

FEEDING SYSTEMS

V O L U M E 1 I S S U E 2

Large diameter KALMINEX* 35 RND sleeves offer increased performance for heavy section steel castings

Round neckdown (RND) sleeves reduce riser contact area by 75% as compared to full contact cylindrical risers. This contact area reduction is the same as can be obtained through the use of a 50% opening breaker core on a full contact cylindrical riser. An RND sleeve has the additional advantages of being able to be located on a smaller casting contact area and may offer the ability to be knocked off, versus burning or cutting, for many alloys. Use of an RND sleeve can often reduce or eliminate metal padding otherwise needed to achieve an adequate riser contact to the casting.

KALMINEX* 2000 RND sleeves are available in diameters ranging from 2.5" to 12". KALMINEX 35 RND sleeves are now available in diameters ranging from 6" to 14" for increased riser performance in larger sizes.

When foundry handling is rigorous and the molding operation is demanding, the higher strength KALMINEX 35 formulation is required. Otherwise, to determine which product is right for a given application in the larger diameter sizes, one must consider a particular casting's geometry and its alloy's feeding and solidification characteristics.

In general, for carbon steel castings, a riser starts with a minimum of 20% greater freezing time and is adequate if it can remain liquid slightly longer than the casting feeding from it. Geometry is useful in predicting whether casting feeders will be tasked with a mainly modulus (freezing time) or volume (feed metal) performance requirement. Very chunky castings with principal dimension ratios of 1 : 1.33 : 2 and chunky castings (1 : 2 : 4) generally place a heavy modulus feeding demand on a riser. For average (1 : 3 : 9) to rangy (1 : 10 : 10) to very rangy (1 : 15 : 30) castings, riser performance is more a matter of providing an adequate volume of feed metal. Initially, the freezing time of a riser for average to very rangy castings is much greater than that of the casting fed, until the casting begins freezing and draining riser feed metal. The riser volume

required to feed rangier castings is affected by the performance of the riser sleeve, but to a lesser degree than the volume of a riser required in a modulus feed to a chunkier casting. KALMINEX 35 RND sleeves have a higher riser modulus than KALMINEX 2000 RND sleeves and are more capable of enhancing casting yield for heavy section applications when compared to KALMINEX 2000 RND sleeves.

Compared to a tube sleeve, the geometry of an RND sleeve is not as efficient in providing a required modulus in a given sleeve volume to feed a casting. This is the trade-off to employ the contact advantage of an RND sleeve. Typically, RND sleeve volume will have to be greater as compared to a cylindrical sleeve volume to provide an equivalent modulus for a given sleeve formulation. Using KALMINEX 35 RND sleeves versus KALMINEX 2000 RND sleeves will increase the yield when feeding heavy section castings. KALMINEX 35 RND sleeves increasingly outperform KALMINEX 2000 RND sleeves with increasing diameter. Additionally, KALMINEX 35 RND sleeves have a higher sleeve density and are more resistant to dilation from higher metallostatic head pressure and longer freeze times.

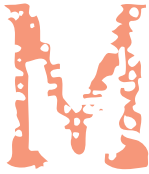
Limitations on feeding performance of KALMINEX 2000 RND sleeves is not a great issue in final feed performance when a riser is chiefly sized to provide a given volume of feed metal as required for average to rangy to very rangy geometry castings. For chunky to very chunky geometry castings where modulus requirements are the primary driving selectors to sleeve size, an RND design having a greater modulus feeding capacity is desirable. KALMINEX 35 RND sleeves can achieve adequate feed with a more economical casting yield than KALMINEX 2000 RND sleeves in diameters 6" and above. The KALMINEX 2000 formulation is still an economical choice for volume feeding of castings in larger sleeve sizes, especially for high feed volume demand alloys having 8% or more feed metal demand.



The increased performance possible with KALMINEX 35 sleeves also provides a tool to the foundryman to minimize segregation that leads to under-riser cracking for segregation-prone alloys. Due to its increased thermal performance in larger sizes, the KALMINEX 35 material is capable of providing a flatter feed that shows less piping and is able to more readily produce a greater margin of good metal at the riser contact as compared to KALMINEX 2000 material in a high modulus feed. Normal process variables in hot topping, pour height, pour temperature, metal chemistry, and gas content can often produce casting defects. KALMINEX 35 RND sleeves can give greater margin at a lower cost than KALMINEX 2000 RND sleeves when feed safety margin must be maintained.



The relationship between sleeves and hot topping



Most steel foundries have realized the value of using quality riser sleeves to reduce costs, either through increased casting yield or through improved safety factors that reduce scrap. However, by neglecting good hot topping practice, many foundries only go part way to realizing all the benefits an efficient risering system can provide. Good hot topping practice begins with a high efficiency hot topping, applied at the right time in the right amount.

The right amount is dependent on the size of the feeder since the topping added must produce a layer equal to one-tenth of the feeder diameter. When calculating the amount required for a hot topping compound such as FERRUX* 746 topping, the expansion of the topping also has to be taken into account. To minimize radiant heat loss, the topping should be applied as soon as the feeders are full.

Figure 1 shows what happens when a casting with a sleeve is poured without any topping at all. Most of the heat is lost as radiant heat out the top of the riser. While the top of a 250 mm diameter by 200 mm high (10 x 8 inch) feeder only represents approximately 24% of the cooling surface area, it accounts for about 60% of the heat loss. The solidification profile is very narrow, with shrinkage going into the casting.

Radiation heat loss is kept to a minimum (Figure 2) if dry silica sand is used as a topping, but the shrinkage profile is only marginally improved. Even though radiant heat loss is reduced, heat transfer through the sand is still relatively high. The resulting low safety margin is too close to the casting. There may be enough alloy segregation at the contact to cause cracking problems during riser removal or heat treatment.

A standard grade topping reduces the radiant heat loss and tries to reduce the heat loss due to convection. Used in conjunction with the sleeve (Figure 3), it doubles the feed safety margin over sand, but still may cause problems with segregation in higher alloy steels.

The best overall feeding system is shown in Figure 4. The use of a sleeve with a high efficiency hot topping shows the best feed profile. The high efficiency topping not only reduced the radiant heat loss but it also kept the convection losses to a minimum. Notice the "champagne glass" look to the feed profile: most of the shrinkage is taken out of the top of the feeder. The safety margin is five times greater when using a high efficiency topping versus silica sand, and over twice that of a standard topping.

Why is this increase in safety margin important? A certain safety margin is required (rule-of-thumb: 20% for a top feeder) to make sure the casting is fed without shrinkage and to keep alloy segregation to a minimum. To maintain this desired safety margin without the use of a high efficiency topping, these cubes would need a larger feeder.

Mathematically, the modulus of a cylindrical feeder with a sleeve and hot topping can be calculated as shown in formula (1). The "ASAF" value stands for Apparent Surface Alteration Factor and is empirically derived. The ASAF value for silica sand is derived to be 1.0 and the values below that are a measure of the relative feeding efficiency of a sleeve and topping.

$$1 \quad M_{\text{riser}} = \frac{\text{Height} \cdot \text{Diameter}}{(4 \cdot \text{Height} \cdot \text{ASAF}_{\text{sleeve}}) + (\text{Diameter} \cdot \text{ASAF}_{\text{topping}})}$$

For the cube shown in Figure 2 with a sleeve ASAF value of 0.75 and the ASAF of the sand topping at 1.0:

$$2 \quad \frac{16.7 \cdot 16.7}{(4 \cdot 16.7 \cdot 0.75) + (16.7 \cdot 1)} = 4.18 \text{ cm}$$

The high efficiency topping used on the cube in Figure 4 has an ASAF of 0.7. The new modulus calculation is:

$$3 \quad \frac{16.7 \cdot 16.7}{(4 \cdot 16.7 \cdot 0.75) + (16.7 \cdot 0.7)} = 4.51 \text{ cm}$$

This means that the solidification time has increased from approximately 38 minutes to almost 45 minutes just by adding a high efficiency hot topping.

In conclusion, a good sleeve is only part of effective risering technique. A high efficiency hot topping is also important to provide cost effective casting yield.

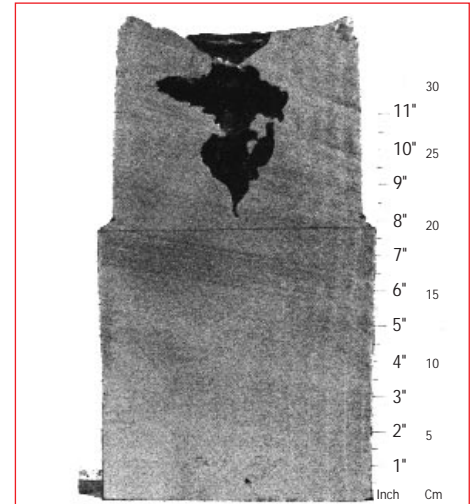


Figure 2. Silica Sand used as hot topping

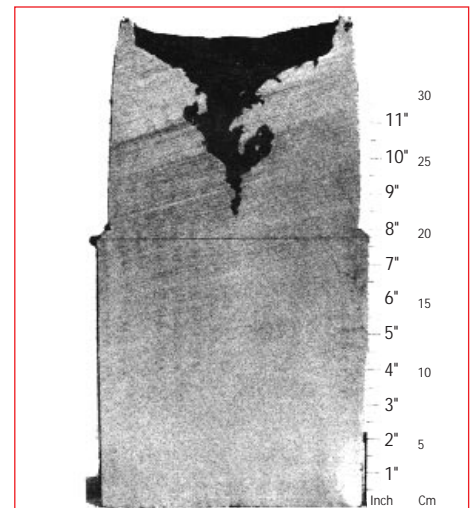


Figure 3. Standard Grade Topping

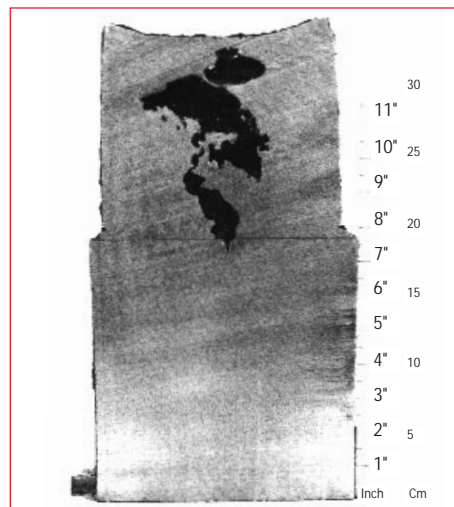


Figure 1. 20 cm cube with no topping

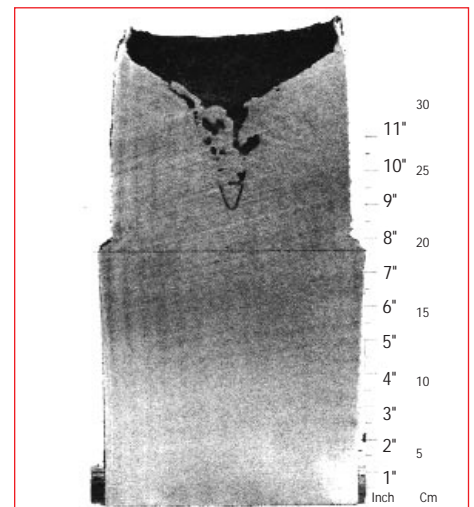


Figure 4. High Efficiency Topping

Computer simulation of exothermic/insulating feeding system performance is now a reality.



Insulating and exothermic/insulating feeding system product performance data have been developed for use in casting process simulation software. These results are "off-the-shelf" inputs for feeding system materials that are intended to assist the foundry engineer in obtaining accurate feeding system performance predictions and to directly reduce the software input required.

Currently, most software packages try to use a generalized database of thermophysical data to simulate the effects of insulating feeding systems. These simulations use first principle fluid dynamics and thermodynamics to predict the filling and solidification characteristics of the casting process. If the heat transfer characteristics of the system are to be predicted, accurate thermal information is needed for all materials in the casting process. While extensive testing had been done to evaluate the thermodynamic properties of various metals and molding materials, equivalent data on insulating/exothermic feeding systems were lacking. Now that need has been answered.

► **Taking a closer look at exothermic performance.** Until now, exothermic feeding system material performance was not readily understood and performance data was not available, so simulation software users made adjustments to insulating feeding system performance to approximate exothermicity. However, these efforts have failed to consistently predict the performance of exothermic/insulating feeding systems across the broad range of product sizes and shapes. It was obvious that more detailed thermal data were needed, so tests were conducted.

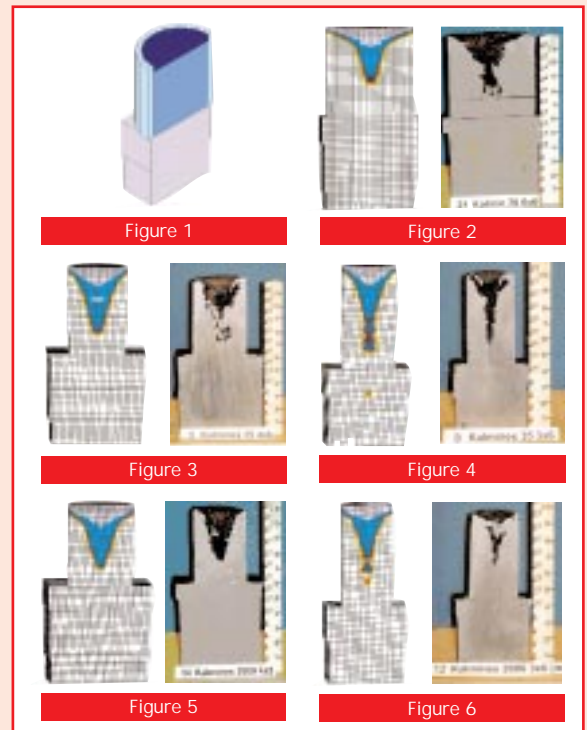
► **Forming a clearer picture through thermal data.** The thermal data collected consists of thermophysical results on feeding system materials from lab tests, molten metal tests and mathematical heat transfer analysis, and inter-facial heat transfer coefficient (IHTC) results from molten metal tests. Thermophysical analysis describes the rate and amount of heat transferred through a given material represented by thermal conductivity, specific heat, and density. IHTC results describe the rate of heat transfer between two materials, including

the thermal barrier effects of any gases present. A material's exothermic energy output is shown as heat of generation values.

► **Simulation vs. reality.** For exothermic/insulating feeding systems, casting process simulations using thermophysical data produced predicted performance, molten metal tests showed measured performance, and the two were compared. All cases involved a simple cube with a cylindrical top riser design. The castings were poured with a top riser covered with an exothermic/insulating hot topping, using low carbon steel (WCB) and phenolic urethane no-bake molds, as shown in the simulation model (Figure 1).

In Figure 2, the predicted and measured results are compared for a low density, insulating feeding system. The casting is sectioned down the middle of the riser, showing the visible macro-porosity for both the simulation (32% safety margin) and the actual riser (26% safety margin). This excellent agreement was repeatedly produced by equivalent tests. In fact, previous simulations have shown prediction to be within +/-6% for low carbon steel in green sand and furan molding materials.

Figures 3 and 4 compare the measured and predicted results for a feeding system with a medium density, exothermic/insulating sleeve and a low density, exothermic/insulating hot topping, respectively. Figure 3 is the comparison for a 6.25" casting with a 4" x 6" top riser sleeve. Safety margin agreement is again within 6% (25% predicted vs. 19% measured), with the predicted pipe shape very similar to the actual shape. Figure 4 is the same comparison for a 4.5" cube with a 3" x 6" top riser sleeve, with a predicted safety margin of 19%, a real one of 22%, and nearly identical pipe shapes. (Note that the small predicted porosity in the cubes center may be present in X-ray level microporosity, but is not likely at the visual level.) Visually, the microporosity comparison is excellent.



Figures 5 and 6 compare measured and predicted results for a feeding system with a low density, exothermic/insulating sleeve and a low density, exothermic/insulating hot topping, respectively. Figure 5, with a 6.25" casting and a 4" x 5" top riser sleeve, reveals predicted 26% and measured 32% safety margins. Figure 6, with a 4.5" cube and a 3" x 6" top riser sleeve resulted in predicted 37% and measured 40% safety margins. Once more, this ignores the small predicted porosity at the riser's bottom, which may or may not be present at the X-ray level.

► **Consistently dependable results.** For all the sectioned cube castings, predictions were within +/-6% for insulating and exothermic/insulating feeding systems (Table 1). The data was also evaluated using actual castings with 2" to 26" diameter riser sleeves. While the detailed results cannot be shown due to the castings' proprietary nature, agreement was within +/-10%. Additional foundry trials are underway to further validate this information.

► **The answers you've been looking for.** When this newly developed thermal data is applied to current casting process simulation software, feeding system performance can be accurately and reliably predicted. With this information, foundry engineers can confidently optimize the riser size, location, and the type of feeding system product they should choose. This significantly simplifies software inputs, and allows the software to become an even more valuable tool that foundries can use every day to achieve more cost-effective operations.

Table 1: Measured vs Predicted Safety Margin

| Sleeve Type (Size) | Figure | Predicted Safety Margin (%) | Measured Safety Margin (%) |
|---------------------------------------|--------|-----------------------------|----------------------------|
| Low density, insulating | 2 | 32 | 26 |
| Medium density, exothermic/insulation | 3 4 | 25 19 | 19 22 |
| Low density, exothermic/insulating | 5 6 | 26 37 | 32 40 |

Maintaining feed safety margins for uncovered riser sleeves.

Due to cost factors, foundries often do not fill their mold flasks with sand all the way to the top, leaving 1-2 inches of the feeder sleeve uncovered and exposed to ambient conditions. To assess the effects on feed safety margin performance, Foseco simulated this practice using MAGMASOFT™, a first-principles

mold filling solidification simulation software program. The result of these simulations indicated a definite correlation between exposed height and loss of the safety margin, represented by a simple curve as shown in Figure 1.

If 25% of the sleeve height is exposed, then approximately 9% of the feed performance may be lost. For instance, for a 6" x 6" KALMIN* 70 riser sleeve on a 6.25" cube with the top 1.5" of the riser sleeve exposed (25%), the safety margin performance is reduced from 39% to 30%. If more than 1/3 (33%) of the sleeve is exposed, feed performance becomes severely affected, and feed performance cannot be guaranteed.

However, it is not necessary to increase the overall height of the mold to counteract these negative effects. Simply forming a ring of sand around the exposed riser sleeve section can help to solve

the problem. Most of the lost performance can be regained by conically mounding sand around the top of the riser sleeve to a thickness of 15% of the riser diameter. Nearly all of the performance can be regained if the mounded sand ring thickness is 25% of the riser diameter. This approach can also be applied to exothermic riser sleeves with similar beneficial results, giving foundries an easy and inexpensive way to reach their performance goals.

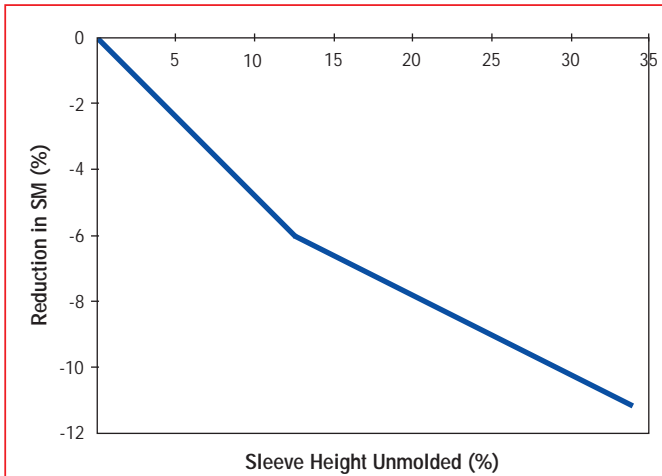
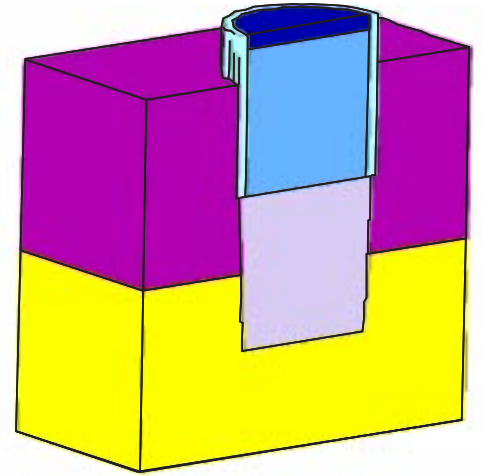


Figure 1. Effect of unmolded riser sleeve height on feed safety performance

Feeding Systems Facts are intended to promote the exchange of information, to contribute to the fund of available knowledge in the foundry industry and to promote good feeding system practice. Foseco will also use *Feeding System Facts* to highlight new products and concepts and to provide application tips and guidance.

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