

# Reverse taper direct pouring system for iron castings

Runner systems can be viewed as necessary evils in the production of high quality iron castings. The design and placement of chokes, crossovers and ingates are all fraught with potential erosion and reoxidation issues. In addition, the traditional running/gating system takes up valuable space on the production pattern plate. Direct pouring via a specially designed pour cup/feeder sleeve/ceramic foam filter unit can eliminate the entire running system, giving yield improvements, increased productivity and cost reduction. However, space limitations on some automatic moulding equipment may complicate the application of these direct pour units.

This paper describes a reverse taper variation of a direct pouring system for iron that brings the quality improvements of reticulated ceramic foam filtration and the cost-reduction benefits of direct pouring to users of automatic horizontal moulding lines. Application of this system to commercial foundry practice is illustrated in a variety of ductile iron castings produced by a major manufacturer of fluid handling pumps.

Each of the castings was originally produced using conventional gating elements, and each offered opportunities for yield and scrap rate improvements. After redesigning the patterns to incorporate reverse taper, direct pouring, castings were evaluated for sand inclusions, porosity, scabbing and soundness. Substantial casting quality and yield improvements were noted.

## Introduction

The well-accepted yield improvement, productivity and quality benefits of direct pouring when combined with filtration are widely acknowledged by both ferrous and non-ferrous major metal casting foundries. (Moffat, 1992; Sandford, 1993; Adams, 1996)

The reverse taper direct pouring system\* was developed to bring the same benefits of direct pouring and filtration to operators of automatic horizontal moulding lines in grey and ductile iron foundries, where the mechanics of the moulding process or the confines of the equipment make it difficult or impossible to utilise the conventional direct pouring sleeve-and-filter combination.

\*KALPUR for iron Reverse Taper Direct Pouring System

## Conventional direct pouring

A conventionally tapered (from top to bottom) direct pouring unit combines an insulated sleeve with a reticulated ceramic foam filter supported on a ledge at the bottom of the sleeve (figure 1).

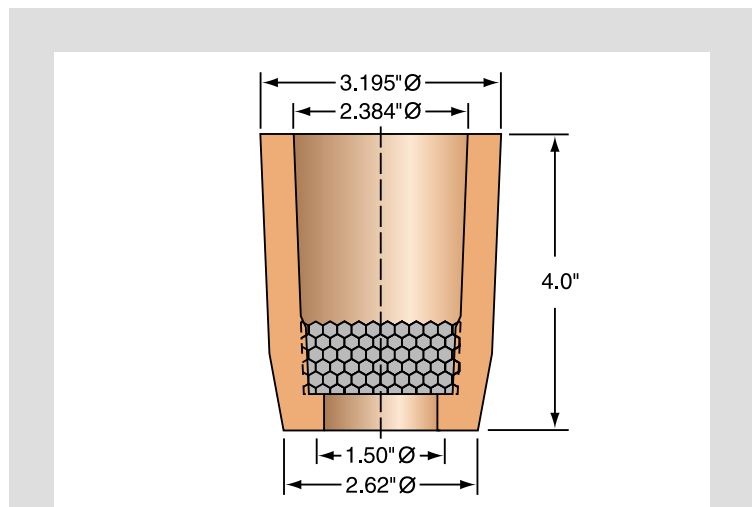
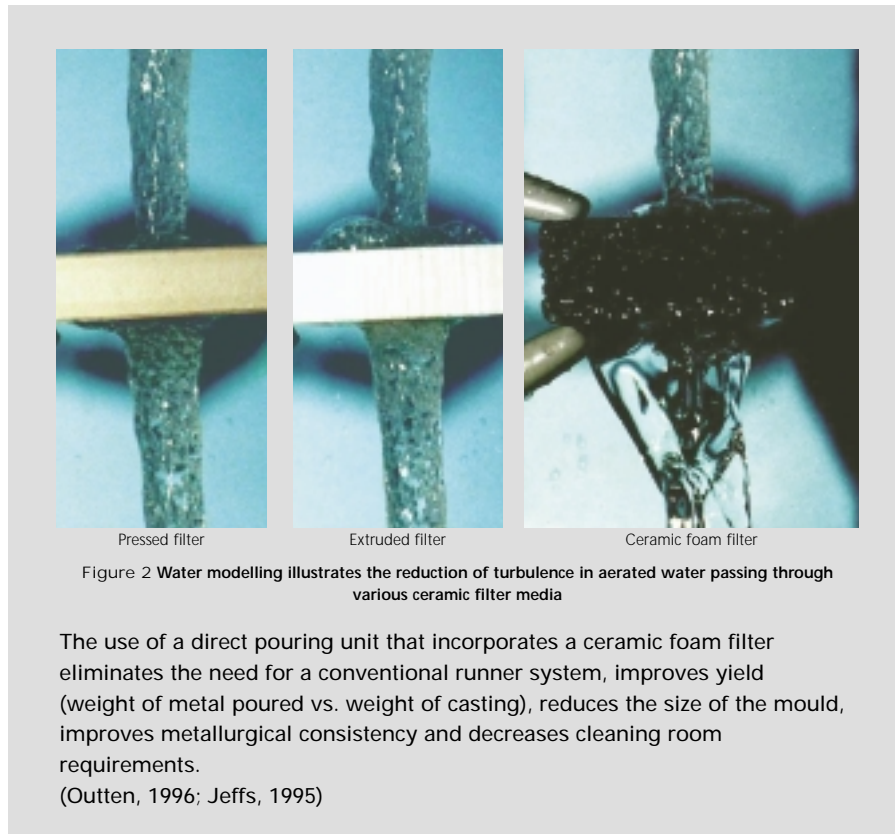


Figure 1 A conventional direct pouring unit is tapered from top to bottom

The filter removes non-metallic inclusions from the molten metal stream and minimises turbulence and the formation of reoxidation inclusions. The insulated sleeve also serves as a feeder, eliminating the need for at least one riser.

In addition to ceramic foam filters, extruded ceramic filters and pressed ceramic filters are used in line to filter grey and ductile iron castings. While all three types are commonly used with conventional gating systems, ceramic foam filters are most commonly used in direct impingement applications and for direct pouring.

Water-modelling experiments have disclosed that both ceramic foam filters and extruded ceramic filters produce notable reductions in pressure and turbulence (Midea, 2001). As can be seen in Figure 2, the ceramic foam filter absorbs the most energy from the stream and has the greatest smoothing effect.



When individual moulds are used to produce the casting, the conventional direct pour unit may be rammed up with the pattern in the cope or inserted into a cavity formed in the cope by a suitable riser bob.

### Use of direct pouring units on automatic horizontal moulding lines

When the cope is accessible (as with individual moulds), the conventionally tapered unit can be readily rammed up in position, or inserted from above into a suitably designed print.

However, application difficulties are encountered when using conventionally tapered direct pour units in conjunction with horizontally parted automatic moulding processes. The cope is normally enclosed, preventing ram-up of the direct pouring unit with the pattern, and the conventionally designed taper (large end up) prevents insertion of the unit into the cope from below.

A variety of approaches have been tried to adapt conventional units to the automated horizontal moulding process, including various plugs, caps and dedicated squeeze plates (head boards) with relief holes to allow the caps to protrude through the plate when the sand is compressed. However, these solutions have proved to be unworkable or too costly.

### Application solution for horizontal moulding machines

These application problems were solved by creating a dimensionally accurate, reverse taper, direct pour unit with the filter contained in a recess at the top (small end) of the unit (figure 3).

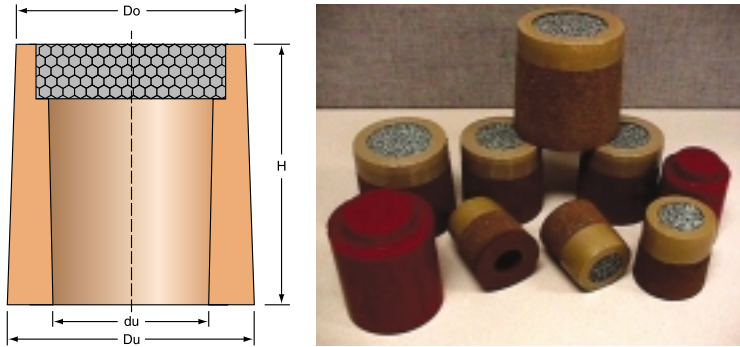


Figure 3 Reverse taper direct pour units are available in a variety of sizes

The direct pouring unit includes a filter that is held in place in the sleeve by heat-shrink tape. This eliminates the need to handle loose filters, and the tape volatilises upon contact with the molten metal. The sleeve is made of a highly insulating material that has been formulated to avoid contaminating automotive foundry sand systems.

### Reverse taper application methods

Reverse taper units may be positioned at the base of the downsprue, directly above the casting, so that the sleeve can provide optimal feed performance. Reverse taper units can be easily inserted into up-turned cope moulds; or they can be placed on the drag half of the mould and closed over, like a core.

#### Insert Technique

If the cope is accessible (as is the case with certain moulding machines that rotate the cope 90 degrees after squeezing), the unit can be manually inserted into a special riser bob cavity.

The riser bob (figure 4a) is combined with a sprue (figure 4b) to produce the mould cavity needed for insert (top feeder) application of the reverse taper direct pour unit into the cope. The riser bob shown is for units that include a breaker core.



Figure 4 A special riser bob creates a cavity for insertion of the reverse taper unit

Crush strips, moulded into the cavity formed by the appropriate riser bob pattern, retain the unit while the mould is rotated and closed. Any sand displaced from the cavity during the insertion of the unit falls into a recess created in the cope mould for that purpose. This approach is applicable to boxed or box-less moulding methods (figure 5).



Figure 5 The reverse taper unit may be manually inserted into a rotated cope for top feeder applications

#### Close-over Technique

In close-over applications (figures 6 and 7), multiple positions for the pouring basin/cup pattern are available across the squeeze plate (head board) to accommodate various casting configurations. After the cope frame is filled with sand, the squeeze plate compresses the sand and the sprue pattern passes through the bore in the basin/cup pattern attached to the squeeze plate (head board). The sprue pattern can extend through the basin/cup pattern as far as necessary during compaction to accommodate the dryness/compressibility of the sand.

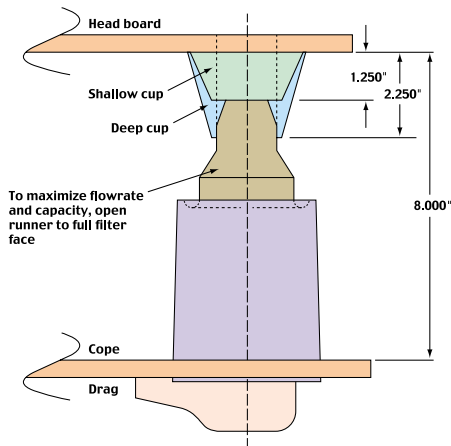


Figure 6 This moulding machine set-up is used in close-over side feeder applications

After the mould is made, the direct pour unit can be set into a slight recess created in the drag pattern. The cope can then be closed over the unit.



Figure 7 For close-over side feeder applications, the reverse taper unit is positioned in a moulded recess in the drag prior to closing the mould

## Feeding and modulus

The "geometric modulus" or feeding capacity of the reverse taper unit sleeve is equal to the feeding capacity of an exothermic/insulating feeder of the same size, and the filter does not affect the unit's feeding efficiency.

However, the "system modulus" or feeding capacity of the reverse taper sleeve-sprue combination is increased since the sprue and pouring basin metal and full mould head height function as part of the feeding system (figure 6). After a period of cooling (approximately 30% of solidification time), the metal in the pouring basin and sprue normally freezes off, and the balance of the feeding is done by molten metal contained in the insulating sleeve.

If the filtration capacity and flow rate of the unit are suitable for the application, the system modulus will normally be more than adequate to feed the casting, the only possible exception being heavy-section, cube-like shapes.

For ductile iron feeding, it is important to have a tall enough feeder so that adequate ferrostatic pressure is created to force metal through the nodular matrix while it is forming.

For side-gated applications that may be used to pour/feed single or multiple castings, the unit should be mounted on a suitable riser base, close to the casting cavity or cavities (figure 8).



Figure 8 In this side-gated application, the reverse taper unit is mounted on a riser base close to the casting

Connecting feeder necks/gates should be adequately sized to promote efficient feeding. Proper sizing of the feeder neck/gate is a function of the casting or section modulus and is unaffected by the application of the reverse taper direct pour system. As the foundry gains experience in the application of reverse taper units, the advantage of a "live" neck/gate condition can be taken to reduce neck contacts by as much as 10%.

In a correctly sized system, the sprue itself functions as the choke, thus producing an unpressurised system that prevents the metal from spraying into the casting cavity. This also allows for faster pouring since the foam filter controls and dampens the velocity of the metal, causing it to enter the casting without turbulence.

## Unit size selection

In most applications, the size of the reverse taper unit selected is determined by the filtration capacity (total weight of metal that can pass through the filter before blockage occurs) and flow rate (weight of metal it will pass per second) of the filter attached to the sleeve. Consideration must also be given to the feed volume requirements of the casting – keeping in mind that the pouring cup/sprue will be part of the feeder for the early stages of feeding.

Filtration capacity and flow rate of the ceramic foam filter are affected by the porosity of the filter, metal temperature, metal cleanliness, melting and inoculation practices, alloy composition and pouring method. Reverse taper units with 10 ppi (pores per linear inch) filters are recommended for ductile iron applications and units with 20 ppi filters, for grey iron applications.

As mentioned above (See FEEDING AND MODULUS), if the filtration capability of the unit is satisfactory for the casting, the "system" modulus/feeding capability will normally be adequate as well.

With some automatic moulding equipment however, the height of the machine frame may restrict the size of the unit since the riser-bob-and-sprue pattern must be short enough to clear the machine framework when the pattern is shuttled out after the mould is compacted (figure 9).



Figure 9 Height limitations on some moulding machines restrict the height of pattern components such as sprues, risers and direct pour units

This condition is limited to the smaller mould machines, which may only accommodate the smallest reverse taper units. However, since the castings that can be moulded on these machines are equally limited by the mould dimensions, the smaller units are usually a satisfactory fit.

## Field trials

Direct pouring units have been successfully applied in a variety of applications. The examples included in this paper were cast by a major producer of well-water pump systems and centrifugal process pumps for industrial applications.

The foundry produces grey iron ( $\approx 75\%$ ), ductile iron ( $\approx 22\%$ ) and bronze castings ( $\approx 3\%$ ). The facility has core and mould making, induction melting, heat treatment and cleaning operations, as well as a pattern shop and metal testing lab. Current capacity is 45.4 tonnes of castings per day. Machining and assembly operations are also conducted at this facility.

Both no-bake and green sand moulding processes are used, with 100% reclaimed sand. Automatic moulding lines include three green sand lines and a no-bake casting line. Flask sizes up to 1.1m<sup>2</sup> are utilised in a no-bake floor moulding operation that can produce castings with pouring weights up to 9 tonnes.

### Pump body

One application of the reverse taper direct pouring unit is a pump body, cast from 60-40-18 no-weld ductile iron (figure 10). The metal is slagged immediately before pouring and is poured at 1331-1427°C.



Figure 10 This centrifugal pump body casting was converted to direct pouring using a reverse taper unit

The casting weighs 31.8 kg. Patterns are mounted on 60.1 cm x 91 cm plates, moulded two-on in a 91 cm x 122 cm flask 35.6 cm over 35.6 cm. The high-density green sand moulds are produced on a jolt squeeze roller strip machine.

Prior to the adoption of the reverse taper system, the casting was produced with a large urethane pouring bush, several ingates and a 11.4 cm x 22.8 cm high sand side riser. Sand inclusions were responsible for 40% of the total scrap cost on this casting.



Figure 11 Cope and drag views of pump casting pattern show the side-feeder position of the riser bob that creates the cavity for the reverse taper direct pouring unit

Prior to conversion to the reverse taper, direct pouring system, total pour weight including a large riser, runner box and downsprue, was 121.1 kg, for a yield of 52%. With the direct pouring unit in place, the total poured weight is reduced to 76.7 kg, for a yield of 83%, a 31-percentage-point improvement.

Since the cope half rolls over after moulding with this equipment, the 10 ppi direct pour unit can be easily inserted by the core-and-close operator, using a simple insertion tool to assure that the unit is fully seated in the riser print.

Cleaning room cost to remove and grind the conventional gating was £10.77. The cost to remove and grind the reverse taper direct pour unit is £6.11, for a saving of £4.66. These savings are accompanied by a saving in cut off saws and carbide bits as well. Appearance of all casting surfaces poured with the direct pour unit is excellent.

A number of other casting trials have been conducted at this foundry using the reverse taper system with similar results.

### Bearing housing

This casting (figure 12) is made from 65-45-12 ductile iron, with pouring temperatures ranging from 1337°C at the start to 1324°C at the end of the pouring. The one-on pattern is moulded in a large jolt squeeze machine in green sand. The flask is 91 cm x 122 cm, with 35.6 cm cope and 35.6 cm drag. The casting weight is 79kg.



Figure 12 This side-gated iron bearing housing casting is poured through a downsprue positioned above a reverse taper direct pouring unit

Originally, the gating included a runner box, sprue, runner system, multiple ingates and risers. With that configuration, the total pour weight was 161.1 kg, with a yield of 57.6%. With the conventional gating, sand inclusions were a major cause of scrap. Visible defects were attributed to lack of filtration, porosity, and scabbing. Defects suggested a need for improved gating and a resolution of sand system problems.

In the new direct pour configuration, the 10 ppi direct pour unit was mounted on a side riser that served as a single ingate. The pattern was modified with a shelf to allow the unit to sit above the well basin. The mould was closed over the reverse taper unit (figure 13).



Figure 13 The bearing housing mould is closed over the reverse taper unit

With the new gating method, the total pour weight was reduced to 91.2 kg, with a pouring time of 10 seconds. The yield increased to 86%, and no scrap (due to sand inclusions) has been encountered since the conversion.

The simplified gating has resulted in a reduction in cleaning room costs since only a single cut is required (figure 14).

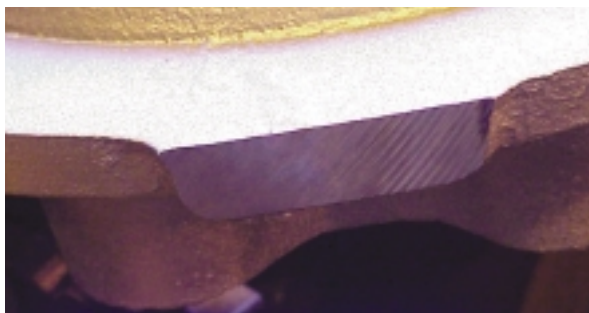


Figure 14 Only one cut is required to remove all gating and risering from the bearing housing when cast with the reverse taper direct pouring system

A cross-section examination of the removed gating disclosed no visible shrink defects in the contact area after cut off, and clean metal was found all the way up to the sprue.

### Impeller

This impeller casting (figure 15) is also made from 65-45-12 ductile iron. It is moulded one-on in a large jolt squeeze machine in green sand. The casting weight is 38.6 kg.



Figure 15 The impeller was cast with a reverse taper direct pour unit that eliminated the need for all conventional gating components\*

\*Note: In Figure 15, the sprue and any remains of the pour basin have broken off at the filter entry face due to slag build-up on the filter face, a common occurrence.

The original gating included a centrally located 10.2 cm x 20.3 cm insulated sleeve riser, ring runner with multiple ingates, a sprue and a runner box. If the sand was dry, excessive sand inclusions resulted; if it was wet, porosity problems occurred. In this configuration, the total pouring weight was 112.5 kg, for a yield of 34.7%.

In a preliminary direct pour trial, a conventionally tapered (large end up) 6.4 cm sleeve was rammed up in the mould and a loose filter was added to the sleeve after moulding. While this configuration did improve yield, visible defects (holes in the drag, porosity, and scabbing) were attributed to filter flotation or occasional use of the wrong filter.

When the casting was re-rigged with a reverse taper, direct pour unit in a top-risered configuration, the unit was inserted by the operator into a print made in the cope half of the mould by a riser bob. The unit is retained in the print by crush strips created by splines in the riser bob (figure 16).



Figure 16 The direct pour unit is easily inserted into the inverted cope half of the impeller mould using a simple insertion tool

The new total pour weight was reduced to 52.2 kg, for a yield of 75%; more than double the original yield.

Sectioning of the hub below the direct pour unit disclosed that the metal below the filter and above the hub of the impeller are clean as expected (figure 17). Shrinkage below the filter results from feeding of the casting after freeze-off of the metal in the sprue. It can be seen that the shrinkage "pipe" stops well short of the casting, indicating proper sizing of the direct pour unit.



Figure 17 Sectioning of the reverse taper direct pouring stub confirmed soundness of the casting at the point of contact

In another direct pour trial on a similar impeller casting, the reverse taper unit chosen was purposely sized smaller, putting it at the high end of the filtration limit for a casting of that weight. The same satisfactory filtration and feeding results were obtained with the smaller unit.

#### Continuing investigations

Results of the initial trials at this foundry suggest a large potential for cost savings using the reverse taper direct pouring units on castings made on both green sand lines, as well as the no-bake line. Based on these results, the foundry is actively applying reverse taper direct pouring to a series of pump castings presently made with larger runners and risers, castings that have current yields in the 30 to 40% range. The objective is to improve quality and efficiency, and to standardise on one gating practice.

### Summary

The reverse taper direct pouring system lets users of automatic horizontal moulding lines enjoy the production savings of high-volume moulding, the yield improvements and reduced engineering expenses of direct pouring, and the proven metallurgical and cosmetic benefits of ceramic foam filtration. The result is an overall increase in productivity and the realistic potential for improved foundry profitability since operational savings are substantially greater than the cost to purchase and apply direct pour units.

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### References

- Andrews, A., "KALPUR direct pouring systems," Foundry Practice, Issue 227, (April 1996)
- Jefts, P., "Aluminum casting productivity increases with predictive techniques," Foundry Practice, Issue 226, (July 1995)
- Midea, A.C., "Pressure Drop Characteristics of Iron Filters," AFS Transactions, 01-042 (2001)
- Moffat, G.L.; Ecob, C.M.; "STELPUR\* – A Novel Concept in Direct Pouring Feeding and Filtration of Steel Castings," Presented at the 35th SCRATA Conference, Sheffield, England, (May 1992)
- Outten, J., "KALPUR For Steel Direct Pouring System Improves Yield, Productivity, and Quality," Foundry Practice, Issue 227, (April 1996)
- Sandford, P., "Advances in the production of high yield aluminum castings using DYPUR\* technology," Foundry Practice, Issue 224, (March 1993)