Foseco Netherlands, would like to thank the following companies without whose support the present article could not have been produced:

Ursula und Emil Berger Anlagenbau / Neustadt
Loire Fontes Industries / Frankreich
Laempe / Schopfheim
+GF+ / Werk Mettmann
Stock Guß / Neumünster
Düker / Karlstadt