New Inorganic Nobake Binder System

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ABSTRACT

The introduction of a new phosphate-based binder system offers the foundry industry a viable alternative to conventional inorganic nobake processes for the production of ferrous castings. This two-part binder system offers considerable advantages over organic binder systems in terms of smoke and emissions at pouring and shakeout. Thermal breakdown of molds and cores prepared using this technology is considerably more facile than for conventional systems at typical binder levels. This advantage is most dramatic in comparison to silicate binder technology.

Conventional mixing and molding techniques have been used to produce molds and cores of up to approximately 5000 pounds. Strength development of the phosphate binder technology is somewhat slower than with organic binders, necessitating attention to proper foundry practice. All understanding of this technology's potential applications is obtained through an overview of recent foundry trial applications.

INTRODUCTION

The foundry industry and its suppliers are faced with increasingly complex environmental regulations as well as increasing concerns in the area of worker safety. Many of these concerns are related to traditional binder systems derived from organic polymer technology, typically supplied as solutions in petroleum-based solvents. Suppliers of these products to the foundry industry are actively involved in pursuing new technologies that are more environmentally acceptable. However, the most direct approach to these problems is the foundry application of water-based inorganic binder systems.

Inorganic binders based on silicate chemistry have been employed in many applications, but these binders often suffer from poor shakeout and sand reclamation characteristics. The binder system described here offers many of the environmental advantages associated with silicate binders but offers superior shakeout and reclamation properties.

Phosphate binder technology has previously been used in the foundry industry as a mold and core binding system. Improvements in the performance characteristics of this technology, as well as increased federal, state and local regulations concerning pollution, have made this technology a viable option to existing mold and core binding systems.

This paper will give a thorough overview of the application of a new phosphate-based binder in trial foundry applications. This discussion will focus on the methods used to make quality ferrous castings rather than on the chemical aspects of the binder systems, which are covered elsewhere.

TECHNOLOGY OVERVIEW

A brief understanding of the binder itself must be achieved before beginning to discuss the methods and means used to make quality ferrous castings. The new phosphate-based binder consists of a clear, acidic water soluble liquid component and a free-flowing powdered component. When these materials are mixed together at the proper proportions on a base sand, a chemical reaction is initiated, causing the materials to harden. The reaction will begin as soon as the materials come in contact with each other. A typical foundry sand mix is shown in Table 1.

Once the reaction has begun, the material will develop its handling and transverse strengths over a period of time. Typical handling, scratch hardness and transverse strength development are also given in Table 1. The increase in strength is accompanied by a moderate increase in temperature due to chemical reaction, providing an indication that the reaction is proceeding as expected.

OPERATIONAL PARAMETERS

Now that a basic understanding of this technology has been established, it is appropriate to discuss the various operational aspects that will ensure that a quality ferrous casting can be created. The operational aspects that will be discussed are as follows: sand requirements, mixing requirements, flasked versus flashless molding, mold making and curing, mold release, handling and assembly. Proper procedures associated with each of these operations have been identified as essential for producing a quality casting with this binder system.

Sand Requirements

The type of sand used with the phosphate binder system has been found to be of considerable importance. This technology performs on a variety of common foundry sands with only minor changes in performance. Optimum performance occurs when used with a clean silica or lake sand in the 45–70 AFS grain fineness number range with a minimum of fines. A round grain shape provides the best physical properties for a given binder level, but acceptable performance has also been achieved using angular and sub-angular sands. Sands that are strongly alkaline in nature, such as olivine, tend to accelerate the
cure rate of the binder system, resulting in shorter work and strip times and lower handling strengths.

High moisture content in sands can affect the performance of this binder system. Significant effects, however, are found only at water levels considered abnormally high for typical foundry no-bake operations. Optimum performance can be achieved with moisture levels below 0.5% water in sand. Moisture levels above 0.5% cause the binder to be diluted and, therefore, slow the rate of reaction. This result is not atypical of other water-based inorganic binder technologies. Table 2 lists performance data on a typical sand when moisture levels exceed 0.5%.

As with most existing binder technologies, this phosphate-based binder produces molds and cores with optimum strength properties when the sand temperature is maintained between 65 and 95°F (18 and 35°C). Sand temperatures above 95°F (35°C) will reduce the rate of the cure and cannot produce molds and cores with weak, friable surfaces.

Sand temperatures below 65°F (18°C) will impede the rate of cure and can result in weak, dense molds and cores. Molds and cores made with sand temperatures below 65°F (18°C) may begin to warp even from the resulting pressure. In many cases, increasing the amount of powder in the sand mix can compensate for the cold sand.

Mixing

Batch and continuous mixers have been employed successfully with this new inorganic binder. All pumps, lines and valves being used to transport the liquid part to the mixer must be resistant to attack by phosphoric acid. Conventional powder feeding equipment, normally used with iron oxide type sand additives, has been proven suitable for the delivery of the powdered component.

In the process of batch mixing, it is preferable to disperse the powdered part onto the sand before the addition of the liquid component. This order of addition will avoid premature reaction due to localized concentrations of the powder. Simultaneous addition of the powder and liquid parts can be made without a significant reduction in performance and strength. However, separate additions are considered the best practice to prevent premature reaction from occurring. Under low-volume sand use conditions, the design of high-efficiency batch mixers makes them the mixer of choice.

Under single-trough continuous mixing conditions, the powdered part should be blended into the sand flow first. This is to ensure that the powder has enough time to be evenly distributed in the sand flow before the liquid is added. Under double-trough continuous mixing conditions, each component should be injected into separate troughs of flowing sand. The powder should not be injected into the sand flow before it reaches the mixing troughs. If the powder were to be injected into the sand flow prior to the mixing troughs, the resulting sand mix would be extremely weak and friable. This would be the result of a premature reaction of the components while in the mixing troughs. The mixing which will cause the liquid and powder to harden should occur within the high-speed mixing head and not within each individual trough.

A double-trough continuous mixer, similar to that in Fig. 1, has been found to produce mixed sand with the highest degree of flowability and cured strength. The position of the powder feeder and the design of the high-efficiency blade in the mixer head are the keys to producing an optimum sand mix for higher sand outputs. In most cases, conventional high-speed mixing head blades must be modified to produce a more uniform sand mix.

Flasked Vs. Flaskless Molding

A wide range of flasked and flaskless molds have been made using the improved phosphate technology. Flaskless molds from 12x12x12 in. (30x30x30 cm) to 50x50x45 (127x127x114 cm) in size have been produced and have resulted in successful castings. Larger flasked molds can be made with the use of this material, the only limiting factor being the speed of cure of the binder. As long as the pattern is filled before curing occurs, a quality mold can be made. Figures 2–4 show various flasked and flaskless molds made with the phosphate-based binder system.

Pattern Filling and Curing

As mentioned previously, mixed sand flowability is significantly lower than that of organic-based binder systems. All forms of increased compaction will help to improve the quality of the mold. Attention to detail while hand mixing and tucking are essential for

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**Table 2.** Standard Phosphate Binder Sand Mix with 0.5% Water Added
*(Based on Sand)*

<table>
<thead>
<tr>
<th>SAND</th>
<th>WEDRON 540 WITH 0.5% H2O B.O.S.</th>
<th>TEMPERATURE</th>
<th>HUMIDITY: 49% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>BINDER</td>
<td>LIQUID PART @ 2.5% B.O.S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>POWDER PART @ 6.0% B.O.S.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WORK TIME</th>
<th>STRIP TIME</th>
<th>TENSILE STRENGTH (PSI)</th>
<th>24 + 1 HR @ 95% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 MIN</td>
<td>20 MIN</td>
<td>1 HR 3 HRS 24 HRS</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TRANSVERSE STRENGTH (PSI)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 HR 3 HRS 24 HRS</td>
<td></td>
</tr>
<tr>
<td>9 MIN</td>
<td>20 MIN</td>
<td>80 320 400</td>
<td>40</td>
</tr>
</tbody>
</table>

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*Fig. 1. Dual trough mixer and modifications.*
producing an acceptable mold. Vibratory techniques can also be used to increase the mold quality, but should not be a substitute for hand ramming and tucking techniques.

The reduced flowability and increased cohesiveness of large quantities of mixed sand result in a sand mix that will flow very little when vibrated. In both laboratory and foundry applications, it has been demonstrated that small quantities of mixed sand (20 lb and under), using the phosphate-based binder, have significantly higher flowabilities than larger volumes of mixed sand. Therefore, vibration

Fig. 2. Various molds 25x25x40 in. (64x64x101 cm).

Fig. 3. Various molds 42x42x24 in. (107x107x61 cm).
would be the choice means of compaction for small molds while hand ramming and tucking would still be necessary for large molds.

The lower flowability of the mixed sand is the result of the curing mechanism of the binder components. The components begin to react as soon as they come in contact with each other. The curing profiles of various organic binder systems are compared to the improved phosphate technology in Fig. 5, showing that many other types of organic foundry binders exhibit a more pronounced latent cure profile. The latent nature of the cure for organic binders allows the sand mix to retain a high degree of flowability, resulting in a more uniform and dense mold.

The use of a high-speed mixer with a significantly higher output of sand will allow the user to avoid this limitation. The higher output of sand will enable the operator to fill larger molds in a shorter period of time, thereby compacting the sand before curing can negatively influence flowability.

**Mold Release and Removal**

The release characteristics of this new binder system are excellent. For example, molds and cores have been removed from patterns without sticking within 30 minutes after they have been cured. Release agents are thus unnecessary in most applications but can be used in problem areas.

Because this binder technology develops strength more slowly than conventional organic no-bake systems, it is essential that molds and cores be stripped with attention to detail. When attempting to remove the mold from the pattern, proper stripping techniques are essential. The mold must be removed in a perfectly vertical manner. This will prevent core and mold breakage in critical corner areas. Ideal conditions consist of a standard vibratory roll-over apparatus along with level backboards. A suitable roll-over device can be seen in Fig. 6. Use of this type of equipment will eliminate mold warpage and breakage during removal.

**Handling and Assembly**

The handling strengths developed by the binder system (Table 1) require attention to detail during assembly of mold parts. Early handling strengths are not those typically observed with organic-based binders. Therefore, care must be taken when cured mold halves are manipulated and set into place. Mechanical grappling devices have been successfully used to handle large molds, although in some cases small modifications in the squeezing pressure generated by this equipment must be made. A slight decrease in pressure allows the molds to be handled without significant damage to the mold walls. If conditions allow, final assembly should take place after approximately 3–5 hours of curing time. Figure 7 shows conventional handling equipment being used to assemble mold halves within 3 hours of strip time.

**Casting Performance**

Extensive casting tests have been conducted in Ashland Chemical’s Metals Application Laboratory, as well as in several foundries, to demonstrate that high-quality, defect-free castings can be produced. During pouring, small amounts of steam and a very slight amount of smoke are released from the mold and/or cores, but no noxious fumes or odors are generated. The lack of noxious fumes at pouring and shakeout make this technology extremely attractive to those foundries considering the purchase and installation of industrial scrubbing devices.
Data from evaluative test castings have shown that the phosphate-based binder is resistant to veining and penetration. Further tests have been conducted to determine the performance characteristics of this technology under various foundry conditions. Table 3 is a brief summary of how this material has performed.

Perhaps the single most important feature of this new binder system is its excellent shakeout performance as compared to many other popular binder systems. Figure 8 contains shakeout data for many binder systems presently being marketed. It is evident that this new binder system is far superior to most conventional organic-based and silicate-based binder systems.

### Table 3

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rating</th>
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<tbody>
<tr>
<td>VEINING</td>
<td>1</td>
</tr>
<tr>
<td>EROSION</td>
<td>4</td>
</tr>
<tr>
<td>PENETRATION</td>
<td>1</td>
</tr>
<tr>
<td>LUSTROUS CARBON</td>
<td>1</td>
</tr>
<tr>
<td>SHAKEOUT</td>
<td>1</td>
</tr>
<tr>
<td>GAS DEFECTS</td>
<td>1</td>
</tr>
</tbody>
</table>

1 = Very Good 2 = Good 3 = Average 4 = Poor 5 = Very Poor

![Fig. 8. Shakeout comparison.](image)

![Fig. 6. Roll-over equipment.](image)

![Fig. 7. Handling operation.](image)
The data summarized in Fig. 8 comes from the standard seven-inch disk shakeout casting. Figure 9 shows the mold assembly for the seven-inch disk, which can be varied in thickness to evaluate different metal-to-sand ratios. 356 Aluminum was poured at 1300°F (704°C) to evaluate the various binder technologies. On cooling, the aluminum castings were clamped to a pneumatic vibrator and positioned horizontally to allow the sand to fall out. 1.5 in. (3.8 cm) diameter holes during vibration. Shakeout times were determined from the start of vibration to the time all the sand was removed from the casting. In all cases, shakeout performance of the new binder system in foundry operations has been consistent with the data generated under test conditions.

As-cast surface quality remains an issue for inorganic foundry binders. This is due, in part, to the lack of carbonaceous materials found in these systems, and, in general, the quality of the as-cast surface will not be as good as those made with organic binders. The application of a zircon-based alcohol refractory coating has been found to improve the as-cast surface finish and make it comparable or better than those that use organic binders. Figure 10 shows a steel casting in which half of the mold was coated with a zircon-based alcohol refractory coating.

Preliminary Reclamation Information

Information generated in conjunction with a leading sand reclamation company has shown the ease of reclaimability of the new phosphate-based binder system. A total of seven mechanical, thermal and combination reclamation techniques were used to determine how well the system reclaims and which method provides the most efficient reclamation. Dry attrition and warm attrition reclamation processes have been found to be the most successful in removing the binder from the sand. Wet reclamation is not necessary because this phosphate-based inorganic binder does not fuse to the sand in the same manner as conventional inorganic binder systems. The absence of the need for wet reclamation processes results in a significant cost savings and waste water reduction over conventional sodium silicate binders.

CONCLUSION

The introduction of a new phosphate-based binder has given the foundry industry a viable option to conventional no-bake processes. Although this new technology requires the foundryman to pay very close attention to detail in all operational parameters, it has been successfully used to make high quality ferrous castings. Future improvements to the process, products and foundry handling equipment will yield a second generation process, which can have an even greater impact on the foundry industry.

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REFERENCES